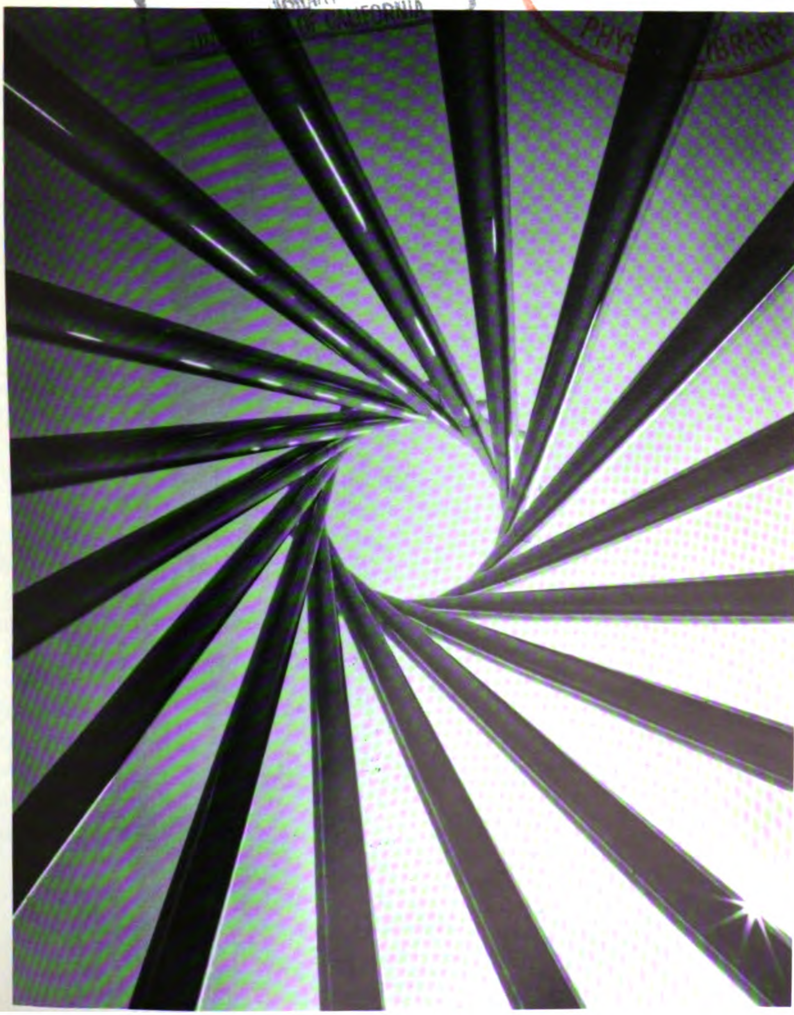
fermilab report

Fermi National Accelerator Laboratory Monthly Report

May/June
1988



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88/5 **Fermi National Accelerator Laboratory**

On the cover: Tractricious, *the latest addition to Fermilab's collection of Robert R. Wilson sculptures, as visualized by Fermilab Photographer Reidar Hahn. For a more conventional view, see page 40.* *(Fermilab photograph 88-725)*

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fermilab report

May/June 1988

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Physics Advisory Committee Meeting

June 18-24, 1988

General Remarks and Recommendations

In February, Fermilab completed a very successful fixed-target run with over $2x10^{18}$ protons accelerated during which 14 experiments were completed and four new TEVATRON beamlines and experiments were brought into operation. A long Collider run in which the goal is an integrated luminosity of 1000 $(nb)^{-1}$ is now being started. The immediate focus of the Laboratory is maximum utilization of its facilities within the available resources.

Among the many recent successes, the Committee notes particularly the following:

- Publication by the Collider Detector at Fermilab (CDF) group of the first results from its initial $\bar{p}p$ collider run during which a total luminosity of 33 $(nb)^{-1}$ was obtained;

- Measurement by E-710 of the slope parameter in elastic scattering at 1.8 TeV;

- Measurement of the multiplicity dependence of the p_t spectrum at 1.8 TeV by E-735;

- First operation for physics of the four major new TEVATRON II beamlines: the Wide Band Photon Beam for E-687 and E-774, the New Muon Beam for E-665, the Polarized Beam for E-704, and the MWest Pion Beam for E-706/E-672;

- Observation of exclusive semileptonic charm decay modes and excited charm states by E-691;

- The successful completion of the approved program of neutrino experiments by E-632, E-733, E-745, and E-770;

- Completion of data-taking for the precision measurement of ε'/ε by E-731;

- Observation of production of polarized Ω^- hadrons and first measurement of the Ω^- magnetic moment by E-756;

- Successful Superconducting Super Collider aperture studies performed in the TEVATRON at the end of the fixed-target run.

Long-Range Plans for Fermilab Accelerator Facilities

The Committee believes that it is essential for Fermilab to continue to upgrade its accelerator facilities. In this way, ongoing experimental programs can be enriched and new opportunities can be created, maintaining the Laboratory's vitality. We commend the Laboratory for vigorously exploring future options at this time of new success with the TEVATRON.

In these circumstances, the scientific exploitation of the TEVATRON, both with colliding and fixed-target beams, must continue with the highest priority. Possible new discoveries (for example, the t quark) should be followed up, and a hospitable climate for new initiatives maintained. Therefore, a flexible phased upgrade plan is most attractive to the Committee. We strongly endorse the first phase of this plan, involving "adiabatic" steps that are already well identified. It involves the Linac modifications already validated by the Department of Energy; new, stronger low-β magnets; improvements in the Antiproton Source; and small increases both in the Collider and fixed-target beam energies. The increased proton and antiproton intensity and energy will benefit the fixed-target and especially the Collider program, where a peak luminosity of 5×10^{30} cm^{-2} sec^{-1} may thereby be reached.

A possible second phase of the upgrade, already described in the Laboratory's study of the pp option, is the construction, in a smaller separate tunnel, of a new main ring, the Main Injector. It appears likely that the Main Injector can offer excellent injection into the TEVATRON, copious antiproton production, and availability of >100-GeV protons for test beams during Collider operation and possibly for very-high-intensity moderate energy secondary beams during fixed-target operation. Existing Main Ring bypasses and penetration of the D0 detector, with their potential backgrounds, would be eliminated. The quality and intensity of protons and antiprotons injected into the TEVATRON for Collider and fixed-target operations would be improved, with greater reliability. It may be possible to construct most of the Main Injector while the existing accelerator complex continues to operate. Eventual removal of the Main Ring would enhance the possibility of building a third major collider detector area.

The Committee heard presentations describing the Laboratory's study and planning for a further phase of the upgrade, designed to explore the 200- to 400-GeV mass region both for discovery and for physics exploitation of discovery. The options described, still tentative, were (A) $\bar{p}p$ at 2 TeV, $L = 5 \times 10^{31}$; (B) pp at 2 TeV, $L = 2 \times 10^{32}$; and (C) $\bar{p}p$ at 3 TeV, $L = 10^{31}$. Options (A) and (C) have a greater reach for production processes requiring antiquarks in the initial state, while (B) with its higher luminosity, favors processes requiring gluons. The implications for necessary upgrading of the collider detectors also are still tentative, but it does seem clear insofar as the detectors are concerned that option (C) would be the most straightforward to handle, and (B) the least. Construction of the Main Injector would free Main Ring tunnel space needed for (B) and (C). Initial pursuit of option (C) would not preclude later luminosity improvement along the lines of (A) or (B).

In general, the Committee is enthusiastic about further upgrades. We do see the need for a flexible approach, allowing for further enhancement both of the Collider and fixed-target programs. There are still opportunities for new information (e.g., indications from the current CDF run) to point to a direction, and we expect to review the Laboratory's plans at the fall PAC meeting.

Computing, Advanced Computer Program, and Lattice Gauge Calculations

The Committee listened with interest and concern to the growing demand for computing support by the fixed-target and Collider experiments. The Laboratory is presently expanding its capacity with a new Amdahl machine in its Central Computing Facility, and is vigorously and aggressively expanding the Advanced Computer Program (ACP) capability.

The Laboratory has already successfully demonstrated the ACP capability for crunching large data sets. It is preparing to process the large amount of data resulting from the recent fixed-target run. Future fixed-target runs and Collider runs promise to seriously aggravate the backlog of unprocessed raw data. Therefore, the Committee strongly encourages the ACP group and endorses its goals of developing higher-speed processor boards and the Computing Department effort to develop higher-density data storage media. The Committee supports the effort to make this technology commercial.

A specific application of the ACP technology to a system suitable for lattice gauge calculations was described. Although the steps ahead to develop a suitable machine and its related software and support equipment look long, the potential is enormous. The ability to make improved lattice gauge calculations appears to be reachable at a relatively modest cost by this highly motivated group. The Committee encourages the Laboratory to continue to pursue this program.

Test Beams

The Committee requests the Laboratory to review the general subject of test beams with the purpose of establishing general policy and guidelines for consideration of future test beam requests. The Committee foresees an increasing interest in test beams from groups associated with collider detector calibration and future detector R&D activities. The purpose in establishing general policy and guidelines would be to strike a proper balance between the Laboratory physics program and support for the calibration and those R&D studies which are so important to the future.

John Peoples Named Deputy Director Designate

The Board of Trustees of the Universities Research Association, Inc., and Fermilab Director Leon M. Lederman have announced the appointment of John Peoples, Jr., to the position of Deputy Director Designate at Fermilab. Peoples will begin his tenure as Deputy Director on a full-time basis beginning in September 1988.

John Peoples received his Ph.D. in physics from Columbia University in 1966, and has served on the faculties of both Columbia and Cornell universities. He joined the staff of Fermilab (then the National Accelerator Laboratory) on March 1, 1972, as a physicist. From 1975 to 1980, Peoples was Head of the Fermilab Research Division. In 1981, Peoples was named Head of the Antiproton (Pbar) Source project at Fermilab.

In 1985, the efforts of Peoples and his colleagues were rewarded when the Antiproton Source accumulated its first batch of pbars in September of that year. By 1987, the Pbar Source entered into extended operation for Collider physics, providing the Collider Detector at Fermilab (CDF) with the bunches of pbars that, on March 29 of that year, during CDF's engineering run, produced the first "new world" W and Z particles. In April of 1987, the maximum rate at which antiprotons were collected reached 1.2×10^{10}/hour, exceeding the previous world record held by the CERN AA by almost a factor of two.

"John Peoples has been a tower of strength in this Laboratory," Lederman stated, "and has also represented us well as a HEPAP member and, most recently, at the Central Design Group for the Superconducting Super Collider. As we sit on the threshold of an era in which we exploit and upgrade the TEVATRON, John will be a major force in helping to steer the Laboratory to ever greater success."

Fermilab Experiment 705

Brad Cox

The E-705 Collaboration:
University of Arizona, University of Athens, Duke University, Fermilab,
Florida A&M University, McGill University, Northwestern University,
Prairie View A&M University, Shandong University

During the fixed-target run (June 1987 to February 1988), Fermilab Experiment 705, operating in the High Intensity Laboratory of the Proton Area with a large aperture, open geometry spectrometer (see Fig. 1) took data with a variety of 300 GeV/c beams (π^+, π^-, proton, and antiproton) on a Li^7 target accumulating high statistics on hadroproduction of charmonium and high-p_t direct photons.

FERMILAB HIGH INTENSITY LABORATORY SPECTROMETER

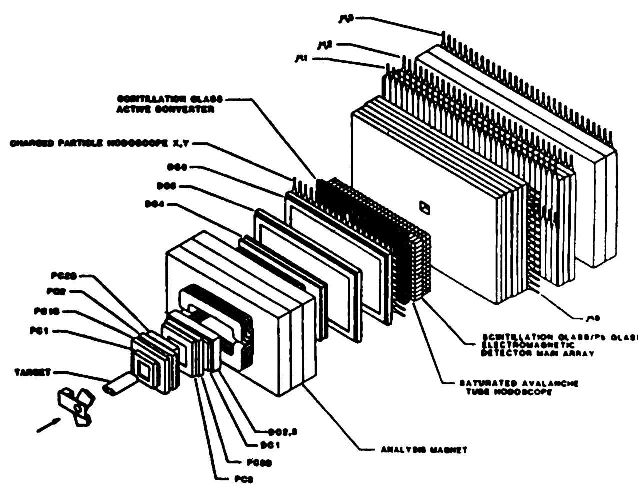

***Fig. 1.** The Fermilab high-intensity laboratory spectrometer*

The E-705 spectrometer operated at interaction rates up to one MHz during this run (test runs of up to 3.5 MHz were also performed), taking over 7500 data tapes containing approximately 200 million dimuon and high-p_t photon triggers. The major components of this spectrometer consisted of a wire chamber system containing both drift and proportional wire chambers, a high-resolution electromagnetic detector made from scintillation and lead glasses, and a large muon detector coupled to a sophisticated multistage muon trigger.

The prime objective of the experiment was the measurement of the hadroproduction of the P states of charmonium system. The particular production and decay sequence of P states which the experiment is designed to detect is:

$$\begin{matrix}\pi^{\pm} \\ p^{\pm}\end{matrix} Li^7 \rightarrow \chi + x$$
$$\rightarrow \psi + \gamma$$
$$\rightarrow \mu^+ \mu^-$$

The comparison of the total and differential cross sections for hadronic production of the various charmonium states, as well as the measurement of the angular distribution of their radiative decays, will shed light on the production mechanisms of bound states of charm quarks. This experiment will study the role played by soft gluon emission in the creation of quarkonia and eventually will allow a rather unbiased extraction of gluon structure functions.

(Fermilab photograph 88-180-4)

The apparatus for Experiment 705 looking down stream. Pictured are: Joseph Kuzminski (McGill University), Leonard Spiegel (Northwestern University), George Zioulas (McGill University), Merrill Jenkins (Fermilab), Yao Tan (Northwestern University), Steve Delchamps (Fermilab), Takis Pramantiotis (University of Athens), Ionnas Koutentakis (University of Athens), Chuck Serritella (Fermilab), Spyros Tzamarias (Northwestern University), Xveyao Zhang (Shandong University, People's Republic of China)

Experiment 705 attains good sensitivity for the charmonium events by triggering on the dimuons from the ψ decays. This trigger is composed of three levels:

1) A pipelined fast-logic stage, capable of resolving individual rf buckets (18.7 ns bucket separation), which requires two or more muons energetic enough (6 GeV/c) to penetrate the steel of the muon detector;

2) A second-level asynchronous processor which finds, tracks, and reconstructs their momenta. This processor then forms, in an average time of 50 microseconds, all pair-wise two-muon mass combinations, keeping only the events in which at least one combination has mass greater than 2.4 GeV/c^2;

3) A third-level trigger constructed from Fermilab Advanced Computer Program modules, which recalculates the dimuon mass with greater precision and applies a higher mass cut.

Such a trigger arrangement can achieve a rejection of total cross section events approaching 10^{-5}. During the running of E-705, this dimuon trigger operated in parallel with the high-p_t photon trigger (described below), allowing the experiment to be run at raw interaction rates of 1 MHz with live times of 80%. The efficiency of this trigger for collecting J/ψ events where both muons satisfied the constraints of the first-level trigger was close to 100%. As a result of the effectiveness of this trigger system, over 100,000 $J/\psi \rightarrow \mu^+\mu^-$ decays are estimated to be in the data collected in the 1987-88 Fermilab fixed-target run. Figure 2 shows the preliminary J/ψ signal reconstructed from a small portion of the data accumulated by the experiment.

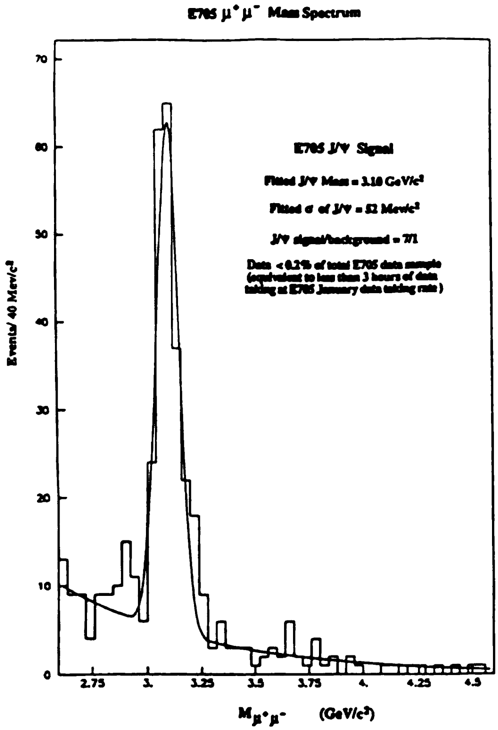

Fig. 2. Preliminary J/ψ signal from E-705.

One of the major challenges of this experiment is to resolve the closely spaced χ states. This objective requires the reconstruction of the invariant mass of the ψγ system with a resolution of better than 15 MeV/c². To this purpose, a unique component of this experiment, an electromagnetic detector whose central region is composed of scintillating glass, was developed and constructed. The increased light output of this glass gives better electromagnetic shower energy resolution (test-beam results indicate $1\% + 2\%/\sqrt{E}$ is achievable) than that of previous experiments. Combining this photon energy resolution with the precise spatial information provided by fine-granularity (0.7 cm), gas-tube hodoscopes which measure shower profiles in the first five radiation lengths of the detector, it is possible to make a precise enough reconstruction of the photon four vector to resolve the charmonium P states.

A second unique aspect of this glass is its good resistance to radiation damage which allowed operation at high rates for long periods of time during the run. The measurements of the radiation resistance of the scintillation glass indicate that it is 100 times less vulnerable to radiation damage than lead glass at the critical wavelength (470 nm). No problems were experienced during eight and one-half months of operation, an appreciable fraction of which was at 1 MHz interaction rate.

In addition to the charmonium data sample, a large amount of high-p_t direct photon data was accumulated.

$$\begin{matrix}\pi^\pm \\ p^\pm\end{matrix} Li^7 \rightarrow \gamma + x$$

The high-p_t photon trigger, which operated in parallel with the dimuon trigger during the 1987-88 Fermilab fixed-target run, formed energy clusters from the signals from the electromagnetic detector and took triggers at several p_t thresholds simultaneously. As well as taking single high-p_t triggers, data were taken for part of the run with a di-photon trigger with mass threshold set at 3.4 GeV/c^2. The estimated amount of high-p_t photon data taken will give sensitivities at the level of 7.7, 0.16, 7.03, and 6.4 events per pb per nucleon for π^-, p, π^+, and p nucleon interactions respectively. These data are an appreciable addition to the world data sample. This is especially true in the case of the π^+N data, which represent an increase of more than five times the accumulated data of previous π^+N experiments.

The future plans of the E-705 collaboration (with the addition of the University of California, Berkeley; the University of California, Los Angeles; the University of Lecce; the University of Pavia; the University of Pennsylvania; and the University of Rome) for the next Fermilab fixed-target run include an upgrade of both beamline (to 800-925 GeV/c) and spectrometer to prepare for E-771, an experiment which intends to detect and measure B production via the $B \rightarrow J/\psi$ decay modes. The upgrade of the spectrometer will include addition of a multi-target silicon microstrip detector and addition of proportional wire chambers to increase the momentum resolution of the dimuon trigger.

A successful first run of E-771, presently scheduled to start in the late summer of 1989, is expected to yield a sample of several hundred $B \rightarrow \psi$ inclusive decays, as well as a large sample of same- and opposite-sign dimuons from the double semileptonic decays of the B pairs. These data will be analyzed to extract the cross section for B hadroproduction, to look for particular exclusive decay modes, to detect production of the various B species such as the B_s as well as B_u and B_d mesons and baryons, to extract lifetimes, and to study $B \leftrightarrow \overline{B}$ mixing.

The Fermilab Fixed-Target Beauty Physics Experimental Program

Peter H. Garbincius

Introduction

Any discussion of beauty physics would be incomplete without an acknowledgment of the discovery at Fermilab of the upsilons, a family of bound $b\bar{b}$ quarks, by E-288, and the beautiful high-resolution hadro-production studies of the upsilons by E-605. Most additional information on the upsilons and the particles containing open bottom or beauty quarks has since been provided by the e^+e^- colliders at DORIS, CESR, PEP, and PETRA. Over the last few years, fixed-target experiments at CERN and Fermilab have searched for, and sometimes found, indications for production of bottom particles. The current and future programs of fixed-target physics at both CERN and Fermilab place major emphasis on observing hadronic production of particles with open beauty (bare bottom or naked beauty, if you prefer), b-particle spectroscopy, and decay studies. UA1 at the CERN $S\bar{p}pS$ has observed indications of $B^0\,\overline{B}^0$ mixing, and we anticipate a strong program of both bottom quark and top quark physics at the Fermilab TEVATRON Collider. In this abbreviated report, I will emphasize recently published results, recent theoretical predictions, and the Fermilab program in fixed-target beauty physics.

Early Fixed-Target Searches for Open Beauty

During the late 1970s through the mid-1980s, there have been several experiments at Fermilab and CERN searching for open bottom production in hadron and muon beams. The techniques used employed both pion and proton beams, and open and closed geometries to search for three or four muons, or same-sign dimuons which would signal production of $b\bar{b}$ pairs followed by semi-leptonic decays into charm pairs, with subsequent charm decays into muons. The technique of WA-17 Goliath (CERN) was slightly different in that this open-geometry experiment attempted to reconstruct exclusive decays of the b-particles

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This report is a condensed and updated version of the author's presentation at the Workshop on High Sensitivity Beauty Physics at Fermilab, Batavia, Illinois, November 11-14, 1987. The complete version and references may be found in the workshop proceedings or in FERMILAB-Conf-88/39.

into ψ-φ, ψ-π, or ψ-K^*(n-π's). The cumulative results of these searches were 90% confidence limits on the production of beauty pairs at about the 2 nb/nucleon level. If the production of $b\bar{b}$ was assumed to be diffractive-like, these limits would increase to about 10 nb/nucleon. These limits were quoted for 400-GeV proton beams and 190- to 350-GeV negative pion beams.

Observation of Bottom Particles

Two experiments at CERN have observed bottom particles using pion beams. The WA-75 collaboration used a 350-GeV π^- beam, an emulsion target, and a closed geometry muon spectrometer. The total number of interactions observed was $3x10^8$, $1.5x10^6$ with a single muon trigger, and 10,000 with a single muon with p_t > 1-GeV cut. They observed one event (Fig. 1) found in the emulsion with four decay verticies in which two negative muons were analyzed in the muon spectrometer. The most likely scenario is the production of a $B^+\overline{B}^0$ pair followed by decays to D^0 and D^- subsequently, followed by the decays of the charmed particles. This observation is a very striking graphic of both the beauty of the physics and the difficulties and opportunities for event reconstruction awaiting electronic detectors.

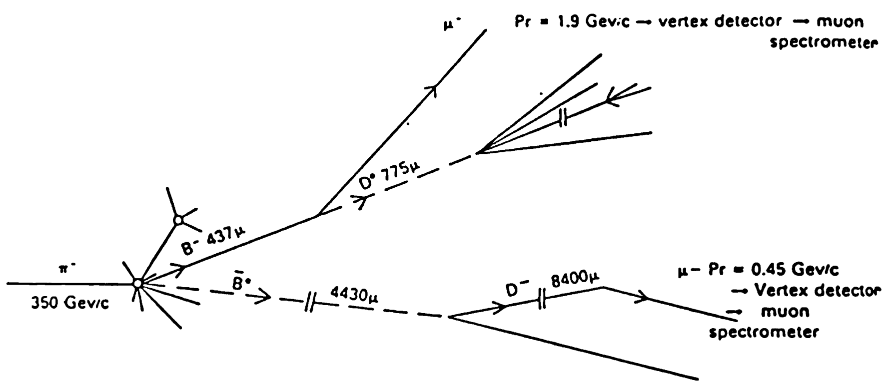


Fig. 1. WA-75 observation of a 4-decay vertex event in a π-emulsion collision.

The WA-78 collaboration interacted a 320-GeV negative pion beam in a uranium target calorimeter. The hardware trigger required two muons. Software cuts were applied to require both high-p_t for the muons and missing energy signaling neutrino production. In this manner, 13 tri-muon events were observed consistent with the production of B-pairs, and semi-leptonic decays at at least three of the four bottom and charm decay verticies. In addition, 64 same-sign dimuon events, consistent with $b\bar{b}$ production and decay, were observed. The quoted cross section for 320-GeV π^- U interactions is:

$$\sigma(\pi^- U \rightarrow b\bar{b}) = 2.0 \pm 0.3 \pm 0.9 \text{ nb/nucleon (assume } A^1)$$

with kinematic dependences

$$\frac{d^2\sigma(\pi^- U \rightarrow bx)}{dx_f\,dp_t^2} \sim e^{-3.3(x-0.05)^2}\, e^{-0.14p_t^2}$$

Theoretical Predictions for Hadroproduction of Beauty Pairs

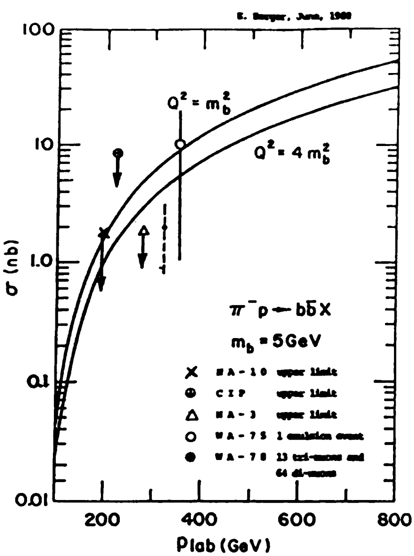


Fig. 2. Compilation of theoretical cross sections, upper limits, and observations of beauty production.

A range of theoretical estimates of the beauty hadroproduction cross sections, taken from Ed Berger's paper, are shown in Fig. 2. Also included are the production limits and observations of WA-75 and WA-78.

Berger has recently updated his calculated cross sections for the hadroproductions of b-particles through next-to-leading order in QCD to attempt to account for the mysterious K-enhancement factors. The range of cross section predictions occur for various theoretical choices for the renormalization and evolution scales, the cut-off parameter (Λ_{QCD}), and the mass of the bottom quark. For m_b=5 GeV:

	$\sigma(pp \Rightarrow b\bar{b}\,X)$	
400-GeV	0.7 nb	(0.4 to 1.6 range)
600-GeV	3.6 nb	(2 to 8 range)
800-GeV	9.0 nb	(5 to 20 range)
	$\sigma(\pi^- p \Rightarrow b\bar{b}\,X)$	
300-GeV	5 nb	(3.7 to 6 nb range)
400-GeV	10 nb	(7.5 to 12 nb range)
500 GeV	16 nb	(12 to 20 nb range)
600 GeV	24 nb	(18 to 30 nb range)

B-Physics Techniques and Tricks

All current attempts to study bottom production in fixed-target experiments employ sophisticated vertex detectors to try to observe and isolate events with downstream secondary verticies signaling the decay of either the beauty particle or its charm particle daughter. It is also worth noting that each of these beauty experiments, notwithstanding the difficulties of observing beauty, is, in its own right, a powerful charm experiment. A brief preview of the varied techniques employed is given.

The vertex detectors chosen include silicon micro-strip detectors (SMD or SSD) by most experiments, emulsions (WA-75 and E-653), optical scintillating fiber targets (WA-84 and E-687), and a high-resolution streamer chamber (T-755). In addition, the emulsion, the scintillating fiber, and the streamer chamber experiments also use silicon microstrips as part of their vertex detectors. Some experiments use very loose total hadronic or transverse energy triggers (E-687, E-769, and E-791). WA-82 uses a reconstructed vertex algorithm for triggering. Single lepton triggers are quite in style (WA-75, WA-82, E-653, E-706). The channel $B \Rightarrow \psi X \Rightarrow \mu^+\mu^- X$ is popular (E-771 and E-672/E-706). The son of E-605 proposes to search for exclusive two-body decays of bottom at high luminosity (P-789). E-690 will use a data driven track processor for full event reconstruction at the trigger level. Finally, the unique advantages of photon (E-687) and hyperon (P-781, CERN I/166, and WA-89) beams will be used to enhance observation of bottom particles.

Note on Sensitivities and Projected Event Yields

For the following discussion and comparisons of individual experiments, I have tried to normalize all the expected sensitivities and event yields for a typical data run. The recently updated benchmark cross sections were used. In addition, an A^1 dependence for the beauty cross sections was assumed unless otherwise noted. I have assumed the following models for a typical future data run. At Fermilab, the 1987 fixed-target run is seven months long with an assumed 20% of this time devoted to experiment startup. Typical maintenance and study periods and accelerator operational efficiency (65%) were assumed. This produces 3.4×10^6 data spill seconds per run. Similarly, the CERN 1987 run of 79 days with 3.0-second spill/10.8-second cycle and the projected LEP-era schedule of 125 days with 3.0-second spill/15.6-second cycle both give 1.9×10^6 spill seconds-per-year run. Including a similar 20% of this time for experiment startup and a 65% accelerator efficiency typical of Fermilab operations, this gives a CERN rate of 1.0×10^6 data spill seconds per year. The experiments are assumed to be running at 30% dead time.

A Survey of Beauty Experiments

Fermilab E-653, a U.S., Japan, Korea collaboration, has completed an experiment using a hybrid emulsion spectrometer to study the hadronic production and lifetimes of charm and bottom particles. The incident hadron beam is 10^4 particles/second impinging on a 5% interaction length target. The single muon trigger fires at approximately 0.03 times the total interaction rate. The heavy quark candidate events are identified in the conventional spectrometer. Secondary verticies are identified using the silicon microstrips. The event vertex is projected using the silicon microstrip detector back into the emulsion target. This is the starting point for the vertex scan. This experiment has recently completed its data taking and is presently in an analysis-emulsion event finding phase. In the 1985 run with 800-GeV proton beam, 6 million triggers were taken, giving a sensitivity of 1.2 events/nb, including trigger, reconstruction, and event finding efficiencies. In the 1987 run, a 600-GeV π^- beam was used. This gave 9.6 million triggers and a sensitivity of 2 events/nb. These would correspond to approximately 9 $b\bar{b}$ pairs produced for the proton data, and 30 $b\bar{b}$ pairs produced for the pion data.

WA-82-IMPACT is a currently running experiment at CERN using the Omega spectrometer along with an impact parameter trigger. The pitch (strip resolution spacing) of the trigger SMD stations is chosen to be proportional to the distance downstream of the target. Given a well-tracked beam particle, this provides a simple algorithm using the address of the hit strip to tag tracks that do not appear to originate in the primary vertex. For tracks that originate at the primary vertex, the strip addresses follow a particularly simple relation for each coordinate projection. The resolution of this impact parameter trigger is expected to be in the 100- to 1000-micron range.

This experiment will run with 360-GeV π^- and 280-GeV enriched π^+ beams. Its expected interaction rate is 0.9×10^4 interactions per second on a 0.84% λ-int W + 0.27% λ-int Si target. For a typical CERN running period of 40 days (including eight days for setup), this would correspond to an expected sensitivity of 150 events/nb. Assuming 3-nb production cross section scaling as A^1 and a 1-picosecond b-particle lifetime, the expected $b\bar{b}$ sample would be 4000. With a p_t >1.3-GeV electron cut, this would be reduced to 360 $b\bar{b}$ pairs (with a $D\bar{D}$ background of 3000 pairs). A further missing p_t cut would produce 130 b's with a background of 60 D's.

WA-82 has completed a data run during the summer of 1987. This included a 15-day setup period and 30 days of data. During this period 10 million triggered and 3 million unbiased events were recorded. Five per cent have been analyzed, and several thousand charm events are expected from this data sample. This experiment is anticipating a major data run in 1988.

WA-84-SCIFI is another CERN experiment using the Omega spectrometer with a specialized target. The production target-detector consists of optical SCIntillating FIbers giving the experiment nickname. The scintillating Ce_2-0_3 fibers are 20 microns in diameter and are oriented longitudinally along the beamline. The readout is by a phosphor screen for trigger delays followed by a gated image intensifier and CCD readout.

For comparison, E-687 is also working to develop a scintillating fiber active target vertex detector, SFT. In this case, the fibers were chosen to run perpendicular to the beamline. A three-stage gated intensifier is used. This device was tested in the wide-band photon beam during the 1987-1988 running period. Future enhancement may include small-angle stereo to allow three-dimensional tracking.

WA-84 will use a 360-GeV π^- beam at incident intensity of 5×10^6 pions per second. A simple interaction trigger will gate the image intensifier within 50 nanoseconds. A 4-particle high-p_t trigger developed by WA-77 will arrive within one microsecond to veto to the clear for the CCD. Readout dead time for the CCD is expected to be about 20 milliseconds. The trigger rejection using this 4-particle trigger with $p_t > 0.6$ GeV is anticipated to be 1/600 with an efficiency of about 10%. The request is for a 50-day data run producing 1700 $b\bar{b}$ pairs assuming an 8-nb production cross section, approximately 1/3 of these events with all four decay verticies observed within the SCIFI target. The experiment is scheduled for two short test runs in 1988.

E-771 (Fermilab) is a study of beauty production associated with dimuon production in proton-nucleon interactions. Figure 3 shows the augmented E-537/E-705 spectrometer. This experiment is preparing to run during the next Fermilab fixed-target running period. The physics goals are to study the cross sections, lifetimes, mixing, and some exclusive decay modes of bottom particles. This experiment uses an open-geometry spectrometer with a muon trigger, and a silicon vertex detector. Future growth may include a ring imaging Cerenkov counter (RICH). The current E-705 spectrometer is capable of operating at 2×10^6 interactions per second with a data acquisition system capacity of 200 events/second. The trigger acceptance of the B => ψ => $\mu^+\mu^-$ is 25%. The reconstruction and other efficiencies are estimated to be 60%. A typical Fermilab data run would produce a production sensitivity of 160 events per picobarn/nucleon.

The main trigger of E-771 will use the large branching fraction of B => ψ (1%) followed by ψ => $\mu^+\mu^-$ (7%). This gives a total BR of 7×10^4 (times two for each of the b and $\bar{b}$). Using a benchmark cross section for b-production of 9 nb/nucleon and a A^1 enhancement for a tungsten target, this would yield approximately 1100 $b\bar{b}$ events with a $\psi \Rightarrow \mu^+\mu^-$ tag in a typical data run.

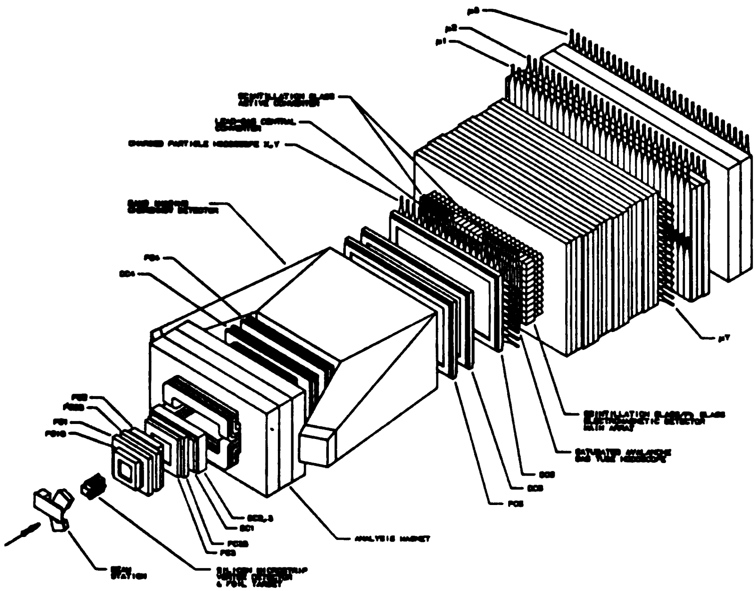


Fig. 3. *The E-537/E-705 spectrometer augmented for E-771.*

The second physics goal is to study $B^0\bar{B}^0$ mixing. This is manifested by same-sign dileptons from the semi-leptonic decays of the B's. Using the integrated luminosity and sensitivity above, 11,000 non-mixed +- muon pairs would be observed. Using the ARGUS results and assuming 20% mixing for the B_s^0, there would be 1300 ++ and -- mixed muon pairs. However, there would be 5800 ++ and -- muon pairs from the b => c => μ decay chain where the semi-leptonic decay of a charm produced from a non-mixed beauty would mimic the mixing process. Therefore, a 4/1 background-to-signal ratio is anticipated at this level. The signal will be cleaned up by reconstructing the decay verticies to insure that the observed trigger muons come from the parent b and not the daughter c decays. Cuts could also be placed on the effective mass of the ++ or -- muon pairs to possibly enhance the mixed content of the data sample.

A third physics goal of E-771 is to observe some exclusive decay modes including ψ similar to that of WA-17. Each of these decay channels: ψK^-, $\psi K^- \pi^+$, $\psi\psi$, $\psi K^+ K^-$, $\psi\, n\pi$, are anticipated to have branching ratios on the order of 0.1%. The study of these channels may also require the RICH counter which has not yet been approved by the Physics Advisory Committee.

The combined apparatus E-706 and E-672 has a capability of studying many of the topics covered by E-771. E-706 (Fig. 4) is a study of hadronic production of high-p_t single photons and features a silicon microstrip target-detector, an open geometry magnetic spectrometer, and large-aperture electromagnetic and

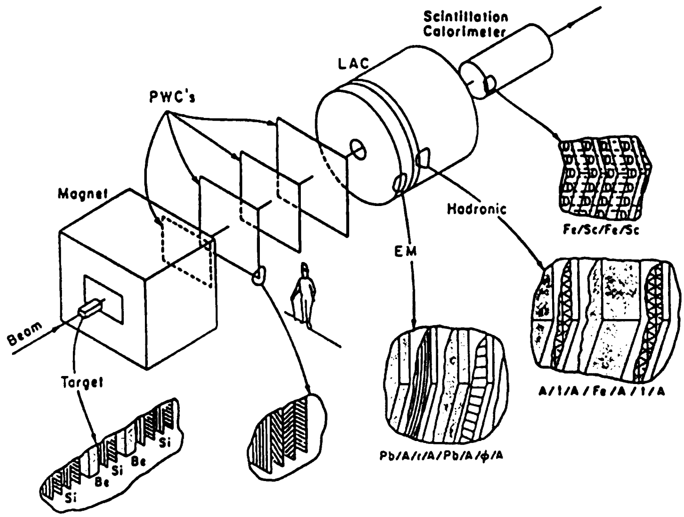


Fig. 4. The E-706 spectrometer.

hadronic liquid argon calorimeters (LAC). This LAC can provide a high-p_t electron trigger for beauty physics. E-672 has a dimuon toroid spectrometer and trigger that was used in conjunction with the Fermilab Multiparticle Spectrometer to study hadronic states associated with dimuon production. These two experiments share the apparatus, triggering, and data sets. After a lengthy startup period for the liquid argon calorimeter, these experiments have begun common data taking.

The beauty physics goals of E-706/E-672 are similar to those of E-771. It uses a 530-GeV π^- or 800-GeV proton beam with a maximum interaction rate of 10^6 interactions per second. In a typical Fermilab data run, this would result in a production sensitivity of about 116 events/picobarn/nucleon. Including the A^1 enhancement would give a production sensitivity of 220 events/picobarn. The dimuon acceptance for B => ψ => $\mu^+\mu^-$ is 12%, giving an event yield of about 500 $b\bar{b}$ pairs. Similarly, for continuum muon production above the ψ, the acceptance is 3.5% for the study of mixing. This would lead to 300 same-sign dimuon pairs from $B^0\bar{B}^0$ mixing. The experiment is currently operational and taking data. It is expected that there will be a few B => ψ => μ^+ μ^- and mixed ++ or -- muon pairs for the 1987-1988 run at a luminosity of 10^6 interactions per second.

Additional future (not yet approved) enhancements for the study of beauty physics would be the use of a heavy W target, the upgrade of the hadronic part of the liquid argon calorimetry to provide hadronic triggers, the upgrade of the proportional chambers with higher resolution mini-drift electronics, and a possible ring imaging Cerenkov counter. A local processor for the liquid argon calorimeter would trigger on high-p_t electrons from the semi-leptonic decay of bottom particles.

Experiment 690 uses a high-rate spectrometer and a data driven, real time, track reconstruction processor to study the production of charm and beauty. The track processor has operated at rates of 10^5 fully reconstructed events per second at the trigger level. This experiment (which has used the Brookhaven apparatus as BNL E-766), had two weeks' data using n-p interactions at 15 to 28 GeV, accumulating 300 million events with a nine- (or more) track trigger. Similarly, another 300 million events were taken in less than two weeks using 28-GeV p-p interactions requiring 10 or more (and some prescaled 8) track events. These data were typically taken at 10^6 interactions/second with 30% dead time. The spectrometer is probably capable of operating at up to 2×10^6 interactions/second. Beyond that, it would be limited by overlapping event confusion. For the BNL data, the event processor was not available for triggering. The data was taken on tape and analyzed later, at input physics data speeds, using the processor in a playback mode. At Fermilab, the processor is expected to provide online event reconstruction and trigger selection.

E-690 will be installed at Fermilab for the next fixed-target physics run. E-690 has been split into two phases. The first approved phase is to move the BNL E-776 spectrometer to Fermilab and add a forward spectrometer to study p+p=>p(forward) + target fragmentation. The existing BNL E-766 spectrometer would study the target fragments. At 2×10^6 interactions/second, assuming a beauty content of 10^{-7} in the target fragments, this would correspond to the production of 100,000 $b\bar{b}$ pairs per run. A goal of Phase 1 is to search for beauty production among the target fragments. The recoil $b\bar{b}$ state would have a laboratory momentum of 50-75 GeV/c, approximately three times that of the states studied at BNL. This Phase 1 detector uses a liquid hydrogen target, and does not have neutral particle or lepton detection. The vertex proportional chambers are designed to have sufficiently high resolution for the study of $b\bar{b}$ decays.

P-690 Phase 2 would add a second analysis magnet, an additional Cerenkov counter, EM and hadronic calorimetry, and a muon detector to increase the phase space region studied. This enhancement has not yet been approved by the Physics Advisory Committee.

P-789 is a proposal by the E-605/E-772 collaboration to use the existing spectrometer in the open geometry configuration to study the two-body exclusive decays of b-particles at high luminosity. The main features of the apparatus include the refurbished ring imaging Cerenkov counter, a new collimator shield and high-resolution proportional chamber station both at the downstream end of the mass selection magnet, and a pair of silicon microstrip vertex detector arrays to be placed just downstream of the primary target. Assuming a branching ratio of about 0.005% for exclusive two-body states such as $\pi^+ \pi^-$, $K^+ K^-$, $\pi^+ K^-$, and $K^+ p^-$, this would correspond to a $\sigma * B$ of approximately one picobarn per channel. This is comparable to the $\sigma * B$ of $\Upsilon \Rightarrow \mu^+\mu^-$ of which E-772 will obtain about 30,000 upsilons during the 1987 closed geometry, high-intensity data run. The general idea is to tune the spectrometer to 5-GeV masses corresponding to an acceptance of about 6%, reduce the incident proton rate to 5×10^8 interactions per second corresponding to 10 interactions per rf bucket, improve the spectrometer mass resolution to approximately $\sigma_m = 1$ MeV, and add the silicon vertex tracking system. Finally, add a lifetime vertex trigger processor to provide an online cut of 0.5 B lifetime with $\sigma_t = 0.2$ picosecond. There are many technical questions about the survivability of the silicon vertex trackers and their reconstruction confusion at high rates, the actual mass resolutions attainable, and the development of the vertex trigger hardware. If it all works, assuming a 10^{-4} rejection factor for the background, then in a single data run P-789 may obtain:

$B_d^0 \Rightarrow \pi^+\pi^-$	100 events	S/N = 1/4
$B_d^0 \Rightarrow K^+ K^-$	100 events	S/N = 2.5/1
$B_s^0 \Rightarrow K^+ K^-$	50 events	S/N = 1/1
$\Lambda_b \Rightarrow K^+ p^-$	50 events	S/N = 1/2

The rates and backgrounds are calculated based on the E-605 open-geometry running experience.

Experiment 791 is the extension of the currently running E-769 to study beauty physics. This would use the Tagged Photon Lab Spectrometer, Fig. 5, which performed the very successful charm experiment E-691, with a secondary hadron beam upgraded to approximately 500 GeV. The current spectrometer drift chambers can operate at up to 4×10^4 interaction/second. The current SCC + RBUFF + ACP data acquisition can take up to 400 triggers per spill second at 35% dead time. The current E-transverse trigger threshold of 2.2 GeV (0.33 σ-inelastic) can be increased to an equivalent of 0.05 σ-inelastic. In addition, high-p_t lepton and multiplicity jump triggers will be considered. Such an interaction rate will allow a sensitivity of 4.6 events/pb or 34,000 produced $b\bar{b}$ pairs in a typical fixed-target running period, even without an additional A[1] target enhancement.

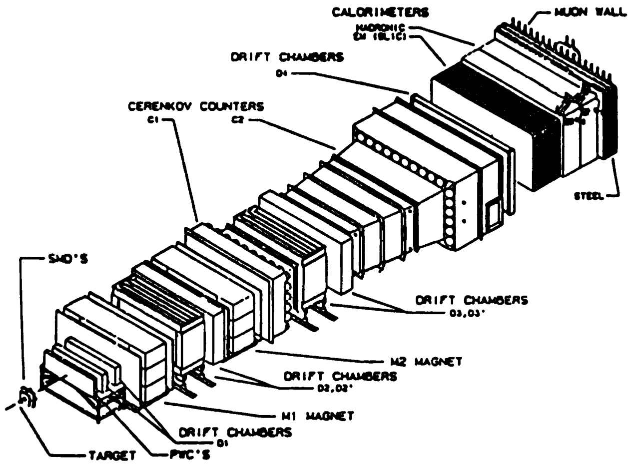


Fig. 5. The E-769/E-791 spectrometer in the Tagged Photon Lab.

NA-32 - HELIOS, a currently running CERN experiment, is intended to study the hadroproduction of electrons, muons, and neutrinos. Although it is not specifically designed to study beauty physics, its high-resolution calorimetry, closed geometry, and silicon microstrip vertex detector may be quite adaptable to study this physics.

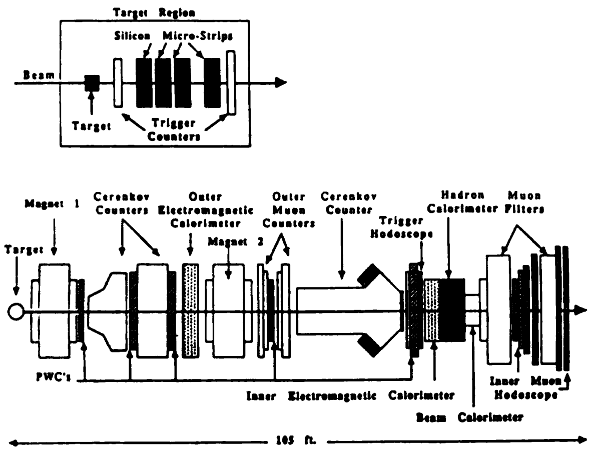


Fig. 6. Schematic view of the E-687 spectrometer

E-687 is a new spectrometer (Fig. 6) featuring two analysis magnets, 20 planes of MWPC with mini-drift, three Cerenkov counters, two muon detectors, three electromagnetic calorimeters, two hadronic calorimeters, and most importantly, an 8400-channel silicon microstrip vertex detector. It uses the high-flux wide-band electron beam at 350 GeV to study photoproduction of charm and beauty. This corresponds to approximately 2.5 times the photon flux used by E-691 in their successful charm photoproduction experiment.

Photon-gluon fusion models predict a photoproduction cross section for beauty pairs that rises linearly from a threshold of about 100 GeV up to the range of 3 to 5 nb/nucleon at 500-GeV photon energies. The added feature of photoproduction is that at a typical photon energy of 225 GeV, the ratio of $b\bar{b}$/hadrons is 0.9 nanobarn/120 microbarn = 7.5×10^{-6}, compared to a similar ratio of 3.6×10^{-7} for 800-GeV p-p interactions, an enhancement of about 20!

The 350-GeV electron energy was chosen to optimize the rate of detected $b\bar{b}$ events per primary proton. The data acquisition system can handle up to 200 hadronic events per second; the expected event rate is 190 hadronic events produced per second over the range of tagged photons 150-400 GeV. This corresponds to production of 0.07 $b\bar{b}$ pairs per pulse, 4 $b\bar{b}$ pairs per hour, or 10,000 $b\bar{b}$ pairs per run. The experiment trigger is designed for tight rejection of e^+e^- pairs with a loose hadronic trigger requirement of a minimal hadronic calorimeter energy or a dimuon pair. This experiment had attained a data taking mode before sustaining a damaging fire in early October 1987. After rebuilding and recommissioning, a total of 60 million photo-produced hadronic triggers were accumulated.

Three experiments are proposed to use hyperon beams to study both charm and bottom production. These proposals have been encouraged by the apparently large cross sections for charmed baryons and exotics such as the $\Lambda \bar{p}$ π's state at 3105 MeV which have recently been reported by E-400, WA-62, and BIS-2 using neutron and hyperon beams. These proposals or letters of intent include CERN I/166, which proposes to either bring a hyperon beam to NA-14 or NA-14 to a hyperon beam; the recently approved WA-79, which will bring a hyperon beam to the Omega spectrometer; and P-781, proposing to build a new large-x baryon spectrometer for the Fermilab P-Center hyperon beam.

T-755 has been testing a diffusion suppressed high-resolution streamer chamber developed by Yale University. The proponents consider a streamer chamber as an ideal device for the study of beauty physics due to its unique ability for pattern recognition and reduced combinatoric backgrounds compared to silicon microstrip projection detectors. It will be able to reconstruct complex four-vertex topologies including the important charged or neutral determination. Finally, this detector could operate along with some spectrometer such as E-791 at rates up to 8×10^3 interactions per second.

Summary

The current and near-future fixed-target beauty physics programs give the promise of: (1) a handful of beauty events with emulsions (E-653, WA-75), (2) a few hundred beauty events with specific partially reconstructed decays (E-771, E-672/E-706, NA-32), (3) a few thousand relatively unbiased beauty events (WA-82, WA-84, E-687, E-791), and (4) a few thousand beauty particles detected with special decay channels, topologies, or restricted triggers (E-690, P-789).

These will be sufficient numbers of events to investigate the b-cross sections with beauty identification by decay topologies. There will be the first attempts at full reconstruction and decay mode studies. The lifetimes of both the charged and neutral B's will be measured. The existence of both the B_s^0 and the Λ_b beautiful baryon will probably be established. There may be sufficient statistics to begin the observation of $B^0\overline{B}^0$ mixing. However, there will not be enough events for the theoretically challenging studies of CP violation.

Further progress will require both technological and conceptual breakthroughs. In addition to the physics potential, the initial steps being taken to extract a small signal in high-luminosity, fixed-target experiments will provide invaluable stepping stones in learning to exploit the incredibly fertile, yet hostile environment of the Superconducting Super Collider.

Fermilab in Retrospect - 20 Years and Counting

NATIONAL ACCELERATOR LABORATORY

MONTHLY REPORT OF ACTIVITIES

F. T. Cole

May 1, 1968

General

1. The AEC authorization bill was passed by the House of Representatives on April 4 and by the Senate on April 8. It has been signed by the President. The 200 BeV accelerator is authorized for construction in fiscal year 1969, with a total authorization of $32.333 million. The appropriation bill is in the House at the time of this report.

2. A tentative decision has been made to incorporate an injection storage ring into the accelerator design. This ring, if built, will have the radius of the main synchrotron and will be mounted on the wall of the main-ring enclosure. In order to avoid confusion with the CERN ISR, we have decided to call our device the accumulator.

Protons will be injected into the accumulator from the booster at 10 GeV kinetic energy. Thirteen bunches will be stored during the 2.6-second cycle. They will then be extracted from the accumulator in one turn and injected into the main ring. The principal advantage of the accumulator is that the booster works continuously rather than in short bursts.

The repetition rate of the booster will therefore be reduced from 15 Hz to 5 Hz. The resulting reduction in the estimated cost of the booster rf system is comparable to the estimated cost of the accumulator.

The accumulator lattice is to be the same as the main ring, except that there will be three bending magnets between quadrupoles instead of four, in order to reduce stray fields. Some parameters of the accumulator are

Radius	1000	m (approx)
Field (dc)	445	G in bending magnets
Magnet Lengths:		
Bending Magnets	351	in.
Quadrupoles	81	in.
Aperture:		
Radial	5	in
Vertical	2.5	in.
Magnet Cross Section	6 by 6 in.	
Excitation Current (single-turn winding)	2200	A
Magnet Power	1.5	MW (approx)
Main-Ring Cycle Period (no flat-top)	2.6	sec
Booster Repetition Rate	5.0	Hz

Various injection storage rings have been discussed over the past several years. The specific idea of utilizing such a ring in the 200 BeV accelerator was proposed to the Laboratory last summer by D. A. Swenson of Los Alamos. The decision will be reexamined in a few weeks before becoming final.

3. The Laboratory staff totals 149 people as of May 1. Of these, 50 are physicists or engineers.

Main Ring

1. Lattice. Reduction of the gradients of the long straight-section matching quadrupoles is being considered

by the theory group in order to increase their apertures. An increase of slightly more than 10% in the product xy would require a reduction in the length of the long straight section by 1 meter.

2. Power Supply. Investigations of possible resonances driven by pulsed loads on the Commonwealth Edison power grid have been initiated. The resonance problems may be made more severe by the shorter main-ring cycle.

An alternative energy-storage system now being studied, which was briefly mentioned in last month's report, could ameliorate these problems. In this system, load variations are smoothed by wound-rotor induction motors. The field winding is connected to the power line and the rotor winding is driven by a cycloconverter, a variable-frequency power oscillator. The frequency is varied with rotor speed to keep the field output in phase with the power line. The cycloconverter also controls the power output of the motor so that the motor acts like a motor when power is flowing back from the magnet system, but like a generator when power is flowing into the magnet, thus decreasing the load variation. In essence, the motor acts as a mechanical amplifier developing its power from the rotational stored energy of its flywheel.

3. Plans for the Coming Month. Bids for the model-magnet power supply have been received and are being evaluated. The stacking fixture is assembled in the EBWR building at Argonne.

The die will be finished May 10 and stamping will begin then.

A permeameter is being constructed and samples will be ordered from steel companies for further permeability measurements.

The coil design for the model quadrupole will be completed.

Booster

1. Lattice. The booster lattice has been restudied with respect to the accumulator. No major changes have been made.

2. Parameters.

Linac	
Energy	200 MeV
Emittance	0.8 π cm-mrad
Booster	
Energy (final)	10.0 GeV
Radius	75.47 m
Cycling rate	5.0 Hz
Injection (nominal)	4.0 × 60 mA
Aperture	
F-magnet	5.0 × 1.5 in.
D-magnet	3.5 × 2 in.
$A_{2V} \times A_{2H}$ (at injection)	$1.6\pi \times 4.8\pi$ (cm-mrad)^2
Number of cavities	6.0
Momentum spread ($\Delta p/p$, after debuncher) from linac	$\pm 0.8 \times 10^{-3}$

3. Plans for the Coming Month. Steel has been ordered for the 3-ft magnet models. The lamination die and copper will be ordered. The stacking fixture is being designed and the power supply is being constructed. Work will also continue on vacuum-chamber development.

Power and cooling requirements for the total booster structure are being studied to provide data for the enclosure design.

Beams and Targeting

Extraction Hall Parameters. A design of the extraction hall without a crane, is being considered. Fork lifts for moving shielding are to be used. The possibility of "blocking" the tunnel to the target areas, which may shorten the extraction hall was looked into. This work will continue for the next month. Parameters for the extraction hall are also being assembled.

Research Facilities

1. Secondary-Beam Transport. A three-day conference on secondary-beam transport elements was held. A tentative decision has been made to build 4-in. diameter quadrupoles and 2-in. vertical-gap dipoles with a peak current density of 2500 A/in^2.

2. Plans for the Coming Month. It is planned to build in May a scale model of a target area with shielding and typical secondary beams laid out.

Fermilab Workshop on QCD in Astrophysics

Mark Bodnarczuk

The Fermilab Astrophysics Group sponsored a workshop on the role of quantum chromodynamics (QCD) in astrophysics from April 29 to May 1, 1988. The meeting was a small, informal workshop designed to bring together particle physicists, astronomers, experimentalists, and astrophysicists interested in sharing recent advances in QCD, lattice gauge theory, models of hadron/quark transition, and primordial nucleosynthesis. The conference was not designed for individuals interested in learning about the subject, but as a gathering of people working in the field to exchange ideas and information.

(Fermilab photograph 88-462-4)

Participants in the QCD workshop were: ***(Front row, l. to r.)*** *S. Sanielevici (BNL), B. Meyer (LLNL), R. Malaney (Cal Tech), P. Salati (U. of California, Berkeley), A. Olinto (Fermilab), H. Kurki-Suonio (Drexel), L. Brown (University of Chicago), T. Reussel (University of Chicago), M. Turner (Fermilab).* ***(Second row, l. to r.)*** *D. Toussaint (U. of California, San Diego), J. Potvin (BNL), E. Kolb (Fermilab), C. Alcock (LLNL), J. Applegate (Columbia), G. Matthews (LLNL), E. Mottola (LANL).* ***(Third row, l. to r.)*** *P. Khare (University of Chicago), K. Greist (University of Chicago), F. Grassi (Fermilab), J. Madsen (Aarhus), D. Seckel (U. of California, Santa Cruz), G. Fuller (LLNL), R. Schaeffer (Ohio State), R. Brinkman (University of Chicago), S. Gottlieb (Indiana), H. Thacker (Fermilab).* ***(Fourth row, l. to r.)*** *S. Marques (Fermilab), L. Hobbs (University of Chicago), G. Steigman (Ohio State), D. Schramm (University of Chicago), T. Van Dahlen (University of Chicago). Not pictured: G. Baym (Illinois), F. Halzen (Wisconsin), D. Cline (U. of California, Los Angeles), K. Wojtila (Cracow).*

There are astrophysical sites in the Universe where we believe the transition between quarks and hadrons can be studied. The two major astrophysical sites are dense matter (neutron stars and supernovae) and high temperatures which simulate the early Universe. Current theory postulates that either high density or high temperature (or some combination of the two) can cause a transition between hadrons and quarks. From a particle theory, lattice gauge theory perspective, there are many things that can be calculated and astrophysicists can help the particle physicists understand exactly what types of calculations are needed to gain insights into these transitions.

The sessions and session organizers included "Lattice Gauge Theory," (Doug Toussaint, University of California, San Diego), "Exotic Phases of QCD," (Charles Alcock, Lawrence Livermore National Laboratory), "Quark-Hadron Transition and Nucleosynthesis," (George Fuller, Lawrence Livermore National Laboratory), "Primordial Element Abundances," (Gary Steigman, Ohio State), and "Cosmic Rays and Heavy-Ion Collisions," (Larry McLerran, Fermilab).

Topics that received a lot of attention at the workshop were issues surrounding primordial nucleosynthesis, which is one of the best available windows into describing what happened in the early Universe. The early Universe was smooth, homogeneous, and full of quarks and gluons which were subsequently super cooled, causing a first-order phase transition in which inhomogeneous regions of hadrons were formed. Several groups have been doing calculations starting with this type of inhomogeniety and predicting what the result of such a primordial nucleosynthesis would actually be.

Other sessions focused on neutron stars and conjectures about what the observational signature of quark stars might be, what sorts of equations of state one would need to calculate this phenomenon, and what masses one would expect to see.

There was also discussion on more exotic phenomena from cosmic rays, like signals that have been seen from Cygnus X-3 and Hercules X-1. High-energy cosmic rays seem to indicate some phenomena in hadronic interactions at very high energies, which again point toward the quark-hadron transition. Much of this discussion centered on the observational signature from these phenomena and what sort of theoretical framework could be built to help understand and account for the observations.

Rocky Kolb, Head of Fermilab's Astrophysics Group, said, "The workshop was a success in making particle physicists aware of what current problems are in astrophysics, what sorts of calculations they can do, what sort of models and questions they can answer to help astrophysicists realize what the state of the art is in QCD."

The Eighth Annual Meeting of the Fermilab Industrial Affiliates: "The Science-Technology Spiral and the Pace of Progress"

Richard A. Carrigan, Jr., and John E. Paulk

The eighth annual meeting of the Fermilab Industrial Affiliates was held on Thursday, May 26, and Friday, May 27, 1988. The purpose of these annual meetings, held every May at Fermilab, is to improve communications between the industrial and university/national laboratory research sectors. More than 150 research directors and senior technical personnel from the Affiliates and other companies (some of them from overseas) visit Fermilab for two days of presentations reviewing technological advances at Fermilab and in our university-based user community that may be of interest to industry.

The eighth annual Affiliates meeting featured, on Thursday, the now-traditional Roundtable, the theme this year being, "The Science-Technology Spiral and the Pace of Progress." The distinguished panelists included Hirsch Cohen, Consultant to the Director of Research, IBM; Joel Goldhar, Dean of the School of Business, Illinois Institute of Technology; Steven Lazarus, President of ARCH, the innovative organization formed to exploit Argonne National Laboratory and University of Chicago technology; Richard Nicholson, Assistant Director for Mathematics and Physical Sciences, National Science Foundation; and Lee Rivers, Washington, D.C., representative of the Federal Laboratory Consortium. The banquet speaker was Donald Frey, Chairman of the Illinois Governor's Commission on Science and Technology and former CEO of the Bell & Howell Corporation.

The Friday presentations provided first-hand accounts of leading Fermilab technologies with immediate relevance to the industrial sector. Tom Nash brought attendees up to date on the latest developments in the Advanced Computer Program (ACP), which has been ordered by several research centers, and which promises to have a major impact on computing at the Superconducting Super Collider. David Anderson ("Detector Development at Fermilab") and Marvin Johnson ("New Developments in Electronic Busses") shed light on some of the more recent Fermilab technology developments. Steven Jones discussed the exotic possibilities of "Muon Catalysis and Hydrogen Fusion." Philip Livdahl, former Deputy Director of Fermilab and now of the Loma Linda-Fermilab proton medical accelerator project, informed attendees on this exciting endeavor, which not only promises a new future for cancer therapy, but is proving to be a model for future commercialization projects.

A main item of interest during the Affiliates meeting was an exhibit of some of Fermilab's current technology set up near the registration desk. Several groups from the Laboratory took advantage of this opportunity to display and show off their latest technology.

Newly developed components of a high-voltage power supply and control system for drift chambers were displayed. The hardware showed the high-density packaging of up to eight separately controllable power supplies mounted on a single VMEbus module. Six of these modules, for a total of 48 supplies, fit into a standard VMEbus crate together with computer control and networking cards. The system was designed to meet the exacting specifications of the new collider detector facility at D0. Fermilab staff contributing to this technology include Tom Droege, Bob Goodwin, Al Jones, Marv Johnson, Mike Shea, and Steve Wimpenny, a collaborator from the University of California.

The Controls Group from the Accelerator Division displayed their latest version of FIRUS, a computer-controlled fire and utility reporting system. This significantly upgraded system is used throughout the site for centrally reporting fire and security alarms, and for monitoring utilities and power consumption. The exhibit featured an IBM personal computer which gave a colorful display of the system's versatility. Viewers were able to push buttons on the computer keyboard and an operator from Controls Group was on hand to answer questions. The FIRUS was developed by Charles Briegel, Kevin Cahill, Al Franck, Rich Mahler, Rich Koldenhoven, and Joe Flores. Although specifically designed for Fermilab, FIRUS can be readily adapted to monitor similar systems at any facility.

Mike Notarus posted a schematic diagram of the proton accelerator and delivery system for the Loma Linda University Medical Center. Under a work-for-others agreement with Loma Linda, a group of Fermilab engineers, scientists, and technicians have been designing, fabricating, and testing a proton therapy facility. Also shown was a pictorial floor plan of the treatment center which will house the accelerator and the treatment rooms.

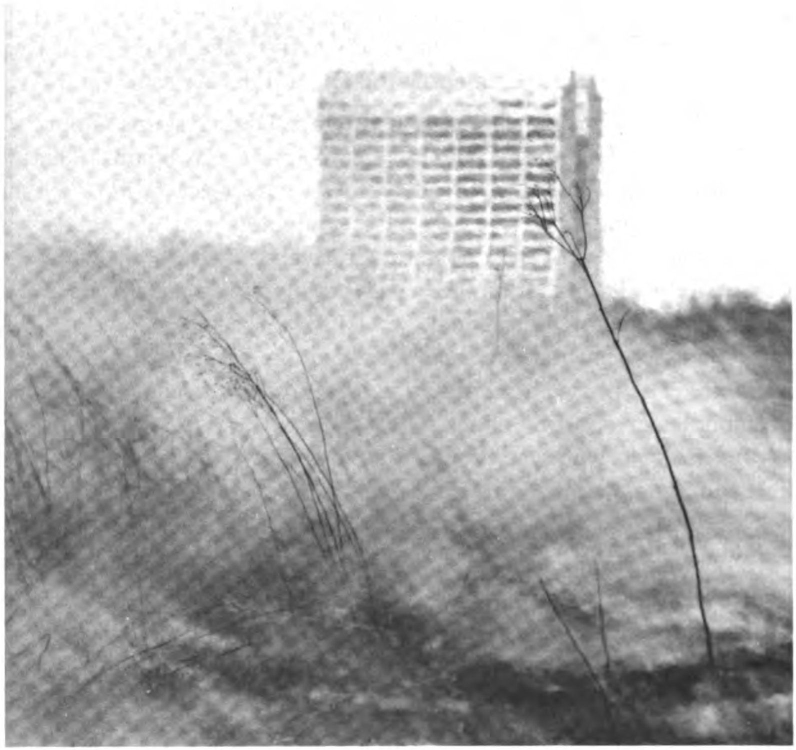
From the Accelerator Division and the Physics Department, full-scale samples of large printed circuit boards were displayed. Boards of this size are virtually not available from commercial sources. Consequently, the process for making them, using a modified Gerber photoplotter and a modified Thermwood routing machine, was developed at Fermilab. Some of the people involved in the Gerber installation a few years ago were Mike Glaubman from Northeastern

University (E-706), and, from Fermilab, Carl Lindenmeyer, Ray Yarema, Tom Fitzpatrick, John Korienek, Ed Arko, Jon Blomquist, and Al Ito. Some of the Fermilab people involved with the more recent Thermwood installation for D0 were Hans Jostlein, Carl Lindenmeyer, John Korienek, Ron Miksa, and Jon Blomquist. The Lab 8 facility is currently being operated by personnel from the Physics Department and Michigan State University. The boards will be used in a liquid argon calorimeter experiment at the D0 collider detector facility.

Two printed circuit boards were provided by the Data Systems Group: a QBUS Processor Interface (QPI) and a Segment Interconnect (SI) board. The QPI was designed here by modifying a UNIBUS Processor Interface (UPI). It is used to combine the computing power of the DEC computers and the data acquisition power of FASTBUS. The SI is a commercially available board originally designed by the University of Illinois. It provides path communications between FASTBUS Segments in a multicrate environment. FASTBUS is rated as one of, if not the, highest speed and lowest cost bus standards of all the major IEEE Standard 32-bit buses available. The people at Fermilab involved in the design and production of these two modules are Carl Swoboda, Gary Moore, Hector Gonzalez, John Urish, and Rick Van Conant, who also prepared the display. To date Fermilab has been responsible for commercializing over 16 FASTBUS devices.

The Technical Support Section provided an impressive display of the post and cradle developed at Fermilab to support Superconducting Super Collider magnets and the surrounding cryostat. A patent application is in process for the support post, and the Universities Research Association, Inc., hopes to license the support system for commercial production. Its design incorporates special features that combine to provide high strength in tension, compression, and bending with low heat conduction into the cryostat. Persons involved are Ralph Niemann, John Gonczy, Tom Nicol, Bill Boroski, Joe Otavka, Mark Ruschman, Chris Schoo, Roger Zink, and John Zweibohmer.

Also displayed was an ACP Multiprocessor, a Fermilab-designed computer, brought in by Omnibyte. Based on a popular 32-bit microprocessor, the parallel processing system is used at Fermilab to track millions of independent high-energy physics events. It makes use of hardware and software developed at Fermilab by the Advanced Computer Program. The combination of hardware and software makes it possible to use a system of 100 independent processors as easily as a single uniprocessor computer, providing the answer to a processing bottleneck that has bogged down earlier computers trying to digest huge numbers of events from fixed-target and colliding-beams experiments. The ACP has worked closely with Omnibyte to develop commercial support for this system.



(Fermilab photograph 88-376-8)

The annual prairie burn at Fermilab, 1988 version.

The Fermilab Prairie: A Functioning Ecosystem

Kevin A. Brown

Illinois is known as the "Prairie State." This is somewhat ironic, because very few healthy, functioning prairie ecosystems remain intact in the state, aside from a few planned prairie restoration and preservation projects. But as a result of an extensive and ambitious prairie restoration project in the center of Fermilab's Main Ring, a 455-acre prairie ecosystem is coming to life.

The Fermilab Prairie Restoration Project: History and Goal

The restoration project is entering its fourteenth year, and is clearly a worthwhile and successful endeavor. It has a history of strong support both inside and outside the Lab. Internally, Robert R. Wilson, now Fermilab's Director Emeritus, supported the project at its inception, and that support has been carried forward by Fermilab's current Director, Leon M. Lederman. Externally, professional consultants Robert Betz, Professor of Biology, Northeastern Illinois University and founder of the project, and Ray Schulenberg, Curator of the Morton Arboretum, provided scientific and practical expertise.

A prairie committee, originally chaired by Tony Donaldson, at that time an electrical engineer in the Neutrino Department, oversaw the project from the beginning. This first committee, guided by Betz and Schulenberg, assisted by Rene Donaldson, then of Fermilab's Technical Publications Office, and supported by scores of volunteers both inside and outside the Laboratory, set the precedent for a successful restoration project.

The Fermilab prairie has its roots in the 100-acre Gensberg-Markham Prairie in southern Cook County, where volunteers collected the majority of the seeds for the initial planting. These seeds were planted using a Nisbet seed drill, a basic farm implement. Later, other machines were used, including a hydroseeder and a salt spreader, but each had certain disadvantages. Currently, the Fermilab prairie is seeded with a commercial broadcast spreader, and it seeds the plot randomly, eliminating rows of vegetation that look more like farmland than prairie.

The overall goal of the project is to restore and encourage the growth of a functioning prairie ecosystem. Specifically, the prairie committee, advised by Betz

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Kevin A. Brown, who is enrolled in a Masters program in technical and scientific writing at Miami of Ohio University, is a summer intern with the Fermilab Publications Office.

and chaired by Finley Markley of Fermilab's Technical Support Section, is attempting to provide large expanses of habitat that will support a greater diversity of plant and animal species.

The Fermilab Prairie as a Functioning Ecosystem

Biotic and abiotic interactions form the base for a functioning prairie ecosystem. If the committee is successful in increasing the species richness of prairie plants, insect diversity will increase and create a favorable habitat for even more plant and animal species. Furthermore, prairie plants modify the soil physically and chemically, which should encourage the growth of prairie plant species and discourage the growth of invasive Eurasian weeds, thereby promoting the development of the prairie ecosystem.

"Although there are remnant prairies growing along railroad tracks and old cemeteries throughout Illinois, their small size makes them more like museum specimens than functioning ecosystems," explained Mitch Adamus, of the Fermilab RF Group, and immediate past chairman of the prairie restoration committee.

In contrast, the Fermilab prairie seems to be developing into a self-sustaining prairie ecosystem, based upon the observed plant, animal, and soil interactions in the 15-plot project. For example, on a tour of the project plot, we came across a raised oval of earth, devoid of prairie plants and covered with ants. "These mound-builder ants are characteristic of the prairie. You've got a mound about three feet in diameter that's essentially brought up from underneath the soil and obliterating everything on top of the ground." Adamus said that some of the ant mounds can be as large as six feet in diameter, which represents a significant disturbance in the prairie.

As Adamus pointed out, "The prairie community is in some sense a disturbance-oriented ecosystem." In the past, long before this region was settled, herds of bison and elk would roam through the great prairies and create quite a bit of disturbance, ripping out and trampling prairie vegetation in their wake. Subtle, yet ongoing disturbances, such as groundhogs, squirrels, and the ants burrowing underneath the prairie, contribute to the dynamic nature of this ecosystem.

Prairie history suggests that another kind of disturbance - fire - is vital to the life of the prairie. Although it can be a devastating disturbance in some ecosystems, it seems to encourage and nurture the growth of prairie species and discourage the growth of invasive Eurasian weeds. For example, purple lead plant (*Amorpha canescens*) won't flower on old stocks - only on lateral stocks or on new stocks that grow as a result of fire.

Diversity and the Healthy Ecosystem

In tropical rain forests or coral reefs, diversity is the key to a healthy ecosystem. This holds true for the prairie as well, and Adamus believes that there's plenty of room for diversity in the Fermilab prairie.

Prairie plants appear to completely cover the surface of the ground. However, as Adamus pointed out, there's still a lot of bare ground. Lifting a clump of vegetation aside and exposing the bare soil, he explained that the bare spots are where additional prairie forbs, or broadleaf herbs, could grow. Essentially, these bare spots show that the prairie is rich in untapped niches; it will only be a matter of time until a variety of prairie plants, each using different root structures and strategies, occupy all of them.

Contributing to the prairie's diversity is the savannah, an open area of trees and grass undergrowth. The savannah isn't prairie or woods, but it has both prairie and forest species and unique species as well. One of the problems of restoring the savannah on the Fermilab site is that little research has been done to define the savannah's community structure and function because few of these ecological communities remain undisturbed in the Midwest. "If we can collect bits and pieces from remnants of savannahs," Adamus said, "we can begin to get an idea of what should be in them."

The savannah is an integral component of the prairie ecosystem. It is comprised primarily of fire-resistant burr oaks (*Quercus macrocarpa*), and Adamus explained that, "In prehistoric times, fires burned right through the oak grove and out the other side without damaging the trees." The oaks are capable of withstanding the heat from prairie fires because they have a corky, thick bark, an open, high-branching pattern, and fire-resistant acorns.

A sedgemeadow also contributes to the prairie's diversity. "It gives us a dozen species that we didn't know we had a few years ago," Adamus said.

The Prairie Ecosystem: Habitat for Plants and Animals

Plot number one, adjacent to a gravel access road, is a good example of a thriving prairie plant community. "Although we haven't burned this particular plot this year," Adamus noted, "it has done very well - we have a lot of prairie forbs, white false indigo (*Baptisia leucantha*), prairie dock (*Silphium terebinthinaceum*), compass plant (*Silphium laciniatum*), and a good representation of the prairie legumes out here."

Some of the plants are starting to spread throughout the prairie, such as white wild quinine (*Parthenium integrifolium*). Biotic routes, such as birds, or abiotic routes, such as wind, transport the seeds of many of these plant species. However, some plants, such as prairie coreopsis (*Coreopsis palmata*) spread themselves throughout the prairie by sending rhizomes, or underground horizontal stems, through the soil.

The Fermilab prairie is not only full of prairie plants, but it is also full of bird choruses; it seems to be a veritable haven for a multitude of bird species. Said Adamus: "A lot of the endangered bird species are prairie and forest dwellers, so it is important to maintain these habitats in Illinois."

A fair number of endangered species nest or use Fermilab's prairie at some point in the year. For example, in the winter, long-eared and short-eared owls, both Illinois endangered species, spend some time on site. Another species, the northern harrier, is on site occasionally, and "we would like to encourage them to nest here," Adamus added. The Lab also has a heron rookery. "We have fairly extensive tracts of suitable habitat, and that's why this prairie attracts so many bird and mammal species."

With enough suitable habitat, the restored prairie could support a number of endangered bird species, including cormorants, black-crowned night herons, and Henslow's sparrow. One species of state endangered bird, the upland sandpiper, already nests on site. Adamus believes that with continued support and proper management, the prairie has the potential to supply huge quantities of suitable habitat for endangered species, which would be a tremendous ecological contribution.

Fermilab's prairie is rich in other wildlife. Adamus has seen a variety of prey mammals in the past few years, including meadow voles, groundhogs, and rabbits. Larger mammals, including mink, beaver, deer, coyote, muskrat, and fox, have been observed on site as well. Elk, bobcat, and wolves are absent, "but these large animals are probably impractical anyway for a plot this size." In the past, there was some concern about the status of the fox population, but it seems to be recovering. The prairie needs to support a lot of predators like fox, coyote, owl, and hawk because of the large prey base.

Prairie Plants: Adapted for Survival

Prairie plants have evolved a number of adaptive strategies which enable them to survive the hostile conditions in the prairie. For example, compass plants orient their leaves north and south to reduce the surface area exposed to the sun. Evapotranspiration rates in plants, such as the compass plant, can be quite high: "Plants transpire a lot of water to keep cool, and this leaf orientation is an excellent example of an adaptive strategy used by this species to survive in the prairie." Another prairie plant in the same genus, prairie dock, also evolved this adaptive strategy.

Competition among plants is intense, and prairie plants need to have strategies to ensure their survival. Most of the plants in the Fermilab prairie are native American grasses and forbs. They are strong and aggressive, and are capable of out competing invading plant species. Adamus said that only a couple of undesirable species remain, such as white sweet clover (*Melilotus alba*). "We may do a fall burn here to help get rid of some of the clover, but it really isn't doing too well this year." Pesky, invasive thistles are gone in two or three years because the prairie drives them out, but "there is a native thistle adapted to the life cycle of the prairie that we would like to see in here eventually."

The prairie flora haven't exhibited pronounced signs of stress from the summer drought. Observed Adamus: "A few of the plants are showing signs of stress; however, for the most part, they're coping well." He explained that many prairie plants have incredibly deep roots - the roots of some prairie grasses and forbs go down 10-12 feet, where the plants can still obtain moisture.

As a result of the drought, however, the plants will probably grow to only five or six feet tall this year instead of seven to eight feet tall. Nevertheless, the prairie plants will get much taller than they are now. "Come August," said Adamus, standing in the center of the prairie, "you could get lost out here, literally. Everything will be over your head, and it's very tiring to walk through the high grass. Right now, it's pleasant, but in a couple of months, it will be a real effort to get through here."

Scientific Research

Fermilab's restored prairie is a relatively untapped ecological storehouse of scientific information.

Scientists find the chronologically successive plots useful for research because they can compare data collected from earlier plots to later plots to better understand soil development and structure, species richness, and how invasive weeds are driven out of the prairie. For example, scientists at Argonne National Laboratory are studying how the Fermilab prairie soil is redeveloping by comparing it to soils in native prairies, fields, and cultivated fields. Their research indicates that with time, as the soil develops under the prairie vegetation, it develops aggregates - clumps of soil held together by organic material. This is good news for the prairie because it indicates that the plant-soil interactions are becoming more "prairie-like."

Vicki Byre, an ornithologist at the Chicago Academy of Sciences, visually and aurally collects extensive qualitative data about the birds living in or using the prairie. Byre has recorded over 200 species of birds at Fermilab, 40 of which breed at the Lab. For example, she recently learned that Virginia rails have been breeding on site, which is an exciting discovery. Next year, she wants to do something more quantitative, such as counting the birds and mapping their territories. She's already mapped out red-tail hawk and great horned owl territories, and found at least six hawk and three to four owl nests on site.

In other research, Ron Panzer, an entomologist from Northeastern Illinois University and manager of the Gensberg-Markham Prairie, is conducting a long-term survey to determine if the prairie insect species that need to be in the prairie are actually absent before they are re-introduced.

Non-disruptive scientific research, such as Argonne's soil research, Byre's bird study, and Panzer's insect survey, can benefit the project in a number of ways. While the prairie *looks* good, the prairie committee would like some quantitative data to demonstrate that the prairie is *doing* well. And scientists, by publishing the results of their research, will bring the project to the attention of the scientific community. "We're encouraging researchers to use the site," said Adamus. "We want more activity and participation out here - we want a whole diverse base of scientific disciplines."

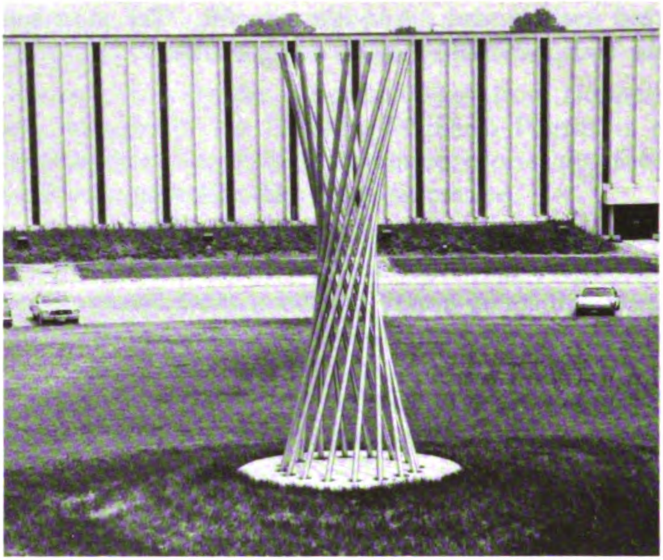
The Future

For the future, Adamus says, prairie restoration and preservation are important. "What we're working on now is restoring some of the small, early forbs - their seeds are difficult to obtain and they're delicate to grow." Most of the seeds for such plants as yellow stargrass (*Hypoxis hirsuta*), blue-eyed grass (*Sisyrinchium albidum*), and prairie phlox (*Phlox pilosa*), have to be collected by hand. In the past, armies of volunteers would undertake the difficult task of collecting and planting seeds in the prairie. One time, he said, the "children of Fermilab employees were recruited to plant grasses by hand, which was a fun project for them."

Rory Nelson, a graduate student at the University of Wisconsin at Madison, is working with Sam Baker, Assistant Head of the Fermilab Safety Section, to establish a restored prairie with an interpretive trail outside of the Main Ring. This would make the prairie more accessible to the general public. In print, *Audubon* magazine brought the project and Robert Betz to the attention of the general public through an article in its July issue.

There's still a lot of work to do on the prairie. Adamus believes that someone should be working on further restoring the wetland habitat to make it more suitable for sandhill cranes, birds that desperately need proper habitat in Illinois.

In spite of all the life in the prairie, it looks calm, giving no hint of the intense struggle between prairie plants and their natural adversaries. As we stood in the middle of the Fermilab prairie plot, Adamus said, "I've been around for roughly half the life of the project. Sometimes, it's frustrating and a lot of work, but there are encouraging aspects, such as when you see the prairie take hold and spread itself around. And it's peaceful. The most sound out here comes from the birds, and that's the way it ought to be."



(Fermilab photograph 88-720-6)

Tractricious, *the latest addition to Fermilab's outdoor sculpture collection, stands erect at last in front of the Fermilab Industrial Complex in general, Industrial Building 1 specifically. The artistic design for the piece came from Fermilab Director Emeritus Robert R. Wilson; the structural design was accomplished by Tom Nicol of the Technical Support Section (TSS); Paul Mantsch, Head of TSS, provided the impetus within TSS for completion of the project. Jerry Peterson and Luis Ramirez of TSS were involved with the welding and machining of the sculpture's tubes; Kurt Kasules, also of TSS, along with Fermilab's Construction Engineering Services Department, provided civil construction support and assured that the sculpture was up to code. Nicol began preliminary work in December of 1985, and the sculpture rose complete the week of June 2, 1988.*

The sculpture is comprised of 16 stainless steel outer tubes, made from scrap cryostat tubes from TEVATRON dipole magnets, and 16 inner tubes, which are 5 in., Schedule 40, carbon steel pipes from old well casings salvaged from the Fermilab "bone yard." Each outer tube is 39 ft long and 6-1/2 in. in diameter, and weigh 550 pounds apiece; the sculpture itself rises to a height of 36 ft.

Each tube is free standing, designed to comfortably withstand winds up to 80 mph. In fact, the sculpture gently oscillates in the absence of wind and a light breeze acts as a damper to stop vibrations.

Accolades:

DOE Distinguished Associate Award to Leon M. Lederman...

In Washington, D.C., on July 11, 1988, Fermilab Director Leon M. Lederman was presented with the U.S. Department of Energy's Distinguished Associate Award "for his outstanding leadership and contributions to improving scientific education and public understanding of science."

Senior Scientist Award to Larry McLerran...

Larry McLerran, a theoretical physicist with the Fermilab Theory Department, has been elected to receive a Senior U.S. Scientist Award of the Alexander Von Humboldt Foundation.

Helen T. Edwards selected as MacArthur Fellow...

On July 19, 1988, Helen T. Edwards, Head of the Fermilab Accelerator Division, was awarded a MacArthur Fellowship by the Chicago-based John D. and Catherine T. MacArthur Foundation in recognition of her efforts as one of those instrumental in the successful construction and commissioning of Fermilab's TEVATRON. MacArthur Fellowships take the form of cash grants which the recipient may use to any end he or she chooses. Edwards plans to use the grant monies, $315,000 over 5 years, in support of basic research education in general and accelerator research education in particular.

Upon notification of the award, Edwards stated: "High-energy physics is a strong group activity. As such, it's important to recognize the many hundreds of people who contributed their intellects, expertise, and years of effort to the development, construction, and successful operation of the TEVATRON. This award is accepted on their behalf, and in recognition of the importance of all basic research and the basic research carried on at Fermilab."

Leon M. Lederman, Fermilab's Director, issued this statement on behalf of the Laboratory: "Helen Edwards has been an important member of the Fermilab accelerator team since the beginning of the Laboratory, circa 1970. In 1979, she became co-leader of the team charged with the construction of the world's first superconducting synchrotron - the 4-mile particle accelerator which was designed to raise the energy of the Fermilab machine from 400 GeV to close to 1000 GeV. This effort, supported by the U.S. Department of Energy, was successful in 1983, making Fermilab the highest energy laboratory in the world.

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

"Today she heads the Fermilab Accelerator Division and is responsible for the operation of the complex of accelerators that includes the TEVATRON Collider where 900-GeV protons collide with 900-GeV antiprotons. She is also leading the effort to improve the accelerator in order to assure the ability to continue incisive research in the structure of matter."

In 1985, Edwards was one of the first recipients of the Achievements in Accelerator Physics and Technology Prize awarded each year by the US Particle Accelerator School. In 1986, Edwards was awarded one of six Ernest O. Lawrence Awards for that year by U.S. Department of Energy Secretary John S. Herrington.

In Memoriam

Herbert L. Anderson - 1914-1988

Herbert L. Anderson, former Director of the Enrico Fermi Institute for Nuclear Physics, passed away at his home in Santa Fe, New Mexico, on July 16, 1988. Dr. Anderson was 74.

In 1983, Dr. Anderson, who was Distinguished Professor Emeritus of Physics at the University of Chicago, was awarded the U.S. Department of Energy's Enrico Fermi Award in recognition of his work in nuclear research. Dr. Anderson's citation noted "his pioneering collaboration with Enrico Fermi in demonstrating the emission of neutrons in fission at Columbia University; for his essential role in constructing the first chain-reacting piles; for his work on production and determination of properties of tritium and helium-3."

Dr. Anderson was the first graduate student of, and Chief Assistant to, Enrico Fermi at Columbia College. After successfully creating the first self-sustaining nuclear chain reaction for the Manhattan Project at the University of Chicago, Dr. Anderson joined Fermi's team at Los Alamos where they worked on the development of the atomic bomb. In 1963, Dr. Anderson was one of the leaders of the movement whose goal was a bilateral nuclear test ban agreement between the U.S. and the Soviet Union. In 1948, he designed and helped build the 2250-ton cyclotron at the University of Chicago.

Dr. Anderson is survived by his wife, Mary Elizabeth; three sons, Clifton, Dr. Kelley, and Dana; and a grandchild.

("Lab Notes" continued)

Illinois' DOE High School Honors Research Program students tour Fermilab...

On May 16, 1988, eight Illinois high school students, their parents, and a few of their high school teachers toured Fermilab. The eight students, among 12 nominated by Illinois Governor James R. Thompson, were chosen as the state's representatives in the Department of Energy (DOE)-sponsored High School Honors Research Program. Created in 1985 and funded entirely by DOE, the program provides outstanding high school science students with an opportunity to gain firsthand experience in advanced scientific research, and is designed to stimulate the interest of students in careers in science and engineering. By providing the facilities of the national laboratories to these students, the Department of Energy can ensure an adequate future supply of well-trained scientists and engineers for its own research needs and those of the nation.

The Illinois DOE scholars included Richard Harmon of Granite City, Jeff Jensen of Decatur, Robert Narske of Rock Island, Janice Nelson of Montgomery, Russell Surratt of Medinah, and Jason Yong of Niles, and alternates Frank Borras of Rosement, Albert Cho of Chicago, Kimberly Kusinski of Chicago, Chris Schmitz of Rosamond, Neil Tice of Petersburg, and Emily Ummel of Cairo. They will join students from the 49 other states, the District of Columbia, and Puerto Rico in studying and working at six national science laboratories operated by DOE. Foreign students, sponsored by their own government, will also be involved.

The selection process varied with each state. In Illinois, a committee comprised of people from the Illinois Junior Academy of Sciences reviewed applications submitted by high school teachers on behalf of students who showed overall academic achievement and an interest in careers in science and engineering.

After a tour of Argonne National Laboratory, the students and guests were greeted at Fermilab by Marjorie G. Bardeen, Program Director of the Friends of Fermilab. Ms. Bardeen introduced the group to Associate Director Richard Lundy, followed by a tour, conducted by Fermilab physicist Drasko Jovanovic, which gave the students an overview of the research and experimentation presently being done at the Laboratory. - *Connie Kania*

Corrections: In the article "Experiment 765 Measures. . ." beginning on page 9 of the March/April *Fermilab Report*, the experiment was incorrectly identified, and should have been Experiment 756. On pages 31 and 33, the talk by Arlene Lennox was, in fact, "Neutrons Against Cancer."

Manuscripts and Notes

prepared or presented from May 25, 1988, to July 15, 1988. Copies of Fermilab TM's, FN's, and preprints (exclusive of Theoretical and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH 3E, or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL. For Theoretical Physics or Theoretical Astrophysics preprints, contact those departments directly.

Experimental Physics Results

Experiment #400
C. L. Shipbaugh, "Production of Charm Mesons by High Energy Neutrons," (Ph.D. Thesis, 1988, University of Illinois at Urbana-Champaign)

Experiment #400
R. Ladbury, Jr., "Production of the Σ_c^0 and Σ_c^{++} by High Energy Neutrons," (Ph.D. Thesis, 1988, University of Colorado)

Experiment #632
V. Jain, "Dimuon Production by 0-600 GeV Neutrinos in the Fermilab 15 ft. Bubble Chamber," (Ph.D. Thesis, August 1988, University of Hawaii)

Experiment #691
T. E. Browder, "A Study of D^0-$\overline{D}^0$ Mixing," (Ph.D. Thesis, March 1988, University of California, Santa Barbara)

Experiment #745
T. Kitagaki et al., "A New Method to Investigate the Nuclear Effect in Leptonic Interactions," (FERMILAB-Pub-88/59-E; submitted to Phys. Lett. B)

General Particle Physics

J. Freeman et al., "Can Gluinos and Squarks Be Discovered at Hadron-Hadron Colliders? How?", (FERMILAB-Pub-87/229; submitted to Nucl. Phys.)

V. Bharadwaj et al., "The Use of the Fermilab Antiproton Accumulator in Medium Energy Physics Experiments," (TM-1527; presented at the European Particle Accelerator Conference, Rome, Italy, June 7-11, 1988)

Accelerator Physics

S. A. Bogacz and S. Stahl, "Coupled Bunch Instability in Fermilab Booster - Longitudinal Phase-Space Simulation," (FERMILAB-Conf-88/65; presented at the European Particle Accelerator Conference, Rome, Italy, June 7-11, 1988)

S. A. Bogacz et al., "Coherent Betatron Instability in a High Energy Synchrotron," (FN-485; submitted to Phys. Rev. D)

S. A. Bogacz et al., "Coherent Betatron Instability in the TEVATRON," (FERMILAB-Conf-88/69; presented at the European Particle Accelerator Conference, Rome, Italy, June 7-11, 1988)

S. A. Bogacz et al., "Effect of Empty Buckets on Coupled Bunch Instability in RHIC Booster - Longitudinal Phase-Space Simulation," (FN-486; submitted to the Proceedings of the Workshop on RHIC Performance at Brookhaven National Laboratory, Upton, New York, March 21-26, 1988)

Y.-C. Chao and K.-Y. Ng, "Analytical and Numerical Studies of the Landau Cavity Longitudinal Coupled Bunch Instabilities in the Fermilab Booster," (FN-470)

F. T. Cole and F. E. Mills, "Recent Progress in Particle Accelerators," (Published in *Advances in Electronics and Electron Physics*, Vol. 71, p. 75)

S. R. Mane, "Polarization Calculations for Electron Storage Rings," (FERMILAB-Conf-88/56; invited talk presented at the Workshop on Polarization in LEP, CERN, Geneva, Switzerland, November 9-11, 1987)

S. R. Mane, "Coherent Betatron Oscillations and Emittance Growth Due to Random Kicks," (FN-479-A)

S. R. Mane, "Equivalence of Two Formalisms for Calculating Higher Order Synchrotron Sideband Spin Resonances," (FERMILAB-Conf-88/57; to be presented at the 8th International Symposium on High Energy Spin Physics, University of Minnesota, Minneapolis, Minnesota, September 12-17, 1988)

A. D. McInturff et al., "The Fermilab Collider D0 Low β System," (FERMILAB-Conf-88/72; presented at the European Particle Accelerator Conference, Rome, Italy, June 7-11, 1988)

K.-Y. Ng, "Effects of Copper Coating the RHIC Beam Pipe," (FN-483; submitted to the Proceedings of the Workshop on RHIC Performance at Brookhaven National Laboratory, Upton, New York, March 21-26, 1988)

K.-Y. Ng, "Resonant Impedance in a Toroidal Beam Pipe," (FN-477-Rev. [SSC-163], submitted to Part. Accel.)

K.-Y. Ng, "Transverse Coupled-Bunch Instability in the Fermilab Main Ring," (FN-482)

K.-Y. Ng, "Toroidal Resonant Impedances in RHIC," (TM-1521; submitted to the Proceedings of the Workshop on RHIC Performance at Brookhaven National Laboratory, Upton, New York, March 21-26, 1988)

M. J. Syphers, "Beam-Gas Scattering Lifetimes in the Fermilab Main Ring," (FN-484)

J. C. Theilacker, "Operational Experiences of the TEVATRON," (presented at the Conference on Superconductivity and Applications, Buffalo, New York, April 18-20, 1988)

Theoretical Physics

C. H. Albright et al., "Renormalization Effects on Phenomenological Mass Matrices Illustrated for the Fritzsch Model," (FERMILAB-Conf-88/76-T; presented at the XXIV International Conference on High Energy Physics, Munich, Germany, August 4-10, 1988)

R. K. Ellis, "Heavy Quark Production in QCD," (FERMILAB-Conf-88/73-T; invited talk presented at the Advanced Research Workshop on QCD Hard Hadronic Processes, St. Croix, Virgin Islands, October 8-13, 1987)

R. K. Ellis and P. Nason, "QCD Radiative Corrections to the Photoproduction of Heavy Quarks," (FERMILAB-Pub-88/54-T; submitted to Nucl. Phys. B)

K. Lee, "Wormholes and Goldstone Bosons," (FERMILAB-Pub-88/27-T; submitted to Phys. Lett.)

L. McLerran, "A Review of H-B-T Correlations and What We Can Learn About the Space-Time Structure of Hadronic Collisions," (FERMILAB-Conf-88/68-T; presented at the International Conference on the Physics and Astrophysics of the Quark Gluon Plasma, Bombay, India, February 8-12, 1988)

Theoretical Astrophysics

A. Albrecht and T. York, "A Topological Picture of Cosmic String Self-Intersection," (FERMILAB-Pub-88/41-A; submitted to Phys. Rev. D)

R. P. Brinkmann, "The Stability Analysis of Magnetohydrodynamic Equilibria: Comparing the Thermodynamic Approach to Bernstein's Energy Principle," (FERMILAB-Pub-88/51-A; submitted to Astrophys. J.)

R. P. Brinkmann and M. S. Turner, "Numerical Rates for Nucleon-Nucleon, Axion Bremsstrahlung (FERMILAB-Pub-88/29-A; submitted to Phys. Rev. D)

E. Copeland et al., "The Effect of Topological Defects on Phase Transitions in the Early Universe," (FERMILAB-Pub-88/30-A; submitted to Nucl. Phys.)

K. Griest, "Calculations of Rates for Direct Detection of Neutralino Dark Matter," (FERMILAB-Pub-88/52-A; submitted to Phys. Rev. Lett.)

L. Kawano, "Let's Go: Early Universe; Guide to Primordial Nucleosynthesis Programming," (FERMILAB-Pub-88/34-A; to be submitted for journal entry)

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-88/50-A; submitted to Math. J. of Phys.)

D. N. Schramm, "Supernova 1987A; One Year Later, A Summary of the La Thuile Symposium," (FERMILAB-Conf-88/45-A; prepared for the Proceedings of the La Thuile Conference, La Thuile, Italy, February 28-March 5, 1988)

Other

M. Bodnarczuk, "QA at Fermilab; The Hermeneutics of NQA-1," (FERMILAB-Conf-88/55; presented at the 29th Annual Meeting of the Institute of Nuclear Materials Management, Las Vegas, Nevada, June 26-29, 1988)

M. Bodnarczuk, "QA Role in Advanced Energy Activities; Reductionism, Emergence, and Functionalism; Presuppositions in Designing Internal QA Audits," (FERMILAB-Conf-88/77; to be presented at the 15th Annual ASQC National Energy Division Conference, San Antonio, Texas, October 23-26, 1988)

G. R. Kobliska, "An Eye for Accuracy - Coordinate Measuring in an R&D Environment," (TM-1526; presented at the Precision Metrology with Coordinate Measurement Systems Conference, Gaithersburg, Maryland, June 15-16, 1988)

Colloquia, Lectures, and Seminars

by Fermilab staff, at Fermilab, May-June 1988, unless otherwise noted.

May 3

J. Mack: "VM Overview: the Amdahl Environment"

May 9

S. Parke: "Neutrino Oscillations"

May 10

S. Hansen: "New ADC's and TDC's for Fixed-Target Physics"

May 11

S. Parke: "Neutrino Oscillations"

May 12

D. Herrup: "Tune and Chromaticity Control in the TEVATRON Parabola"

D. Cossairt: "Production and Transport of Muons in Thick Shields at the TEVATRON, CASIM Calculations and Measurements"

May 17

A. Kreymer: "ACP Systems in the Fermilab Computing Environment: Status and Plans"

May 19

R. Webber: "BPM System Modification for Single Bunch Measurement"

E. McCrory: "Beam Position Measurements in the Linac"

May 24

R. Thatcher: "FORTRAN on the Amdahl"

May 31

G. Chartrand: "Communications to the Amdahl System"

June 7

L. Michelotti: "Differential Algebra Without Blood, Sweat, Tears, and FORTRAN Using C++"

June 14

M. Leininger, T. Nicol, and U. Pabrai: "Workstation Evaluation for Mechanical Engineering Applications"

E. Eichten, S. Holmes, and J. Yoh: "Discovery Potential of Potential Fermilab Hadron Colliders vs. Energy and Luminosity"

June 15

D. Jovanovic: "The Standard Model"

June 16

N. Gelfand, R. Johnson, and E. Martensson: "Store Summary Program"

June 22

L. Teng: "An Introduction to Particle Accelerators"

June 28

P. Kasper: "The E-687 Code Management System: A Solution to a General Problem"

June 29

P.W. Lucas: "Accelerator Computer Control Systems"

June 30

P. Rapidis: "Summary of Pbar Source Studies Period: March-May 1988"

Dates to Remember

September 14-16, 1988

Conference on New Directions in Neutrino Physics at Fermilab. For information, contact Phyllis Hale, Fermilab Users Office, (312) 840-3111 or (BITnet) NUDIR@FNAL.

September 19, 1988

Deadline for receipt of material to be considered at the October Physics Advisory Committee meeting (contact J. Coleman or T. Yamanouchi, ext. 3027).

September 21-24, 1988

Lattice Gauge Theory Workshop. For information contact: Phyllis Hale, Fermilab Users Office, (312) 840-3111 or (BITnet) LAT88 @ FNAL

October 20-21, 1988

Physics Advisory Committee meeting (Please note change from December meetings in recent years)