fermilab report

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89/7 **Fermi National Accelerator Laboratory**

On the cover: *Brazil's President Jose Sarney (left) and Fermilab Director John Peoples in the Accelerator Main Control Room. President Sarney's tour of Fermilab marked the first such visit to the Laboratory by a Head of State. See the article on page 21.* *(Fermilab photograph 89-1065-6)*

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The CDF 1988-1989 Run

by Hans B. Jensen

In the afternoon of May 31, 1989, when a thunderstorm abruptly ended the last $\bar{p}p$ store of the 1988-1989 Tevatron Collider run, a small party took place in the CDF control room to celebrate the completion of a very successful data taking period.

The run had started almost a full year earlier, in June of 1988, with the goal of collecting 1 inverse picobarn (10^{36} per cm^2) of integrated luminosity on tape. Reality turned out even better than expectations, and about 4.7 inverse picobarns had been collected by the time the run ended.

A friendly competition between shift crews to see who could write the most data to tape in a single 8-hour shift resulted in a record of 26 inverse nanobarns, almost as much as was collected during the entire 1987 run. The record accumulation for a single week was about 0.3 inverse picobarn to tape.

To cope with the high luminosity delivered by the accelerator during this run, a trigger system with four levels was used. Levels 0, 1, and 2 were debugged during the summer months, and were fully operational by September 1, 1988. The Level 3 trigger system, consisting of about 50 Advanced Computer Program (ACP) nodes, running further event-filtering algorithms, was originally planned to be used in a test mode only. However, as the luminosity steadily increased during the run, portions of the Level 3 trigger were gradually turned on. Towards the end, an event rejection from Level 3 of about a factor three was reached.

The utility of this highly sophisticated trigger system is illustrated by the fact that an overall trigger rejection factor of about 50,000 was achieved while maintaining low trigger thresholds (and thereby good acceptance for interesting physics processes). The transverse energy thresholds for single muons and electrons, for instance, were in the 9- to 12-GeV range, while the thresholds for pair triggers were in the 3- to 5-GeV range (on each lepton). Tau lepton thresholds were somewhat higher. Altogether, about 25 different triggers were operated in parallel in standard data taking mode.

Events passing the Level 3 trigger were written to magnetic tape for offline analysis. A total of about 5500 9-track tapes, containing about 6 million events, were written. Offline event reconstruction on a large scale ("production") began

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The author is a member of the E-741/CDF collaboration.

on two 65-node ACP systems operated by the Fermilab Computing Department around the first of the year. A "farm" of 20 VAX 3100's was added later on to increase the rate of production. Event processing includes full track reconstruction, and takes about 250 seconds per event on an ACP node. By the time the run ended, about 45 percent of the total data had passed through production. The projected date for completion is December 31, 1989.

In the interest of getting an early look at some of the more interesting physics processes, certain event types were selected for full reconstruction in the course of the run in what was called a "spin" production cycle. Based on such a preliminary event selection, about 600 $Z \rightarrow ee$ and about 5000 $W \rightarrow e\,\nu$ events were identified, and the search for the elusive top quark was begun.

The first result to emerge from analysis of data from this run concerns the mass of the Z^0 particle, discovered at the CERN Collider, and measured by the UA1 and UA2 experiments to be $93.1 \pm 1.0 \pm 3.1$ GeV/c^2 (UA1) and $91.5 \pm 1.2 \pm 1.7$ GeV/c^2 (UA2). The new CDF result, based on $Z \rightarrow \mu\mu$ and $Z \rightarrow ee$ decay events, is $90.9 \pm 0.3 \pm 0.2$ GeV/c^2, consistent with the earlier measurements by UA1 and UA2, but with much improved measurement uncertainties.

Accurate measurement of the Z mass and width is now a very topical subject. A measurement with the MARK II detector at the SLAC Linear Collider yields a mass of 91.11 ± 0.23 GeV/c^2, and results from LEP at CERN are expected soon.

For CDF, a next step is to finish the data analysis for the W mass measurement. Accurate Z and W masses can then be used, within the Standard Model, to get mass limits for the top quark. Combined with other measurements, they can also be used for precision tests of the Standard Model.

At Tevatron Collider energies (1.8 TeV in the $\bar{p}$-p center-of-mass) the dominant production mechanism of top quarks is believed to be the associated production of a $t\,\bar{t}$ pair. Final states containing either an electron, a neutrino and jets, or an electron and a muon provide good signatures for top quarks, and have up to now been the primary focus of the CDF search for the top. The result so far has been negative: no signal has been found, indicating that the mass of the top quark must be larger than 77 GeV/c^2. (Earlier results by other experiments exclude a top mass below about 41 GeV/c^2. The new CDF results extend the limit to 77 GeV/c^2.)

Work is now under way to upgrade the detector and to make it ready for the higher luminosities expected next run (a luminosity increase of about a factor of five is anticipated). Detector upgrades include the addition of a Silicon Vertex Detector, a new set of high-luminosity Vertex Time Projection Chambers, and added muon coverage provided by additional steel plus chambers surrounding

the Central Muon Detector. The higher luminosities will also require modifications to some of the front-end electronics (shorter signal integration times and a faster Level 1 trigger).

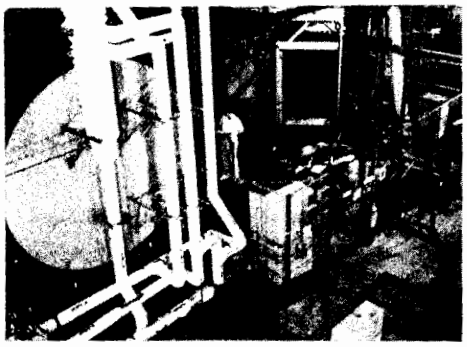
In summary, between working on detector upgrades for the next run in 1991 and continuing the analysis of the rich data collected in the last run, the members of the CDF Collaboration have a busy program planned for the next couple of years.

Experiments in the 1990 Tevatron Fixed-Target Physics Program†

E-665 Muon Scattering with Hadron Detection at the Tevatron *(Spokesperson: H. E. Montgomery)*

ANL, U.C./San Diego, Fermilab, Freiburg (Germany), Harvard, Illinois/Chicago Circle, INP Krakow (Poland), Maryland, M.I.T., Max-Planck (Germany), Washington, Wuppertal (Germany), Yale

The experiment, which is located in the Neutrino Area Muon Beam, studies the interactions of muons with beam energies up to 750 GeV in various targets and with the capability of making detailed measurements on the recoil hadrons that emerge from the collision vertex. The collaboration has combined large magnets, the CERN Vertex Magnet (CVM) and the Chicago Cyclotron Magnet, in a spectrometer that will be as powerful as any known. The experiment took data for the first time during 1987-88 using deuterium, hydrogen, and xenon targets, and will continue these measurements in the 1990 fixed-target running period.



(Fermilab photograph 89-762)

The E-665 apparatus in the Neutrino Area Muon Beam.

E-672 Study of Hadronic Final States in Association with High-Mass Dimuons *(Spokesperson: A. Zieminski)*

Caltech, Fermilab, IHEP, Serpukhov (U.S.S.R.), Illinois/Chicago Circle, Indiana, Louisville, Michigan/Flint

The aim of E-672, an open-geometry dimuon experiment, is to study production of particles produced in association with ψ and high-mass dimuon pairs. The experiment shares the Meson West beamline, magnetic spectrometer, and calorimetry with E-706. Physics goals include studies of hadrons and gammas produced in association with dimuons and a study of the A-dependence of ψ and Drell-Yan pair production with proton and pion beams. The first test/physics run of the experiment took place in 1987/88.

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† *Main source:* 1989 Fermilab Research Program Workbook, *Fermilab Program Planning Office, ed. Roy Rubinstein.*

E-683 Photoproduction of High P_t Jets *(Spokesperson: M. B. Corcoran)*

Ball State, Fermilab, Houston, Iowa, Lehigh, Maryland, Michigan, Rice, Texas/ Austin, Vanderbilt, Wisconsin

Experiment 683 is studying the photoproduction of high p_t jets in the Wide Band Beam of the Tevatron. The quantum chromodynamics (QCD) processes of interest are QCD Compton scattering $\gamma q \rightarrow gq$ (which dominates at high x_t), and quark-gluon fusion $\gamma g \rightarrow qq$. These processes are very distinctive, with the photon coupling as a point particle, giving all its energy to the two high-p_t jets, and producing no beam jet. The three-jet topology allows the separation of the direct-coupling processes from vector-meson-dominance-type processes, which produce the four-jet topology familiar in pp and πp interactions. Due to the lack of a beam jet and the large energy in the parton-parton frame, these jet events are expected to be very clean compared to jets produced in a π or p beam. The collaborators will measure the cross sections of both three-jet and four-jet events as functions of x_t, p_t, and y, and compare them to QCD calculations.

E-687 Photoproduction of Charm and B *(Spokesperson: J. Butler)*

U.C./Davis, Colorado, Fermilab, Illinois, INFN/Frascati (Italy), INFN/Milano (Italy), Milano (Italy), North Carolina, Northwestern, Notre Dame, Pavia (Italy)

E-687 is a photoproduction experiment in the Wide-Band Photon Beam of the Proton Area. Interactions of photons whose energies are typically above 200 GeV are analyzed in a multiparticle spectrometer. The physics goal of the experiment is to reconstruct large samples of particles containing heavy quarks, charm and bottom, in order to study the dynamics of heavy quark photoproduction, to carry out detailed studies of the weak decays of charmed mesons and baryons, to study the decays of particles containing B-quarks, and to study J/psi and upsilon photoproduction.

In the first run of the experiment, in 1987-88, over 70 million events were collected. These are now being analyzed. For the next running period, the beam intensity is being approximately tripled by using a liquid deuterium production target and transporting simultaneously a positron beam which will produce additional photons.

E-690 Study of Charm and Bottom Production *(Spokesperson: B. Knapp)*

Columbia, Fermilab, Guanajuato (Mexico), Massachusetts, Texas A&M

The primary purpose of this experiment, located in Neutrino Area - East, is a detailed, accurate study of the production and decay of charm and bottom par-

ticles. The experimenters will concentrate on fully reconstructed events, for which all final state particles have been accurately reconstructed.

The experiment measures charged particles with a two-magnet spectrometer using drift chambers with small cells. This detector can measure complicated reactions, accurately and efficiently, at rates above 10^6 interactions per second. The readout electronics, including pipelined digital computation hardware, permits detailed numerical reconstruction of 10^5 events per second with little deadtime. A distributed hierarchy of trigger decisions can select any subset of raw data and calculations for transfer to an online computer and its tape drive. The high-rate capability of the detector and its associated event reconstruction hardware permit rare phenomena to be studied with high statistics, with trigger specificity and complexity normally reserved for tedious offline analysis.

E-704 Experiments with the Polarized Beam Facility *(Spokesperson: A. Yokosawa)*

ANL, CEN-Saclay (France), Fermilab, IHEP-Serpukhov (U.S.S.R.), Hiroshima (Japan), Iowa, KEK (Japan), Kyoto Sangyo (Japan), Kyoto/Education (Japan), LAPP-D'Annecy (France), LANL, Northwestern, University of Occupational and Environmental Health (Japan), Rice, Trieste (Italy), Udine (Italy)

Experiment 581 obtained initial data on the properties of the new polarized beam. Completion of a 200-GeV/c conventional-magnet beamline allowed the observation of polarized protons and polarized antiprotons from decaying lambdas and antilambdas, respectively. A beam-tagging system and two polarimeters, using the Primakoff effect and Coulomb-nuclear interference, measured the beam polarization during the 1987-1988 TeV II period. Measured beam polarization was consistent with the designed value.

Experiment 704, in the Meson Area Polarized Proton Beam, continues E-581's work by simultaneously performing substantial parts of previously proposed experiments 674, 676, 677, and 678. The experimenters are exploring the spin dependence of the interactions in a global way using a straightforward experiment measuring the difference in pp and $p\bar{p}$ total cross sections between the states with helicities of target and beam parallel and antiparallel. A longitudinally polarized-proton target in a superconducting solenoid is being used with the polarized beam.

Studies of the inclusive production of neutral pions around $x_F \approx 0$ and large $p_\perp$, of neutral and charged pions at large x, and of Λ^0 (K^0) and Σ^0 at large x are being carried out simultaneously. These measurements will investigate the spin effects as a function of x_F and $p_\perp$.

E-706 A Comprehensive Study of Direct Photon Production in Hadron Induced Collisions *(Spokesperson: P. Slattery)*

Delhi (India), Fermilab, Michigan State, Minnesota, Northeastern, Penn State, Pittsburgh, Rajasthan (India), Rochester

Experiment 706 (situated at Meson Area - West) is studying the gluon structure functions of hadrons, and investigating gluon fragmentation, through analyzing the production of direct photons and their accompanying hadrons in collisions of pions, kaons, and protons with a variety of nuclear targets. At the constituent level, the reactions to be investigated are $qg \rightarrow q\gamma$ and $\bar{q}q \rightarrow q\gamma$. The experimenters are also interested in carrying out an essentially unbiased comparison between the two fundamental quark-antiquark annihilation reactions, $\bar{q}q \rightarrow \gamma\gamma$ and $\bar{q}q \rightarrow \ell^+\ell^-$, by studying, in a single experiment, the relative yields of $\gamma\gamma$ and e^+e^- triggered events. The experiment is to be carried out using 400- and 800-GeV/c protons and 530-GeV/c pions (both signs) using beam intensities $\geq 10^7$ per second.

E-760 Investigation of the Formation of Charmonium States Using the Antiproton Accumulator Ring *(Spokesperson: R. Cester)*

U.C./Irvine, Fermilab, Ferrara (Italy), INFN/Genova (Italy), Northwestern, Penn State, Torino (Italy)

Experiment 760, at the Antiproton Source Accumulator Ring, will study charmonium states formed in $\bar{p}p$ collisions. E-760 will take data during the Tevatron fixed-target run; at the time that the Main Ring is not used as the injector to the Saver, 120-GeV protons will be targeted on the Antiproton Source target. The produced antiprotons will be accumulated in the Accumulator. After four hours of accumulation, the cooled antiprotons will be decelerated to the appropriate momentum (3 to 7 GeV/c) and the gas jet will be turned on. At this point a data taking run 20 hours long will commence. During the data taking period the stochastic cooling systems of the Accumulator will preserve the emittance and momentum spread of the stored antiprotons.

E-761 An Electroweak Enigma: Hyperon Radiative Decays *(Spokesperson: A. Vorobyov)*

CBPF (Brazil), Fermilab, IHEP/ Beijing (P.R.C.), Iowa, ITEP (U.S.S.R.), LNPI (U.S.S.R.), SUNY/Albany, Sao Paulo (Brazil), Yale

Experiment 761 will probe the structure of the electroweak interaction and has two main goals. The first is to measure the asymmetry parameter for the electroweak decay $\Sigma^+ \rightarrow p\gamma$ and verify its branching ratio. The second goal will be to measure, or set new upper limits for, the branching ratio of the

electroweak decay $\Xi^- \rightarrow \Sigma^- \gamma$. Since the Ξ^- are expected to be polarized, information on the asymmetry parameter may also be available.

The experiment will use the Proton Center polarized charged hyperon beam and a new very-high-resolution spectrometer. In the March 1987 run, the experimenters tested their apparatus in Proton Center parasitically.

E-771 Beauty Production by Protons *(Spokesperson: B. Cox)*

Athens (Greece), Brown, U.C./Berkeley, U.C./Los Angeles, Duke, Fermilab, Houston, Indiana, Lecce (Italy), MIT, McGill, Nanjing (PRC),, Northwestern, Pavia (Italy), Pennsylvania, Prairie View A&M, Shandong (PRC), South Alabama, Virginia

The presence of muons in final states produced in hadronic interactions has proved to be a valuable indicator that interesting hard physics processes have taken place. Experiment 771, in the Proton West High Intensity Laboratory, will use both high-$P_\perp$ single muons and high-mass muon pairs as a signature that events are possible beauty production candidates. These muons provide a mechanism for selecting the relatively rare beauty production from interactions due to the total cross section.

The experiment will use the high-rate E-705 spectrometer, which has already functioned well in experiments E-537 and E-705, to detect and measure beauty hadron decays which result in a final state containing either type of muon signature. E-771 will use the primary proton beam from the Tevatron at the maximum energy available at the time of execution of the experiment.

E-773 Measurement of the Phase Difference between η_{00} and η_{+-} to a Precision of $1/2^0$ *(Spokesperson: G. D. Gollin)*

Chicago, Elmhurst, Fermilab, Princeton

The goal of Experiment 773, in Meson - Center, is to measure $\Delta\phi$ to an accuracy of $1/2^o$.

To avoid systematic uncertainties associated with imperfect knowledge of kaon beam flux, detector acceptance, and resolution-smearing effects, the experiment will measure $\pi\pi$ decays using a double-beam technique similar to that employed by E-731. One beam will pass through a thin regenerator at the start of the fiducial decay volume, while the other beam will traverse a thick regenerator 14 meters further upstream. The separation is chosen to make the $\pi^0\pi^0$ decay rate inside the decay volume insensitive to $\Delta\phi$ for K_S from the upstream regenerator, and maximally sensitive to $\Delta\phi$ for K_S from the downstream regenerator. The regenerators will switch beams between machine pulses. Data will be recorded simultaneously for $\pi^0\pi^0$ and $\pi^+\pi^-$ decays in both beams.

E-774 Electron Beam Dump Particle Search *(Spokesperson: M. B. Crisler)*

Fermilab, Illinois, INP/Krakow (Poland), Northeastern

The purpose of Experiment 774 is to search for light, neutral, short-lived particles that couple to the electron. The experiment will exploit the high energy and flux available in the Proton Area's new Wide Band Electron Beam to probe this unexplored region. The search will be performed by positioning a neutral decay spectrometer downstream from the electron dump of the Wide Band Beam. A neutral particle coupled to the electron will be produced in the dump by a Bremsstrahlung-like process and will be observed by its decay in flight if its flight path is longer than the beam dump. The sensitivity of this method to short-lived particles is determined by the energy of the beam and the length of the beam dump. By using a short tungsten beam dump and the highest available beam energy, E-774 will extend the region of search by more than an order of magnitude beyond existing limits.

E-782 Muon Exposure in the Tohoku High Resolution Chamber *(Spokesperson: T. Kitagaki)*

Brown, Fermilab, IHEP-Beijing (P.R.C.), Indiana, MIT, Nagoya (Japan), Tohoku Gakuin (Japan), Tohoku (Japan)

The E-782 experimenters will carry out a muon experiment using the Tohoku High Resolution One-Meter Freon Bubble Chamber in the Neutrino Area NK Beam.

Physics goals are the study of: production of vector mesons, strange particles, and charm particles in a wide range of Q^2 down to $Q^2 \sim 0.1$ GeV^2; energy dependence of meson-baryon pair production in charm and strange channels; comparison of neutrino interactions and muon interactions in the same 4π detector; structure functions in the low Q^2 region down to $Q^2 \sim 0.1$ GeV^2 with small systematic uncertainty; and EMC effect. The new tagging method developed in E-745, using the nuclear debris, will be applied on the muon interactions.

E-789 B-Quark Mesons and Baryons *(Spokespersons: D. M. Kaplan/J.-C. Peng)*

Abilene Christian, Fermilab, LBL, LANL, Northern Illinois, South Carolina

Experiment 789 in Meson Area - East will study charmless two-body two-prong decays of neutral b-quark hadrons.

Under plausible assumptions for beauty production cross-sections and branching ratios to two hadrons, E-789 should record enough such decays to measure the lifetime of the B_d and possibly to discover the B_s and Λ_b and measure their lifetimes and masses. No other experiment now operating or under construction has comparable sensitivity. These measurements are essential to evaluating the suitability of dihadronic decays for the study of CP violation in the B system. In addition to dihadronic beauty decays, E-789 will have excellent sensitivity to dileptonic modes, allowing limits of order 10^{-6} to be set on their branching ratios.

E-791 Hadroproduction of Charm and Beauty *(Spokespersons: J. A. Appel/M. V. Puroit)*

CBFP (Brazil), Fermilab, I.I.T., Mississippi, Ohio State, Princeton, Tufts, Wisconsin, Yale

Experiment 791, located in the Proton Area Tagged Photon Laboratory, aims to break new ground in charm and beauty physics. The experiment will run for 2 x 10^6 spill seconds and write to tape 10 billion events, of which 125 million will contain charm. Extrapolating from the analysis experience of E-691 and E-769 using the same detector, the experimenters know that about 100,000 charm events will be fully reconstructed (10 x E-691's sample of 10,000 fully reconstructed charm events). It should be possible to reconstruct about 700 beauty events partially and perhaps 50 B events fully.

E-791 is simultaneously exploiting challenging new technologies. The vast number of reconstructed events is made possible by fast front-end electronics (< 20 μs readout times), fast data acquisition, and high-speed writing to 8 mm tape (8Mbyte/sec). The second phase of the experiment will employ vertex and other triggers to enhance heavy flavors in the data even further.

E-799 Search for the Rare Kaon Decay Mode $K_L^0 \rightarrow \pi^0 e^+ e^-$ *(Spokespersons: Y.-W. Wah and T. Yamanaka)*

Chicago, Elmhurst, Fermilab, Princeton

Experiment 799, at Meson Center (MC), will search for the rare kaon decay $K_L^0 \rightarrow \pi^0 e^+ e^-$ with a sensitivity of ~1 x 10^{-11}. Theoretical predictions of the branching ratio range from 0.4 x 10^{-12} to 0.6 x 10^{-9}. Within the Standard Model, this decay mode may have a sizable CP violating decay amplitude such that $\epsilon'_{\pi ee}/\epsilon \sim 1$. A high-sensitivity search for this decay will test different models and provide a new window to explore the question of direct CP violation.

In the initial phase of the experiment, a 650-hour run of 2 x 10^{12} protons per spill (pps) with no change to the existing MC beamline and a modest upgrade of the E-731 detector, will yield ~1 x 10^{-10} sensitivity. A later run with 1600 hours of 3 x 10^{12} pps and a modest modification to the MC beam configuration will yield ~1 x 10^{-11} sensitivity.

E-800 A Precision Measurement of the Omega Minus Magnetic Moment *(Spokespersons: K. Johns and R. A. Rameika)*

Fermilab, Michigan, Minnesota, Rutgers

Experiment 800, located in the P-Center beamline, will measure the magnetic moment of the omega minus to 0.04 nuclear magnetons or better. This experiment is a follow-on to E-756, which pioneered a technique for producing polarized omegas, enabling a measurement of the omega moment to be made at the 10 percent level (about 0.2 n.m.). A precise measurement of the omega magnetic moment will provide valuable input to models of how quarks combine into hadrons and bring the omega precision in line with that of the other hyperons.

The magnetic moment of the omega is determined by measuring the spin precession of a polarized sample of omegas. Data from E-756 shows inclusively produced omegas from protons to have very little, if any, polarization. Instead of producing Ω^-'s directly, E-800 will use 800-GeV protons to produce a secondary neutral beam of polarized Λ's and Ξ^0's, which is then used to produce a tertiary beam of polarized Ω^-'s.

A New ACP Machine for Parallel Processing

by Richard Fenner

It wasn't quite "Mr. Watson, come here, I want you," but it was close. At 3 o'clock on the afternoon of August 4, 1989, several members of Fermilab's Advanced Computer Program (ACP) group gathered in their labspace on the 6th floor of Wilson Hall where dialogue was flashing across a computer terminal screen in response to keyboard entries. What they were watching was the first signs of life from a new standalone computer designed by the small band of synergists in the ACP group, headed by Tom Nash, as they quietly attacked one of the most vexing problems high-energy physics (HEP) faces in the immediate future: adequate computing capability for the analysis of millions of particle-interaction events. The new board, known as the ACP/R3000, had accepted the UNIX operating system and was ready to receive its first commands.

In 1983, the Ballam Committee, convened by then Fermilab Director Leon M. Lederman and empowered to assess future computing needs for high-energy physics, issued their report. It confirmed what had been suspected: The amount of computing capacity critical to future HEP experiments would far exceed the current capabilities. (That has certainly come to pass. For example, Fermilab Experiment 791 anticipates collecting 10 billion events during their next run.) Clearly, new computing strategies had to be found.

Various possible solutions were examined in light of realistic requirements such as expansibility and cost. At the urging of Nash, Lederman decided that the Laboratory would be able to design a special computer system that would go far in meeting Fermilab's computing needs. It would be a parallel processing computer built out of the currently best available hardware components. The basic idea, in the words of Mark Fischler of the ACP, was to "build the processor as inexpensively, and as lean and mean, as possible." That concept became the first-generation ACP parallel processor. It consisted of hardware and software combined into a rudimentary operating system, plus some user support from the ACP group. " We made that new computing power available to serious users who were willing to put up with the inevitable inconvenience of using something that is not the same as what everyone else was using," said Fischler.

A parallel processor is a computing engine consisting of several small processing units working simultaneously on different parts of a problem. This is opposed to a typical mainframe computer which processes data in series - very quickly, but one piece at a time. Under the ACP concept, one processor is as-

signed the task of parceling out different parts of the problem to many other connected processors. Each processor performs its discrete task simultaneously with the others. As each task is completed, a new problem is passed to a waiting processor.

The first-generation ACP was, at the time, 100 times more cost effective than any commercially available device. An ACP board that cost three to five thousand dollars was delivering the power of one half to one full VAX equivalent, which then cost approximately $250,000.

In spite of its ''rudimentary'' configuration, the first-generation ACP became a sought-after machine. Several experiments at Fermilab began using the ACP to analyze their events, and ACP's were ordered by the national laboratories at Brookhaven, Los Alamos, and Oak Ridge, as well as by SIN in Switzerland, Saclay in France, and CBPF in Brazil.

Since the advent of the first-generation ACP, the computer industry has continuously introduced new, improved chips, increasing the performance of processors by a factor of two each year. But the ACP group hasn't been idle, either.

The members of ACP set out to combine new higher performance processing units with more flexible and powerful software. The new processing unit, in the words of chief designer Hari Areti, is ''a self-contained computer, incorporating the MIPS R/3000 microprocessor, the most cost effective chip currently available.'' Where the first-generation ACP provided one-half to one VAX equivalents, the new processor provides 15 VAX equivalents in the same amount of space at a similar cost. Depending on the amount of memory, this represents up to a factor of 20 increase in cost effectiveness. This computer, unlike the first ACP, supports a standard operating system, thereby broadening the potential user community. ACP chose the UNIX operating system because of its wide acceptance.

As Jim Deppe of ACP explained, ''A key design element of the ACP/R3000 is that the entire processor fits into a single VME slot. This means that a single crate of ACP/R3000 boards can be loaded with more processors, producing more computing power per crate.'' Designing to VME slot tolerances gives the ACP/R3000 entree to widely used computing architectures. The new module consists of two boards. One, the ''motherboard,'' is an 8-megabyte main memory board with a VME interface. On top of the main memory board, but still within a single slot dimension, is a plug-in ''daughterboard'' which contains the CPU and the instruction and data cache. The motherboard can also stand alone as a standard VME memory board with no processor, or as expansion memory for a CPU. ''For example,'' said Deppe, ''one could have a motherboard and

daughterboard combination and add additional motherboards in adjacent slots, increasing the memory to 16, 24, or 32 megabytes.''

The new software, called cooperative processes software (CPS), is a set of tools which make it easier to divide up a computational task among multiple processors. ''What we've done,'' said ACP's Joe Biel, ''is considerably extend our range over the first-generation ACP.'' There, the emphasis was on hardware because there was a tremendous advantage to be gained from ACP hardware versus what was available from industry. ''With this second-generation ACP/R3000,'' Biel continued, ''we've done substantial software development in addition to new hardware. Unlike the old ACP software, which could only run on ACP computers, CPS is compatible with many other computers. The idea is that an experiment can mix and match - for example, buy Silicon Graphics machines and use CPS software, or use ACP/R3000 boards running CPS, or do both at the same time.''

Universities Research Association, Inc., and Fermilab have entered into a commercial licensing agreement with Omnibyte Corporation, located in West Chicago, which will produce and market the ACP/R3000. In principle, any large computer center could use crates of the second-generation boards rather than their current computers, gaining computational power without a concurrent major dollar investment. According to ACP's Irwin Gaines, ''Anybody who understands computers, has the kind of computational needs that lend themselves to parallel processing, and is looking for increased computational power at less cost, can use this machine.''

Fermilab Education Programs, Summer 1989

by Christine Grusak

Fermilab has been investing in the futures of bright, qualified scientists-to-be for nearly 20 years through a variety of educational programs. This past summer has been no exception. Some of these programs include the Summer Internship in Science and Technology Program, administered by the Fermilab Equal Employment Office (EEO), continued to bring promising minority undergraduates in physics, engineering, and computer science to the Lab. The Target: Science and Engineering Program, also administered through the EEO, provided minority high school students with a chance to discover what it's like to work in a scientific environment. The Undergraduate Honors Summer Program, funded by the Fermilab Physics Department and coordinated by Drasko Jovanovic (CDF), brought yet another group of 25 college students from the United States and around the world to Fermilab where they are introduced to the field of particle physics. And the Summer Research Program for Teachers gave 22 teachers hands-on experience with a wide array of Fermilab endeavors in a broad spectrum of the Lab's elements, from safety and computing to theory and accelerator operations.

The Summer Internship in Science and Technology Program

Students from this program spend 11 weeks at Fermilab, working with a supervisor on either an individual project or a small piece of a larger research project. Finley Markley (TS/Engin.), chairman of the program committee, emphasized that whatever the students work on must contribute positively to their education. "We expect the students to be productive and helpful in their program," said Markley, "but we also expect the reverse. That is, the supervisor should also be helpful and productive in the students' efforts to acquire some knowledge about science. We want them to participate in a research project."

In addition to the research project, students attend weekly lectures and prepare a final paper and presentation based on their project. Dianne Engram, of the EEO, sees the lecture series as particularly beneficial. Each lecture addresses a different area of research taking place at the Lab. "While they're here," said Engram, "they're not just exposed to the one area that they work in, but throughout the ten weeks they get a fuller understanding of the scope of the research at a laboratory of this size." Markley added that the final presentation and paper are also very important aspects of the program. "Both the paper and

the oral presentation give students some experience doing the kinds of things they're going to have to do during their professional lives."

Aggressive recruiting ensures that the top students participate in the program each summer. A committee of approximately seven Fermilab staff visit campuses across the country every fall and winter, interviewing students recommended by their departments. Committee members target schools with high minority enrollments throughout the nation and Puerto Rico. But, as Markley points out, if the committee hears of a single interested and qualified student at a particular university, "We will still certainly try to make contact. We'll do whatever is necessary to find good students."

Jim Davenport, Chairman of the Physics Department and Professor of Physics at Virginia State University, coordinates the Summer Internship Program. Davenport has been involved in the program since its beginnings at Fermilab in 1970. In addition to advising students on educational and scientific issues, he serves as a link between students and their supervisors, and recruits Fermilab staff to give the weekly lectures. As a member of the program committee, Davenport also recruits new students in his area of the country.

The Summer Internship Program also serves as a direct conduit for the Universities Research Association Graduate Minority Fellowship. URA Fellowships are awarded to physics students who show potential as scientists and who have participated in the Summer Internship Program.

Feedback on the Summer Internship Program has been consistently positive, both from the professors of participating students and from the students themselves. "Their professors specifically see an improvement in the students' understanding, and an improvement in their attitude," said Markley. "Also, it is almost unanimous that when the student goes back enthused about the exciting scientific summer he or she has had, the next year we are almost overwhelmed with students that want to come and join Fermilab."

The Target: Science and Engineering Program

Students today are faced with complicated career choices and may not have the opportunity to weigh those choices in any detail. Fermilab's Target: Science and Engineering Program has been helping area minority high school students explore careers in science and technology for almost 10 years by showing these students what it's like to work in a scientific environment.

The program began in 1980, when the Department of Energy (DOE) allocated internship funds which enabled minority high school students to spend their summers working in DOE-supported research laboratories. The goal of the program was to provide students with both academic enrichment and practical

employment experience. Lectures and tours expose students to areas of science and industry they may not have known existed. In a computer lab, students brush up on computer skills before attending college, and in counseling sessions, students learn strategies for applying to colleges and choosing a career.

During the program, students may work in an office or technical area with Fermilab scientific personnel. While not engaged in actual research, the students do experience what it is like to work in a technical field. For many, this is their first job of any kind. "If your first work experience is the positive experience we hope to provide, it can be very motivating," said Dianne Engram. "With good science or math backgrounds, the students learn about some of the jobs to which they can aspire."

Afternoon sessions are devoted to one-on-one work with the students. In addition to the computer lab and counseling sessions, students work on special science projects chosen from a list of abstracts sent with their letters of acceptance. At the end of six weeks they present their projects in a paper and a formal presentation.

"The premise of the program is that these are talented minority students," said Engram, "but because of constraints on funds for public education, they may not have had the opportunity, time, or resources to develop something that their imagination and their talents would enable them to develop." Students learn a great deal about critical thinking during their six-week internship. Accustomed to math and science problems where the object is to arrive at a known answer, students must learn to discover the answers on their own. Students also learn about the reality of scientific research, something few high school science labs can offer.

The Undergraduate Honors Summer Program

The purpose of the Undergraduate Honors Summer Program is to inform and perhaps induce students to take particle physics as a subject in graduate school. The program gives students an introduction to a whole field that they wouldn't otherwise be exposed to. While most students involved in the program are physics majors, a smaller number of computer-science and engineering majors also participate.

Out of 200-300 applications every year, Jovanovic first selects the 100 best-qualified students. "And then it becomes very hard, because about 100 of them are really good," he said. A maximum of two students from the same university may attend the program, and this demographic screening, along with students' experience, abilities, and interests, goes into determining the 25 finalists. Jovanovic then matches each of the 25 students with a participating Fermilab

research associate. "The number 25 is not arbitrary," said Jovanovic. "That is the number of research associates at the Lab. We like to keep one student, two at the most, per associate. It would be nice if we could take more students, but we can't."

Writing computer programs and building or running tests on lab equipment are some of the activities students may perform. Chris Lobello, from Illinois Benedictine College, worked with E-771, building a test station for CAMAC. After performing an internship at Fermilab in the spring, his supervisor asked him to apply for the summer program.

"One very good aspect of the program is the laboratory experience and the exposure it gives you to experimental physics," said Lobello. "The Fermilab people do a good job of making sure students gain a basic understanding of physics. You pick up a lot of knowledge in some very specialized areas. It's hard to go back and sit in a classroom."

In addition to their work, students are encouraged to attend the weekly undergraduate lectures coordinated through the Summer Internships in Science and Technology Program. "It's a good introduction to the field to also go to all the other lectures, even if you may not understand everything," said Jovanovic. Students also meet with Jovanovic each week for short informal lectures and advising.

Jovanovic feels that the presence of summer students at Fermilab creates a university-like environment. "There is a certain amount of youthful enthusiasm that students communicate to the Lab," he said. The summer students also give Fermilab staff a chance to exercise their teaching skills. Jovanovic explained, "Since most of our staff here does not teach, the program may partially fulfill that function. In any process of education you also hone your understanding of an issue as you explain it to someone else."

Jovanovic advises students to develop a familiarity with other domains of physics. Though a supervisor may re-hire a student for the following summer, students may only participate specifically in the Undergraduate Honors Program once. If they wish to do more physics work, Jovanovic suggests they explore other areas of physics. "I strongly encourage them to apply to other labs, such as Bell Labs," said Jovanovic. "They should not necessarily see particle physics as the only field open to them."

However, some students from the program have remained in particle physics and have even returned to Fermilab to do graduate work. Richard Benson, a graduate student at the University of Minnesota, is doing his doctoral work at the Lab. He is enthusiastic about his work on E-706 (direct photon production), and his experience with the Undergraduate Honors Program.

"The program gave me an opportunity to meet other people doing physics," said Benson. "I've worked at the Oak Ridge and Brookhaven labs. To me, the most interesting work is being done at accelerators." As a summer student at Fermilab in 1983, Benson had just graduated from Reid College in Oregon. He worked on a neutrino experiment under Karol Lang, who is now at Stanford.

Jovanovic feels that the program creates a sense of good-will toward Fermilab. Benson echoes this sentiment, saying, "The program left me with a very positive feeling about Fermilab and the research being done here."

Participants in Fermilab's ***Summer Research Program for Teachers****. Top row, l. to r.: Dane Camp, Ray Dagenais, Paul Madsen, Richard Kick, Robert Pacyga, Joel Klammer, and Michael Hand. Second row, l. to r.: Willam Burt, Nathan Unterman, Michael Salisbury, Neil Michels, Roger Demos, and James Mashek. Third row, l. to r.: Frank Burzynski, George Eblin, Donald Whelpley, Yvonne Richter, and Anthony Marturano. Bottom row, l. to r.: Charles Osborne, Randall Zamin, Harold Mulderink, and Kenneth Leszczynski.*

The program began in 1983 with seven teachers from local schools. By summer 1989, the program had grown to include 19 teachers from area schools, as well as one teacher each from Pennsylvania, Minnesota, and Nebraska. Travel and housing funds for out-of-state teachers were provided by the Department of Energy's Office of Energy Research in order to make the opportunities at Fermilab available to a larger set of teachers. Each teacher was assigned a Fermilab staff member as a supervisor, and each of the teachers received a Certificate of Recognition and a congratulatory letter from DOE Secretary James D. Watkins. - Arlene Lennox

Lab Notes

The Department of Energy (DOE) has concurred with Fermilab Director John Peoples' appointment of Kenneth C. Stanfield as Fermilab's Deputy Director, effective July 1, 1989.

Stanfield, who received his Ph.D. in physics from Harvard University in 1969, is an experimentalist who led a number of investigations at the Argonne National Laboratory ZGS and at Fermilab. He joined the Fermilab staff in 1977 as a physicist in the Proton Laboratory, where he addressed the problems associated with preparing that group for the era of Tevatron experiments.

Kenneth C. Stanfield

In his letter to Andrew Mravca, DOE Batavia Area Office Manager, seeking DOE concurrence with Stanfield's appointment, Peoples noted that Stanfield's "work on the Wide Band Beam was particularly valuable as it became one of the four major beams built as part of the Tevatron II project. The Laboratory quickly recognized his management skills, and he was appointed in succession to the position[s] of Associate Department Head of Proton, Department Head of Proton, and Head of the Experimental Areas Department. . . [where] he was responsible for merging the three experimental areas. . . into a coherent single department. He carried out the merger very smoothly and successfully. The large, powerful, fixed-target experiments are sufficient testimony of the effectiveness of the merger. In this work he had to use his very fine skills as a communicator and persuader to make the disparate coherent."

In the fall of 1983, Stanfield became Head of the Business Services Section. In 1984, he was appointed Head of the Research Division, where, again quoting from Peoples' letter, he "refin[ed] the organization of the Research Division to meet the challenges of the changing experimental environment. . . Of particular note was his creation and subsequent strengthening of the Research Division support departments and the integration of the two large collider collaborations into the fabric of the Laboratory."

In addition to, as Peoples put it, being "my backup in every way when I am absent," Stanfield will also be the Lab's primary contact with the DOE Program Office in Washington, D.C.; will be responsible for the initial fielding of requests

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

for help from Fermilab generated by the SSC Laboratory; will resolve major issues between Fermilab and experimenters; and will direct the preparation of long-range plans, such as the Lab's 15-year plan and Fermilab's annual budget request to DOE.

"I believe," wrote Peoples, "that Ken, together with [Associate Directors] Rich Orr and Dennis Theriot, will give the Directorate balance and strength in administration, technology, [and] planning, and thus enhance our chances for a long, prosperous scientific future."

On Wednesday, 27 September, 1989, Fermilab was honored by its first visit of a Head of State, President Jose Sarney of Brazil. The President had been in New York for the opening of the United Nations General Assembly, and came to Fermilab for a special trip before flying back to Brazil. The President had previous knowledge of Fermilab because of his acquaintance with some of the Brazilian physicists working on experiments at the Laboratory.

The strong presence here by Brazilians is a result of the program of cooperation with Latin American institutions initiated a decade ago by then Director Leon M. Lederman. Starting with four Brazilian physicists in 1984, by 1990 this will have grown to about 30 physicists and engineers, from five institutions in Brazil, working on two fixed-target experiments (E-761 and E-791), and on several engineering projects including the Advanced Computer Program.

Presidential visits are not undertaken lightly, by either the visitor or the visitees. This one was initiated in early August in conversations between Laboratory staff and the senior Brazilian physicist here, Professor Alberto Santoro of Centro Brasileiro de Pesquisas Fisicas (CBPF) of Rio de Janeiro, and his colleague, Dr. Isaias Costa, both of whom work on E-791 in the Tagged Photon Laboratory. These discussions quickly escalated, and an invitation to the President was subsequently issued by the U.S. Secretary of Energy. There then began a myriad of meetings and phone conversations with people whose titles (unfamiliar to Fermilab!) included Ambassador, Minister of Protocol, etc., and including many security personnel from both the U.S. and Brazil. On the Fermilab side, coordination for the visit was by Jeff Appel (Computing and co-spokesperson for E-791) and Roy Rubinstein (Director's Office).

A president does not travel alone! On September 27, after a greeting at O'Hare airport by Jeff Appel, Deputy Energy Secretary Henson W. Moore, and other Department of Energy (DOE) officials, a motorcade of some 14 vehicles, containing close to 50 people together with about 20 Brazilian press, set off for

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

Fermilab, arriving at 11:20 a.m. to be met on the Wilson Hall steps by Fermilab Director John Peoples and other senior Laboratory and DOE staff. A sizeable number of U.S. and Brazilian press were present then and at other prearranged opportunities throughout the day.

After a welcome to the Laboratory by Deputy Secretary Moore, a briefing on Fermilab and its programs was given in the 1West conference room by John Peoples, followed by a report on the Lab's Latin American activities by Leon Lederman. After a luncheon on the 15th floor, a tour of the Laboratory was arranged for the President, while the press and some members of his team stayed in 1West to hear more reports about the Laboratory and its activities. The President visited E-791 in the Tagged Photon Laboratory, the Collider Detector at Fermilab, the Antiproton Source, the Accelerator Control Room, and the Neutron Therapy Facility. There followed a 3/4-hour private meeting with the Brazilian scientists currently at the Lab, arranged by Alberto Santoro, and then a short closing meeting with John Peoples, together with senior Lab and DOE staff; at 5:15 p.m. the motorcade left for O'Hare and hence to Brazil.

The whole visit went very smoothly, due to the hard work of a large number of Fermilab people. One person always in the midst of the action was Gary Verseput, Chief of Fermilab Security. Afterwards he said, "This was a unique opportunity to coordinate security operations with three federal agencies and the security services of Brazil, using at least two languages. Everyone here at the Lab cooperated with our security requirements in every way, and made it easy to coordinate the visit."

Among others who took a large role were Mary Cullen, Barbara Lach, Bob Kephart, Bob Mau, Arlene Lennox, Stan Orr, Peggy McAuliff, Pete Loomis, Joe Lach, Peter Cooper, and Fred Ullrich. Of the efforts by these and others, John Peoples commented "A fantastic job was done by the Laboratory staff - their efforts made this a truly memorable occasion. This was our first visit by a Head of State, and we trust that it will only be the first of many." - *Roy Rubinstein*

Continuing its educational efforts, the US Particle Accelerator School (USPAS) held two summer schools this year. The USPAS has two basic purposes - to educate people in accelerator physics and technology (in particular, to train apprentices and update experts), and to encourage U.S. universities and laboratories to offer programs in accelerator physics by developing textbooks, training faculty, and organizing schools at these institutions.

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

The first of this year's two summer schools was a two-week university-style school held at the University of California, Berkeley (UCB). The university-style schools were created to allow courses to be presented in greater depth, to promote student-teacher interaction and feedback, and to encourage the attendance of younger students, as university credit is earned for courses that are successfully completed. Each of the five courses given this year included 45 hours of lectures, problem-solving, and recitation periods, and as a final examination.

(Photograph courtesy of Brookhaven National Laboratory)

From the left: Mel Month, Director of the USPAS; Karl L. Brown, SLAC; James Leiss, who presented the USPAS awards for 1989; Daniel L. Birx, Science Research Laboratory; and Marty Blume, Deputy Director, BNL, at the presentation to Brown and Birx of the 1989 Prizes for Achievement in Accelerator Physics and Technology.

Emphasizing the importance of a university education in the study of particle accelerators, Mel Month, founder and Director of the USPAS, said, "As graduated students, physicists are taught at the university how to build detectors or portions of large detectors - but their only real opportunity to learn how to build an accelerator or any of its parts has been at accelerator laboratories after graduation. This situation just won't do. In the future, we must find new ways for students to study particle accelerators in the university."

The School at UCB, held from June 19 to June 30, 1989, was the most successful university-style school to date. Over half of the 140 registered students will receive up to three university credit hours for their efforts. Courses included "Theory and Design of Particle Beams," "Introduction to Accelerator Physics," "Introduction to Free Electron Lasers," "Principles of Acceleration,"

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

and "Introduction to Beam Instabilities." The second 1989 School was held from July 24 through August 4, 1989. This symposium-style school, at Brookhaven National Laboratory (BNL), consisted of an intense series of lectures. There were over 60 lecturers, covering a wide range of subjects on the physics and technology of particle accelerators. Topics covered particle-beam fundamentals, intense beams, accelerator technology, instabilities, nonlinear dynamics, high-luminosity colliders, and linear colliders, in addition to an afternoon symposium on the Superconducting Super Collider.

Also at BNL, on August 3, the 1989 Prizes for Achievement in Accelerator Physics and Technology, an annual award by the USPAS initiated in 1985, were presented. This year, prizes went to Daniel L. Birx of Science Research Laboratory of California, and Karl L. Brown of the Stanford Linear Accelerator Center (SLAC).

Daniel Birx was cited "for developments in high-power magnetic switching technology with applications such as high-repetition-rate induction linacs, free-electron lasers and laser isotope separation." His important work has impacted a number of nationally prominent projects, for example, high-power free-electron lasers (FEL) for Department of Defense applications, FEL's for heating fusion plasmas (MTX experiment at Lawrence Livermore National Laboratory [LLNL]), high-average-power gas lasers, and the development of high-power "relativistic klystrons" in a collaborative effort involving SLAC, LBL, and LLNL. These microwave-source developments may be an important technology in future high-gradient linear colliders for high-energy physics applications.

Karl Brown was honored "for insights into particle beam transport and for introducing formalisms in use throughout the world." He has been a pioneer in both the development and applications of concepts of charged particle optics, making major contributions to linear and non-linear optics. His contributions have helped make possible the modern, sophisticated designs represented by the arcs of the SLAC Linear Collider (SLC), the final focus of the SLC, and the initial design of the arcs of the LEP collider at CERN.

Winners of the USPAS prizes are chosen on a competitive basis. The 1989 Prize Committee consisted of J. E. Leiss, W. K. H. Panofsky, R. H. Siemann, and S. Van der Meer. This year's awards were supported by Universities Research Association, Inc., the Continuous Electron Beam Accelerator Facility, SURA, Intermagnetics General Corporation, Varian Vacuum Products, and the Westinghouse Electric Company.

The US Particle Accelerator School is sponsored by the U.S. Department of Energy, the National Science Foundation, and major high-energy physics laboratories. - *S. Winchester*

Fermilab's Advanced Computer Program Multi-Array Procesor System (ACPMAPS) has received the R&D 100 Award as one of the top 100 new technologies in 1989, the twelfth time the Laboratory's technology has been recognized by this award. The R&D 100 Awards are selected by the publisher of *Research and Development Magazine*. The ACPMAPS parallel-processing supercomputer, which was developed by members of Fermilab's Advanced Computer Program (ACP) and Theoretical Physics groups, will allow scientists and engineers to perform calculations faster, more conveniently, and less expensively then before. ACPMAPS is at present being utilized for lattice gauge theory calculations, but the system will have applications in stress analysis, fluid dynamics, weather forecasting, and the solving of differential equations.

Co-leaders of the ACPMAPS collaboration are Thomas Nash and Estia Eichten. Members of the ACP contingent include Robert Atac, Joseph Biel, Arthur Cook, James Deppe, Mark Edel, Mark Fischler, Irwin Gaines, Ming Gao, Donald Husby, Michael Isely, Thinh Pham, and Ted Zmuda. Collaborators from the Theory Department are George Hockney, Andreas Kronfeld, Paul Mackenzie, and Hank Thacker.

Final agreement has been reached between Fermilab and Data Research Associates, Inc. (DRA), of St. Louis, Missouri, to provide an automation system for the Fermilab Library. When installation is completed (expected to be spring 1990), Library users will have greatly improved access to Library resources.

Through terminals in the Library and over DECnet connections, users will have expanded access to the "card catalog" and will have the ability to request, reserve, and check out items electronically. The system will provide users with up-to-date status of Library holdings through its automation of the day-to-day tasks performed by the Library staff.

The automation system is the result of a two-year project by the Fermilab Library Committee and the Library staff with the support of the Director's Office and Chuck Marofske, Head of Laboratory Services Section. The Library Committee, chaired by Hank Thacker and consisting of Dave Carey, John Grimson, Leo Michelotti, Tim Miller, Tom Nash, Stephen Parke, and David Ritchie, selected the

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

DRA product after an extensive review by Automation Subcommittee members Paula Garrett and David Ritchie.

A note to those calling Fermilab: The Laboratory's area code is changing from 312 to 708 on November 11, 1989. Individual 7-digit telephone numbers will not change, nor will FTS numbers.

Manuscripts and Notes

prepared or presented from July 1, 1989, to September 30, 1989. Copies of Fermilab TM's, FN's, and preprints (exclusive of Theoretical Physics and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH6NW, or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL. For Theoretical Physics or Theoretical Astrophysics preprints, contact those departments directly. For papers with no Fermilab catalogue number, contact the author directly.

Experimental Physics Results

Experiment #672
K. De et al., "The Production of J/ψ and Associated Particles in the Collision of 530 GeV/c Protons and Pions with Nuclear Targets," (FERMILAB-Conf-89/151-E; to be published in the proceedings of the XXIVth Rencontres de Moriond: "New Results in Hadronic Interactions," Les Arcs, Savoie, France, March 12-18, 1989)

Experiment #691
J. C. Anjos et al., "A Study of Decays of the Λ_c^+," (FERMILAB-Pub-89/144-E; submitted to Phys. Rev. Lett.)

Experiment #705
C. M. Jenkins et al., "Results from the E-705 Electromagnetic Shower Position Detector," (TM-1591; presented by C. M. Jenkins at the 1989 IEEE Nuclear Science Symposium, Orlando, Florida, November 9-11, 1988)

Experiment #710
N. A. Amos et al., "Measurement of the $\bar{p}p$ Total Cross Section at $\sqrt{s}$ = 1.8 TeV," (FERMILAB-Pub-89/176-E; submitted to Phys. Rev. Lett.)

Experiment #715
L. H. Trost et al., "New Measurement of the Production Polarization and Magnetic Moment of the Cascade Minus Hyperon," (FERMILAB-Pub-89/145-E; to be published in Phys. Rev. D)

Experiment #740
W. J. Womersley, "New Tools for the Simulation and Design of Calorimeters," (FERMILAB-Conf-89/155-E; presented at the 4th Pisa Meeting on Advanced Detectors, La Biodola, Elba, Italy, May 21-25, 1989; proceedings to be published in Nucl. Instrum. Methods)

Experiment #741/CDF
F. Abe et al., "Measurement of the Mass and Width of the Z^0 Boson at the Fermilab TEVATRON," (FERMILAB-Pub-89/160-E; submitted to Phys. Rev. Lett.)

F. Abe et al., "Search for Heavy Stable Particles at the Fermilab Collider," (FERMILAB-Pub-89/161-E; submitted to Phys. Rev. Lett.)

A. Byon, "Central Production of Charged Particles at CDF," (Ph.D. Thesis, Purdue University, West Lafayette, Indiana, December 1989)

G. W. Foster (for the CDF Collaboration), "Status of the Top Quark Search at CDF," (published in the proceedings of the 1989 International Symposium on Heavy Quark Physics, Cornell University, Ithaca, New York, June 13-17, 1989)

The CDF Collaboration, reported by J. Freeman, "A Missing Transverse Energy Analysis of 1.8 TeV $\bar{p}$-p Collisions Observed at CDF," (FERMILAB-Conf-89/148-E; presented at Les Rencontres de Physique de la Vallee d'Aoste: "Results and Perspectives in Particle Physics," La Thuile, Italy, February 26-March 4, 1989)

J. Huth, "Jet Energy Measurement - CDF Experience," (FERMILAB-Conf-89/117-E; presented at the SSC Workshop on Calorimetry for the Superconducting Super Collider, Tuscaloosa, Alabama, March 13-17, 1989)

S. E. Kuhlmann, "Inclusive Central Jet Production at $\sqrt{s}$ = 1.8 TeV," (Ph.D. Thesis, Purdue University, West Lafayette Indiana, August 1988)

M. H. Schub, "Strange Particle Production in Proton-Antiproton Collisions at Center-of-Mass Energies of 630 GeV and 1800 GeV," Ph.D. Thesis, Purdue University, West Lafayette, Indiana, August 1989.

Experiment #769
D. Errede et al., "A High Rate Transition Radiation Detector for Particle Identification in a Hadron Beam," (FERMILAB-Conf-89/170-E; talk given by M. Sheaff at the Symposium on Particle Identification at High Luminosity Hadron Colliders, Fermilab, Batavia, Illinois, April 5-7, 1989)

Experiment #774
A. Bross et al., "A Search for Short-Lived Particles Produced in an Electron Beam-Dump," (FERMILAB-Pub-89/138-E; submitted to Phys. Rev. Lett.)

General Particle Physics

R. H. Bernstein, "A New Method of Determining SIN^2 θ_w in Deep-Inelastic ν_μN Scattering," (FERMILAB-Conf-89/149; based on a talk presented at the XII International Workshop on Weak Interactions and Neutrinos, Ginosar, Israel, April 9-14, 1989)

S. Qian and A. Van Ginneken, "Energy Deposition in Large Targets by 1-20 TeV Proton Beams," (FN-514)

Accelerator Physics

S. A. Bogacz, "Longitudinal Emittance Blow-Up Due to Coherent Motion of Coupled Bunches," (FN-517)

S. A. Bogacz, "Transverse Coupled Bunch Stability with Landau Damping," (FN-516)

S. Childress et al., "Fermilab Fixed Target Beams from the Main Injector," (TM-1599; reference work for the Workshop on Physics at the Main Injector, Fermilab, Batavia, Illinois, May 16-18, 1989)

G. Dugan, "Tevatron Collider: Status and Prospects," (FERMILAB-Conf-89/182; presented at the XIV International Conference on High Energy Accelerators, Tsukuba, Japan, August 22-26, 1989)

G. Dugan and V. Bharadwaj, "An Empirical Model for the Luminosity of the Fermilab Tevatron Collider," (FERMILAB-Conf-89/181; presented by G. Dugan at the XIV International Conference on High Energy Accelerators, Tsukuba, Japan, August 22-26, 1989)

N. H. Engler et al., "SSC Superconducting Dipole Magnet Cryostat Magnet Cryostat Model Style B Construction Experience," (TM-1595; prepared for the 1989 International Industrial Symposium in the Super Collider [IISSC], New Orleans, Louisiana, February 8-10, 1989)

D. A. Finley, "Calculation of Integrated Luminosity for Beams Stored in the Tevatron Collider," (TM-1607; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

S. D. Holmes et al., "The Fermilab Main Injector," (FERMILAB-Conf-89/183; presented by S. D. Holmes at the XIV International Conference on High Energy Accelerators, Tsukuba, Japan, August 22-26, 1989)

G. Jackson and T. Ieiri, "Stimulated Longitudinal Emittance Growth in the Main Ring," (FERMILAB-Conf-89/87; presented by G. Jackson at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

T. G. Jurgens and F. A. Harfoush, "Finite Difference Time Domain Modelling of Particle Accelerators," (FERMILAB-Conf-89/137; presented at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

P. Mantsch et al., "A New High-Gradient Correction Quadrupole for the Fermilab Luminosity Upgrade," (FERMILAB-Conf-89/92; presented by P. Mantsch at the 1989 IEEE Particle Accelerator Conference, Chicago, Illinois, March 20-23, 1989)

Theoretical Physics

W. A. Bardeen et al., "Minimal Dynamical Symmetry Breaking of the Standard Model," (FERMILAB-Pub-89/127-T; submitted to Phys. Rev. D)

W. A. Bardeen et al., "Addendum to Minimal Dynamical Symmetry Breaking of the Standard Model," (FERMILAB-Pub-89/127-T; submitted to Phys. Rev. D)

R. K. Ellis, "The Theory of Heavy Flavour Production," (FERMILAB-Conf-89/168-T; lectures given at the 17th SLAC Summer Institute: "Physics at the 100 GeV Mass Scale," Stanford, California, July 10-21, 1989)

G. F. Giudice, "Gamma Ray Lines from Dark Matter Annihilation," (FERMILAB-Conf-89/188-T; talk given at the Topical Seminar on Astrophysics and Particle Physics, San Miniato, Italy, May 8-12, 1989)

G. F. Giudice, "Multiple Production of Supersymmetric Higgs Bosons in Z^0 Decays," (FERMILAB-Pub-89/150-T; submitted to Phys. Lett.)

G. F. Giudice, "R-Parity Breaking in Low Energy Supergravity Models," (FERMILAB-Conf-89/167-T; talk presented at the XII Warsaw Symposium on Elementary Particle Physics, Kazimierz, Poland, May 29-June 2, 1989)

P. Griffin, "Radial Quantization of the Ising Model in the Scaling Regime, and Integrals of the Motion," (FERMILAB-Pub-89/153-T; submitted to Nucl. Phys. B)

P. A. Griffin and D. A. Kosower, "Curved Spacetime One-Loop Gravity in a Physical Gauge," (FERMILAB-Pub-89/177-T; submitted to Phys. Lett. B)

B. Grinstein, "Critical Reanalysis of CP Asymmetries in B^0 Decays to CP Eigenstates," (FERMILAB-Pub-89/158-T; submitted to Phys. Lett. B)

C. T. Hill et al., "Was There a Late Time Phase Transition in the Early Universe?" (FERMILAB-Pub-89/166-T; submitted to Nature)

K.-i. Kobayashi and T. Uematsu, "Higher Integrals of Motion in a Perturbed k=1 SU(2) Wess-Zumino-Witten Theory," (FERMILAB-Pub-89/174-T; submitted to Phys. Lett. B)

D. A. Kosower, "Light-cone Recurrence Relations for QCD Amplitudes," (FERMILAB-Pub-89/192-T; submitted to Nucl. Phys. B)

M. Leurer and M. Golden, "A Model for a Large Neutrino Magnetic Transition Moment," (FERMILAB-Pub-89/175-T; submitted to Nucl. Phys. B)

J. Maharana, "Spontaneous Symmetry Breaking in 4-Dimensional Heterotic String," (FERMILAB-Conf-89/164-T; presented at the NATO Advanced Research Workshop, "Physics and Geometry," Lake Tahoe, Nevada, July 2-8, 1989)

M. Mangano and S. Parke, "W Boson Plus Two Jet Production at the Tevatron," (FERMILAB-Pub-89/106-T; submitted to Phys. Rev. D)

S. Parke and M. Mangano, "The Structure of Gluon Radiation in QCD," (FERMILAB-Conf-89/180-T; invited talk presented by S. Parke at the Workshop on QED Structure Functions, University of Michigan, Ann Arbor, Michigan, May 22-25, 1989)

Theoretical Astrophysics

A. Albrecht and N. Turok, "Evolution of Cosmic String Networks," (FERMILAB-Pub-89/140-A; submitted to Phys. Rev. Lett.)

K. Griest, "Erratum," (FERMILAB-Pub-89/139-A; submitted to Phys. Rev. D)

S. Marques, "The Dirac Equation in a Non-Riemannian Manifold: II An Analysis Using an Internal Local N-Dimensional Space of the Yang-Mills Type," (FERMILAB-Pub-89/146-A; submitted to J. Math. Phys.)

S. Marques-Bonham, "A New Way to Interpret the Dirac Equation in a Non-Riemannian Manifold," (FERMILAB-Pub-89/147-A; submitted to J. Math. Phys.)

A. Peréz and R. Gandhi, "Pair Production of Helicity-Flipped Neutrinos in Supernovae," (FERMILAB-Pub-89/156-A; submitted to Phys. Rev. D)

Computing

M. Bernett and G. Oleynik, "Uniform Communications Software Using TCP/IP," (FERMILAB-Conf 89/133; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

D. Berg et al., "A Real Time Integrated Environment for Motorola 680xx-Based VME and FASTBUS Modules," (FERMILAB-Conf-89/131; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

P. Constanta-Fanourakis et al., "Exabyte Helical Scan Devices at Fermilab," (FERMILAB-Conf-89/132; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

T. Dorries et al., "FEREAD Front End Readout Software for the Fermilab PAN-DA Data Acquisition System," (FERMILAB-Conf-89/130; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

H. Johnstad, "PAW at Fermilab - CORE Based Graphics Implementation of HIGZ," (FERMILAB-Conf-89/142; presented at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

H. Johnstad, "Physics Analysis Workstation," (FERMILAB-Conf-89/143; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

P. Lebrun and A. Kreymer, "High Level Language Memory Management on Parallel Architectures," (FERMILAB-Conf-89/124; presented by P. Lebrun at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

T. Nash, "Event Parallelism: Distributed Memory Parallel Computing for High Energy Physics Experiments," (FERMILAB-Conf-89/120; invited talk presented at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

D. Petravick et al., "The PAN-DA Data Acquisition System," (FERMILAB-Conf-89/136: presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

D. L. Petravick et al., "Remote Procedure Execution Software for Distributed Systems," (FERMILAB-Conf-89/135; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

R. Pordes et al., "Software for FASTBUS and Motorola 68K Based Readout Controllers for Data Acquisition," (FERMILAB-Conf-89/134; presented at "Real Time Computer Applications in Nuclear, Particle, and Plasma Physics," Williamsburg, Virginia, May 16-19, 1989)

Cryogenics

R. W. Fast and H. L. Hart, "Use of Glass Beads to Increase the Breakdown Voltage in Subatmospheric, Cold Helium Gas," (presented at the 1989 Cryogenic Engineering Conference, University of California, Los Angeles, July 25-28, 1989; to be published in Advances in Cryogenic Engineering)

Other

D. F. Anderson, "Cerium Fluoride: A Scintillator for High-Rate Applications," (FERMILAB-Pub-89/169; submitted to Nucl. Instrum. Methods A)

M. Kuchnir and J. L. Tague, "Thermal Conduction of SSC Wire," (TM-1613; presented by M. Kuchnir at CEC ICMC 89, University of California, Los Angeles, July 24-28, 1989)

Colloquia, Lectures, and Seminars

by Fermilab staff, at Fermilab, July-September 1989, unless otherwise noted.

May 24

D. Summers, "A High-Speed Data Acquisition and Off-Line Reconstruction System," at CERN.

July 5

D. Anderson, "Particle Detectors"

B. Grinstein, "CP Violation"

July 7

T. Murphy, "LEP Detector Installation Progress: Scuttlebut and Slide Tour"

July 12

J. Bjorken, "The Fifth Force"

July 19

D. Green, "Scattering and Structure"

J. Fuerst, "Cold Compressor Performance"

J. Theilacker, "F Sector Power Tests"

August 2

J. Strait, "The Superconducting Super Collider"

August 24

D. Ryu, "Evolution of the Intergalactic Medium," at the Korean Institute for Space Science and Astronomy

September 8

J. Huth, "Experimental Status of QCD and Jets - Summary Talk from Photon-Lepton Conference"

September 12

T. Peterson, T. Nicol, J. Theilacker, R. Stanek, and G. Mulholland, "Update on Cryogenic Groups' Personnel/Projects - Report on 'Physics at Fermilab in the 1990's' Workshop"

G. Jackson, "Accelerator Issues for an e^+e^- B-Factory"

September 18

M. Turner, "Inflation in the Universe," at Universidad Autonoma Metropolitana - Iztapalapa, Mexico City

September 21

G. Mulholland, "D0 Cryogenics"

September 22

R. Gregory, "Cosmic Strings and Skyrmion Decay," at the Observatoire de Meudon, Paris, France

M. Turner, "Dark Matter in the Universe," at Gran Sasso Lab, Italy

September 25

D. Schramm (University of Chicago/Fermilab), "Lithium: A Cure for Cosmic Manic-Depression"