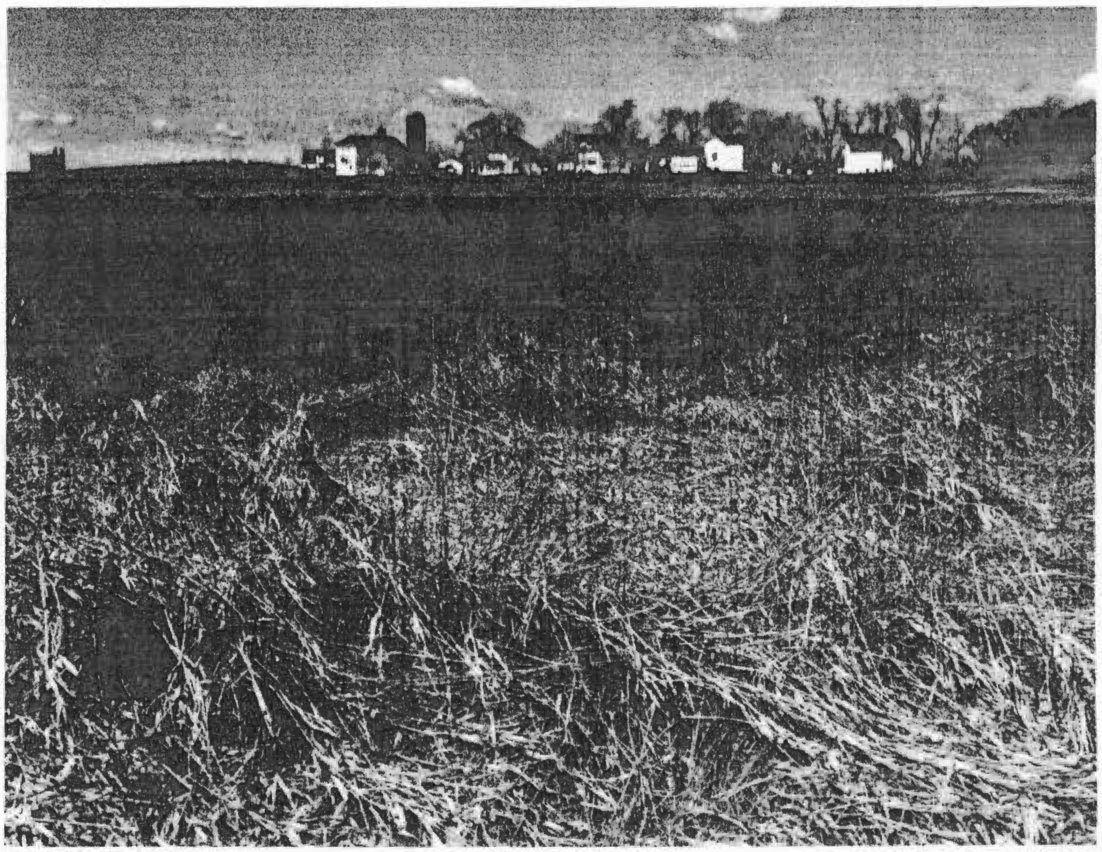
fermilab report

Fermi National Accelerator Laboratory Monthly Report

April 1985



fermilab report is published monthly by the Fermi National Accelerator Laboratory, P. O. Box 500, Batavia, Illinois 60510 U.S.A.

Editor: R. Fenner
Associate Editors: R. Carrigan, Jr.; L. Voyvodic
Contributing Editors: D. Beatty, M. Bodnarczuk, R. Craven, D. Green, L. Mc Lerran, S. Pruss, R. Vidal
Editorial Ass't.: P. Roberts

The presentation of material in **fermilab report** is not intended to substitute for or preclude its publication in a professional journal, and reference to articles herein should not be cited in such journals.

Contributions, comments, and requests for copies should be addressed to the Publications Office.

FERMILAB-85/4 Fermi National Accelerator Laboratory 0090.01

THE COVER: The view across Lake Law toward the Fermilab Village, home away from home to visiting experimenters. (Photograph by Ellen Lederman)

"At the same time that we are earnest to explore and learn all things, we require that all things be mysterious and unexplorable, that land and sea be infinitely wild, unsurveyed and unfathomable by us because unfathomable...We can never have enough of nature." -from *Walden*, by Henry David Thoreau

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

FERMILAB ANNUAL USERS MEETING
RAMSEY AUDITORIUM, MAY 10-11, 1985

PRELIMINARY AGENDA

Friday, May 10

8:00 a.m.	Registration
9:00 a.m.	Users Executive Committee Report (R. McCarthy, SUNY at Stony Brook)
9:10 a.m.	The State of the Laboratory (L. Lederman, Fermilab)
9:55 a.m.	URA Report (G. Stever, President of URA)
10:10 a.m.	Coffee Break
10:40 a.m.	TeV I Project Report (D. Young, Fermilab)
11:10 a.m.	The Status of DO (D. Green, Fermilab)
11:25 a.m.	The Status of CDF (Lee Pondrom, University of Wisconsin)
11:45 a.m.	Discussion
12:00 p.m.	Address by Erich Bloch, Director of the NSF
12:30 p.m.	Lunch
1:30 p.m.	Experimental Schedule (R. Rubinstein, Fermilab)
1:45 p.m.	Accelerator Operations (R. Mau, Fermilab)
2:05 p.m.	Fixed-Target Operations, and Research Division Reorganization (R. Dixon, Fermilab)
2:30 p.m.	An Experimenter's View of Fermilab Operations (G. Thomson, Rutgers University)
2:45 p.m.	Fixed-Target Physics at the Tevatron (P. Slattery, University of Rochester)
3:00 p.m.	Coffee Break
3:30 p.m.	HEPAP Town Meeting (Moderated by B. Winstein, Enrico Fermi Institute)
5:30 p.m.	Adjournment (URA-hosted cocktail party at Users Center)

Saturday, May 11

9:00 a.m.	Changes at the Users Center (S. Hagopian, Florida State University)
9:10 a.m.	Computing (H. Montgomery, Fermilab)
9:30 a.m.	New Physics Opportunities at Fermilab (J. Bjorken, Fermilab)
10:00 a.m.	Coffee Break
10:30 a.m.	Status of the SSC (S. Wojcicki, SSC Design Group/Stanford University)
11:30 a.m.	To Be Announced
12:00 p.m.	Adjournment

THE LAB E SPECTROMETER AND NEUTRINO EXPERIMENTS†

Frank Sciulli
Columbia University

When beam began arriving in the Neutrino Area on January 23, the denizens of Lab E trembled in ready anticipation. For the past two years, they have been upgrading their neutrino detector for use with the Tevatron beam in the Quadrupole Triplet Beam Experiment (E-744) and the Dichromatic Beam Experiment (E-652). The present E-744 run could increase by more than an order-of-magnitude the present world's supply of analyzed high-energy (i.e., E > 100 GeV) neutrino and antineutrino events, if the requested 10^{18} protons can be delivered. Besides providing definitive measurements of high Q^2 structure functions, these data should provide a unique sample for searches for anomalous events, like the much-heralded and completely baffling same-sign dimuons suggested from earlier experiments.

The major modifications to the detector are required primarily because of the high instantaneous event rate produced by the Tevatron beam. The improvements include 78 new drift chambers (most are 3 m × 3 m in area) and multihit TDC readout with 10 μs deadtime between events. All of the collaborating institutions (Columbia/Chicago/Fermilab/Rochester) contributed to design and construction. Drift chamber components were produced at Fermilab, Chicago's Fermi Institute, and Columbia's Nevis Labs. Final assembly of the chambers was carried out at Fermilab by a team of technicians from Fermilab, Chicago, and Columbia. The TDC modules were produced at Nevis Labs. This seemingly complicated amalgam of the efforts of many laboratories worked smoothly and efficiently over about a year to produce the system on time and on cost.

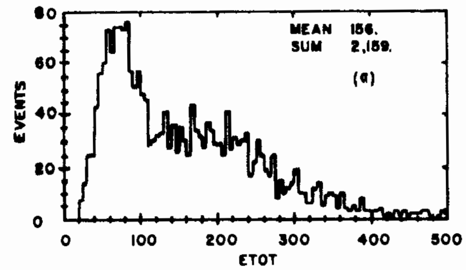
A shakedown of the first few components occurred near the end of the 1984 running period. This gave confidence to the basic designs and showed that the goal of 500 μ spatial resolution was surpassed. One by-product of the upgrade is a substantial increase in information content near the interaction vertex as compared with data taken with the spark chambers used previously.

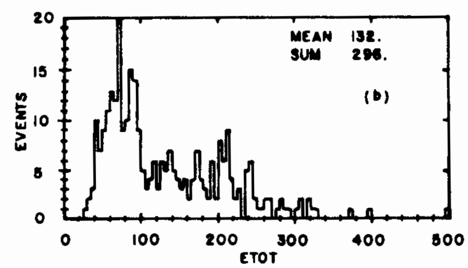
Another modification, under the primary responsibility of the Rochester group, was a new double-veto wall to remove triggers from muons coming through the shield, as well as muons from upstream neutrino interactions. This group also oversaw the installation of a large-area hodoscope to produce the timing information necessary for precision track resolution.

Various other contributions to the upgrade included extension of the target to permit additional chambers to be installed; new chambers installed in the downstream Lab E extension; checkout and calibration of new buffered LeCroy ADC units, replacement and addition of several 3 m × 3 m target scintillation counters, upgrade of the counter-flasher system, development of new PDP-11 acquisition software, and development of new online monitor software made possible by the Laboratory-supplied VAX 11/780.

By the end of January, the new equipment was 95% installed and intermittent operation of the detector had been carried out using cosmic ray triggers. The experimenters began to see the happy consequences of their preparations with high-energy muons and actual neutrino events when beam arrived on January 23. Amidst the revelry, the E-744 spokesman, Frank Merritt, was heard to proclaim, "It's been a long time coming!"

Within approximately one week, data were being taken. These data, treated online, provided important feedback to the Laboratory regarding beam composition, beam steering, etc. The figure below shows the energy distributions for neutrino and antineutrino interactions in the Lab E target as obtained online from

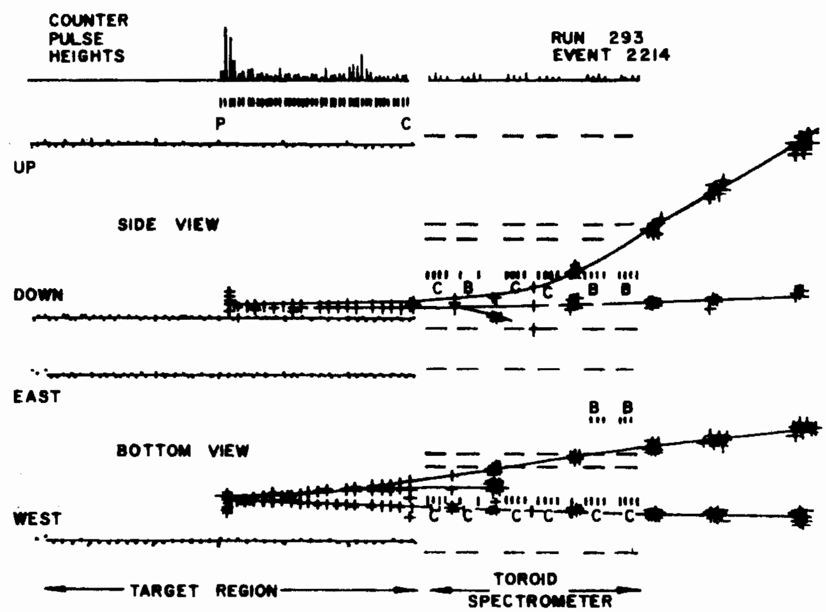




The number of events obtained in a single run versus the total observed energy (ETOT) in GeV for (a) neutrino events and (b) antineutrino events. This is a relatively "hard" spectrum with mean energies of 156 GeV and 132 GeV, respectively, due to the high primary energy of the Tevatron (800 GeV) and the Quadrupole focusing system.

data accumulated over a period of several hours. The spectral shapes, as well as the ratio of antineutrino-to-neutrino events, is qualitatively consistent with expectations. The transverse position profiles of interaction verticies showed that the beam centroid was offset by about 25 cm at Lab E; the Research Division has recently taken steps to rectify this.

Efforts at catching exotic-appearing events online are being made. The following figure shows a trimuon event selected with online software. The figure shows a neutrino interaction vertex about halfway through the detector, with large pulse heights in counters immediately downstream. Following the shower is a sequence of pulse heights at about three times the minimum ionizing level, and three tracks resolved in the target and separated in the magnetized toroid. Two of the muons traverse the entire toroid system while the third exits approximately halfway through the toroid. The two focusing tracks are μ^- and the defocusing track is a μ^+.



A schematic of the Lab E apparatus showing the upstream target region and the downstream toroid spectrometer. The pulse heights observed from scintillation counters imbedded in the steel target are shown at the top of the figure. The drift chamber hits are shown as crosses.

Considerable group effort is being transferred to the off-line analysis system. It is anticipated that major data crunching may begin before the run ends.

To be successful, this run requires an integrated proton flux on target of 10^{18} protons, or about 10^{13} protons per machine cycle. With the 10^{18} protons anticipated in this run, nearly two million high-energy neutrino events would be collected. Several obstacles have appeared which endanger this goal: the ability to extract high intensities in the fast resonant extraction mode, and the total beam available in the machine.

The first problem was formidable, since losses would quench Tevatron magnets when the extracted beam intensity rose above 2×10^{12} protons in a single one-millisecond burst. The Accelerator Division solved this difficulty in short order by extracting four such pulses during the 20 second flat-top without mishap. Additional pulses may feasibly be added if a solution to the quench problem is not found.

At present, the total machine intensity seems to be the limiting factor; typically, slightly less than 10^{13} protons are being accelerated in the Main Ring. This number is substantially less than that routinely achieved in the pre-Tevatron days. With the needs of the slow-spill experiments taken into account, it will be necessary to raise the machine intensity by about a factor of two in order to deliver the requisite protons to the Neutrino Area. Optimism is high that the Accelerator Division will be able to overcome this hurdle.

The physicists in Lab E are genuinely pleased at the progress made thus far. The experiment is taking high-quality data without serious difficulty. They look forward to amassing the large quantity of interactions required for an important step toward an understanding of neutrino interactions.

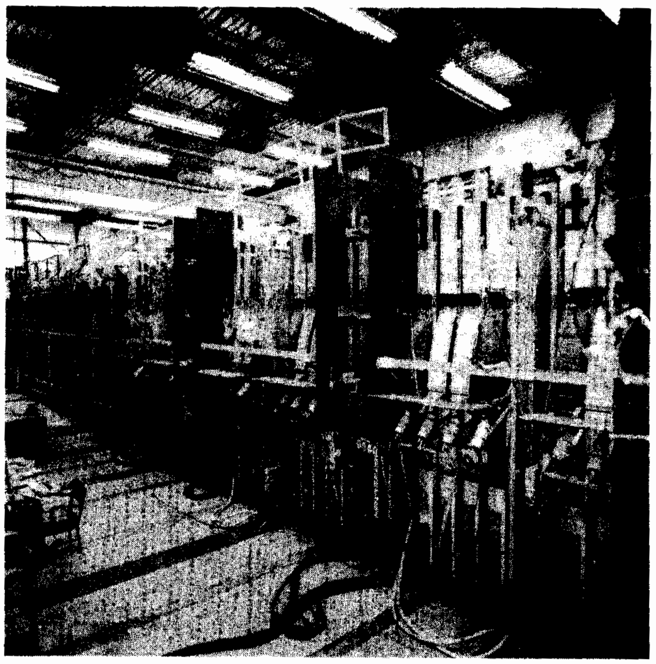
†Participants in the spectrometer upgrade and in the present experiment are:

F. Merritt, M. Oreglia, H. Schellman, B. Schumm, and R. Wagner
University of Chicago

K. Bachmann, R. Bernstein, R. Blair, C. Foudas, K. Gray,
W. Lefman, S. Mishra, E. Oltman, F. Sciulli, M. Shaevitz,
and W. Smith
Columbia University

F. Borcherding, E. Fisk, D. Jovanovic, M. Lamm, W. Marsh,
K. Wyatt Merritt, and P. Rapidis
Fermilab

A. Bodek, H. Budd, and W. Sakumoto
University of Rochester



Neutrino detection apparatus viewed from the rear of Lab E.
(Fermilab photograph 79-319-4)

INTERNATIONAL SYMPOSIUM ON PARTICLE PHYSICS IN THE 1950S
"From Pions to Quarks"

Lillian Hoddeson

An international symposium aimed at identifying the principle themes and problems in the development of particle physics during the 1950s will be held at Fermilab from May 1 to May 4, 1985. Subjects to be explored include the strong and weak interactions, detectors and accelerators, and large high-energy physics laboratories. This symposium will be the second such history meeting held at Fermilab. The first, in May 1980, centered around ten major talks by physicists (including P.A.M. Dirac, Victor Weisskopf, Bruno Rossi, Julian Schwinger, and Carl Anderson) dealing with the roots of particle physics in the 1930s and 40s: cosmic ray studies, nuclear physics, and quantum electrodynamics. The second symposium continues the study into the 1950s, when particle physics became recognized as a distinct field of research.

Historians as well as physicists will play a major role at the meeting. Members of these two groups tend to view their subject in rather different (sometimes contradictory!) terms, and the organizers of the symposium--Lillian Hoddeson, Laurie Brown, and Max Dresden--have arranged representation of both perspectives, hoping thus to provide a fuller picture of the historical period than reflections or historical accounts alone. The group of speakers includes approximately thirty physicists (among them C.N. Yang, Luis Alvarez, Owen Chamberlain, W.P. Panofsky, Eduardo Amaldi, and Murray Gell-Mann) and 9 historians of modern physics (including John Heilbron and Peter Galison). The stage will thus be set for informed historians to confront the recollections of the physicists in a public setting and, reciprocally, for physicists having first-person experiences to confront the analysis of the historians. Afterwards the lecturers will have the opportunity to revise and expand their relatively short talks into more detailed papers to be published by Cambridge University Press in a carefully edited volume, a sequel to the book based on the first Fermilab history symposium [Laurie Brown and Lillian Hoddeson (eds), *The Birth of Particle Physics* (Cambridge, 1983)]. The series is intended to serve as a source for physicists and historians attempting more detailed studies in the field, as well as to provide a first summary of some of the exciting scientific developments that comprise the heritage of the present generation of high-energy physics. For more information and the program, contact Lillian Hoddeson, **Wilson Hall 3W, m.s.109, ext.(312) 840-3401.**

THE COLLIDER DETECTOR FACILITY AT FERMILAB

Alvin Tollestrup,
CDF Collaboration†

Introduction

The $\bar{p}p$ colliding-beam facility at Fermilab is rapidly nearing completion and will be commissioned in 1986. A visit to B0, or to the area where the new Debuncher and Accumulator Rings are being installed, gives striking visual proof of the exciting times that are approaching. With the completion of D0 and the B0 overpass, the long period of constructing new facilities at Fermilab will come to an end, and then exploitation for physics will begin. In addition, we have high expectations that the increased energy of 2 TeV in the center-of-mass will bring into view the area beyond that of the Standard Model which has been so brilliantly explored at CERN. The commissioning is coming at a time of anticipation over the possibility of discovering the effects of supersymmetry, finding the Higgs, or testing for an additional generation of substructures within the quark. We are incredibly fortunate to have a machine that is so well suited to explore this frontier between now and when the SSC will take over.

It is hard to realize now, when viewing the activity in B0, that the first beam was stored almost nine years ago--June 10, 1976--in the Main Ring. It has taken a long time to bring reality to the original dream of colliding beams, but the activity in B0 quickly dispells any doubt about the reality of the program to achieve 2 TeV colliding beams. The first step was construction of the B0 Collision Hall, a part of the TeV I project, which began July 1, 1982, and was completed in March 1983.

The detector design was the result of a combined Italy/Japan/US effort. During this collaboration the design has been greatly strengthened by the various unique contributions that each of the participants has been able to make. There are many examples of individual institutions having access to specialized technology that has improved the performance of the detector. The vitality of a collaboration extending over 16 time zones has been well demonstrated.

At present, one can view the completed magnet in the assembly pit. The magnet consists of the yoke, the end wall calorimeters, the end plugs, and the 3 m × 5 m superconducting solenoid. This magnet has just been tested to its full operating field of 1.5 T and is the first such magnet to be excited without either major or minor disaster! The coil was designed by a collaboration of physicists and engineers from CDF and the Research Division Cryogenic Department at Fermilab, together with physicists and engineers from the University of Tsukuba, Japan, and Hitachi Heavy Industries, Japan. The power supply, refrigerator, and controls were constructed at Fermilab. The coil itself was assembled at Hitachi Heavy Industries.

One arch of the central calorimeter, comprised of modules that have all been calibrated in the test beam, is fully assembled at the side of the magnet. The rest of the modules are now being tested and will be assembled into three more arches. The end plug electromagnetic and hadron calorimeters are under construction and will complete the central calorimetry. One may also observe in the pit two sets of iron plates for the forward hadron calorimeters which are waiting to be moved into the Collision Hall during the April shutdown.

A visit to the counting rooms will give evidence to the progress that is being made with the FASTBUS-based data-acquisition system. Major components of this system which have been tested, and are now working, include the SLAC Scanner Processor as well as the Fermilab-constructed RABBIT System with its MX processor.

The excitement, of course, is being heightened by prospects of the Antiproton Source and Detector tests that are being planned for August 1985. Although many uncertainties exist, there is an excellent possibility that the Source will be working well enough in August, and that the machine-related backgrounds will be low enough, that the central calorimeter, a vertex time-projection chamber (VTPC), and the beam-beam trigger counters can all be installed and made operational. Admittedly with some optimism, we will be able to study QCD jets using the VTPC and the central calorimeter whose granularity is well suited for just such measurements.

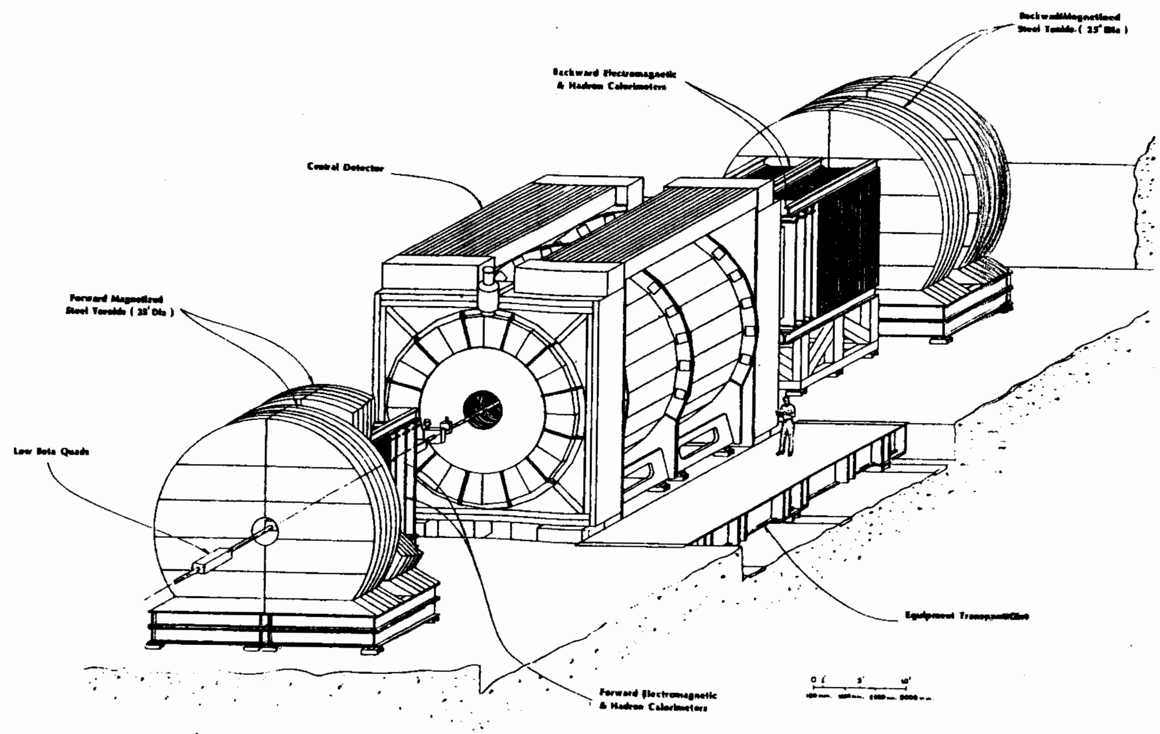
The completion of the detector will take place by the end of FY86 when the first major physics run will occur. We now give a brief description of the detector elements.

Brief Detector Description

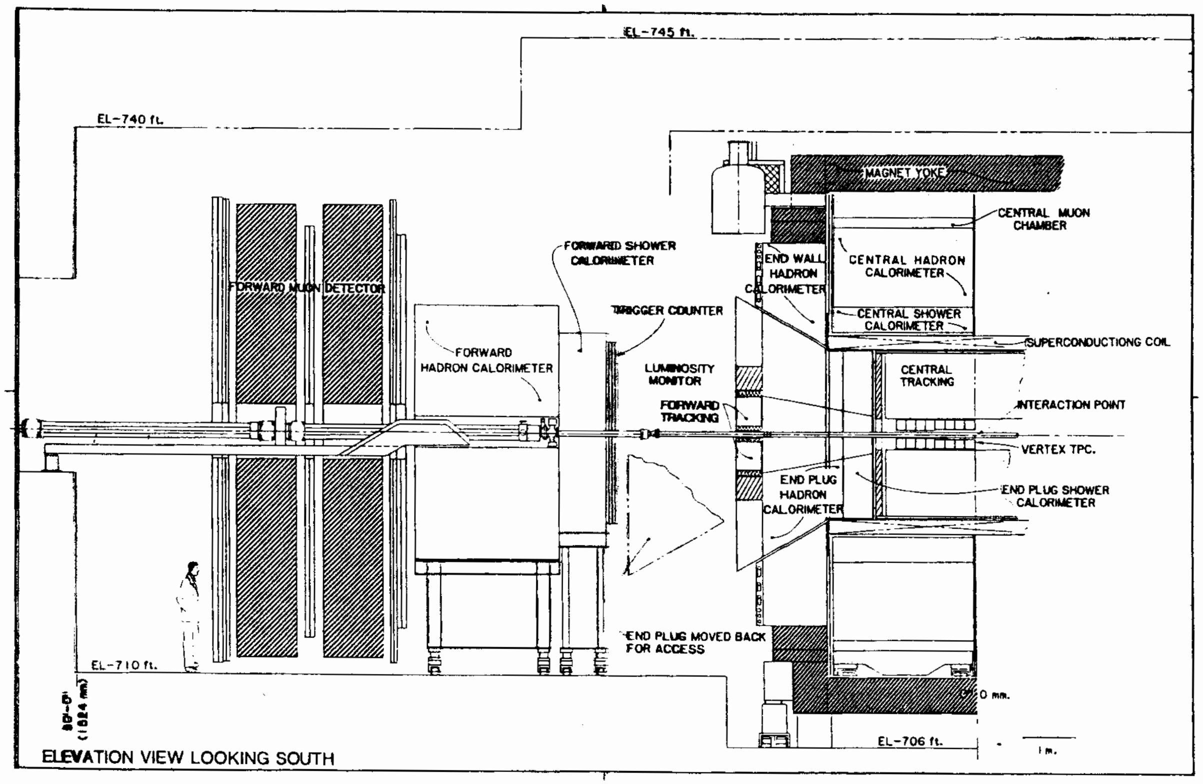
The diagram on page 10 shows a perspective drawing of the detector, and a cross section is shown on page 11. The detector components can be described best by considering what instrumentation is being constructed for each angular interval.

Inside the beam pipe

The region inside the beam pipe is being fitted with Si detectors to make measurements of the elastic scattering cross sections and to implement a trigger for diffractive processes. There are four stations--two on either side of the IR. The nearest stations are in front of the low-β quadrupoles, and the two farthest are actually in the machine lattice where they are used in conjunction with a lattice dipole to form a very high-resolution spectrometer for very high-momentum forward particles.



Perspective drawing of the Collider Detector.



Cross section of the Collider Detector.

Beam pipe to 2°

This region will be instrumented in the future.

2° to 10°

This region is covered by a VTPC and a forward drift chamber using a "Bicycle Wheel" type construction with planes of radial sense wires. Behind these chambers are the forward electromagnetic (EM) and hadron calorimeters. The forward muon system, consisting of drift chambers and magnetized iron toroids, covers this region and extends out to 20°.

10° to 30°

The end plugs of the magnet carry the EM and hadron calorimeters that service this region. Tracking is accomplished jointly by means of the VTPC and the central tracking chamber (CTC).

30° to 90°

Starting on axis, we first come to the VTPC which gives good track information in the RZ plane. Next, the CTC, in conjunction with the 1.5 T magnetic field, allows for precision measurement of individual tracks. There are five superlayers of cells with axial wires, and four superlayers whose wires are skew with respect to the axis and are used to give stereo information. At the outside of the CTC and just inside the coil, an axial set of tubes in the avalanche mode gives z determination on tracks by means of current division to a precision of ±3 mm. This helps in track reconstruction. After passing through the coil ~ 1 X_0 and .5 λ_0, one finds the central EM and hadron calorimetry. A strip chamber is located at approximately EM shower maximum to aid in identifying EM showers and measuring their positions to ~ 3 mm. Finally, on the outside of the hadron calorimeter is located a set of tubes in the avalanche mode which are instrumented with a time-digital converter (TDC) and current division to provide z and ϕ information on muons which succeed in penetrating the calorimeter.

Table Ia and Ib show the characteristics of the various calorimeter elements of the detector. In general, the size of the projective calorimeter towers is such that a QCD jet will span several, allowing an accurate determination of the energy flow vector. In addition, the EM strip chambers have elements that are comparable in size to an EM shower in order to help with the identification of electrons and photons.

The characteristics of the tracking elements of the detector are given in Table IIa, IIb, IIc, and IId. The system is comprised of two drift chamber systems: the CTC and the forward tracking chamber (FTC). These provide track information from 2° to 178°. The vertex time-digital converter (VTDC) provides complementary information to these chambers near the origin. It will also allow multiple interactions to be rapidly identified.

The Si detectors in the beam pipe will cover very small angles, providing a means to identify diffractive events.

The characteristics of the Tevatron are such that with a β^* = 1 m the beam σ is about 60 μ. With such a small interaction transverse cross section, it is anticipated that a very high-resolution vertex detector will be extremely useful for identifying long-lived particles. For this reason a silicon-strip detector that fits inside the VTPC is being developed by the Pisa group. The technology is challenging: the detector must fit in a very confined space and operate at high rates in a location where there is always the possibility of severe radiation damage by accidental beam loss.

The solenoid field of 1.5 T is produced by a NbTi superconductor stabilized by a sheath of extruded, very pure aluminum. The conductor is cooled and supported by means of an external cylinder of aluminum with tubing, which carries liquid He, welded to its surface. This configuration was achieved by first winding the coil on an internal mandrel. This structure was then insulated with glass epoxy, cured, and then ground to a precision round cylinder. The outer support cylinder was heated in order to achieve radial expansion of 3 mm, and then slipped over the coil assembly, after which the inner mandrel was removed.

At present, the detector is being rapidly assembled. The central detector calorimetry is nearly complete and is being calibrated in test beams. The magnet yoke is complete, and the field is being mapped. The tracking chambers are being manufactured, and the VTPC will be ready for preliminary beam tests in the summer of 1985. The spring of 1986 will see all components ready for test with the beam in preparation for the first physics run in the fall of that year.

Table Ia
EM CALORIMETERS

	Forward	End Plug	Central
Angular range	2° to 10°	10° to 37°	37° to 90°
Size of towers in η	(18) $\Delta\eta \sim 0.1$	(15) $.05 < \Delta\eta < 0.1$	(10) $.087 < \Delta\eta < .133$
Angular size in ϕ	$\Delta\eta = 5°$	$\Delta\phi = 5°$	$\Delta\phi = 15°$
Material	Pb-gas tubes	Pb-gas tubes	Pb-scintillator
Number of layers	6 24	5 20 13	20
R.l. each layer	$.85\ X_0$ $.85\ X_0$	$.56\ X_0$ $.56\ X_0$ $.56\ X_0$	$.95\ X_0$
Layers in section	$5\ X_0$ 20 $5\ X_0$	$2.8\ X_0$ $11.26\ X_0$ $7.32\ X_0$	$19\ X_0$
Total X_0	$25.5\ X_0$	$22.4\ X_0$	$19\ X_0$
$\delta E/E$	$\sim 30\%/\sqrt{E}$	$\sim 24\%/\sqrt{E}$	$14\%/\sqrt{E}$
Position resolution	1-5 mm	1-2 mm	1.5-3 mm

Table Ib
HADRON CALORIMETERS

	Forward	End Plug	End Wall	Central
Angular range	2° to 10°	10° to 30°	30° to 45°	~ 45° to 90°
Construction	2 in. Fe + gas tubes	2 in. Fe + gas tubes	2 in. Fe + scint	1 in. Fe + scint
Tower size in η	$\Delta\eta = 0.1$	$\Delta\eta = .09$	$.079 < \Delta\eta < .117$	$.1 < \Delta\eta < .15$
Tower size in ϕ	$\Delta\phi = 5°$	$\Delta\phi = 5°$	$\Delta\phi = 15°$	15°
$\delta E/E$		~ 14% at 50 GeV	~ 14% at 50 GeV	$70\%/\sqrt{E}$

Tracking Chamber Characteristics

The following tables list some of the properties of these chambers.

IIa. VTPC

Drift distance (axial): 150 mm
Sense wires/octant: 16 (22) for R = 3-1/2 (2)
Pads/octant: 24 in three rows of 5; 8; 11 pads
Sense wire spacing: 5.5 mm
Sense wire/pad separation: 10 mm
Pad size: 12 × 45 mm
Gas: Argon/methane - 80%:20%
Drift field: 200 V/cm
Total number of sense wires: 2176
Total number of pads: 2448
Average radiation length: 1.5%
Resolution in Z: 200-350 μ
Resolution in Rϕ: 250 μ (isolated tracks)

IIb. CTC

Number of superlayers: 9
Stereo angle: 0°; 3°; 0°; -3°; 0°; +3°; 0°; -3°; 0°
Sense wires/layer: 12; 6; 12; 6; 12; 6; 12; 6; 12
Number supercells/superlayers: 30; 42; 48; 60; 72; 84; 96; 108; 120
Maximum drift distance: 35 mm
Sense wire spacing: 10 mm in plane of wires
Electric field at center of drift space: 1000 V/cm
Radius innermost sense wires: 309 mm
Radius outermost sense wires: 1320 mm
Length of wires: 3214 mm
Total number of sense wires: 6156
Total number of wires: ~ 36000
Axial load on endplates: 17 tons
Gas - Argon:Ethane:Alcohol: 49.65%:49.65%:0.7%
Resolution: < 200 μ/wire
Double track resolution: $\leq$ 5 mm or 100 nsec
Z resolution: ~ 4 mm
Momentum resolution: $\Delta p_t/p_t < .002\ p_t$ in GeV at 90°

IIc. FTC

Angular coverage: 2°-10°
Inner radius: 12.5 cm
Outer radius: 72.5 cm
Cell: 5° in ϕ or 7272 sectors
Sense wires/sector: 20
ϕ accuracy: σ_{rms} = 130 μ
Total TDC: 3020
Total ADC: 1728

IId. Si Strip Vertex Detector

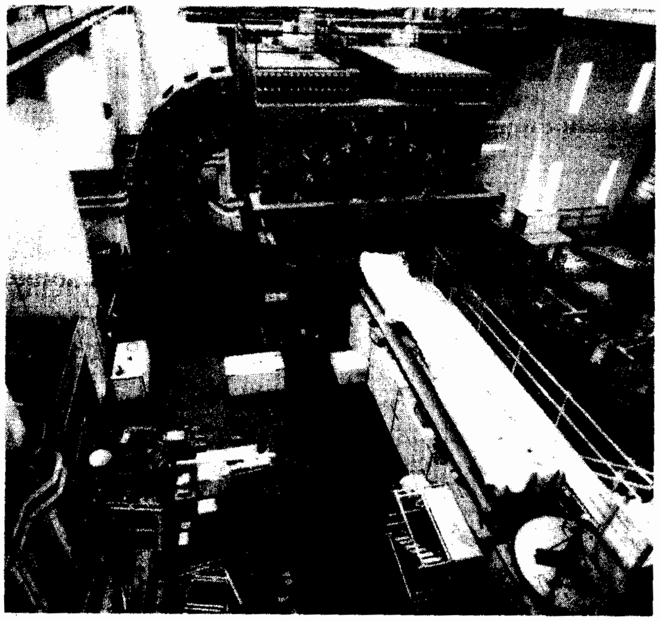
Length: 67 cm, 4 sections
Layers: 4
Thickness:
1 200 μ
2 250 μ
3 250 μ
4 250 μ

Electrode spacing:
1 200 μm
2 250 μm
3 250 μm
4 250 μm

Spatial resolution in $R\phi \sim 20$ μm on all layers

Number of ϕ electrodes:
1 936
2 1248
3 1740
4 2232

Total ϕ electrodes: 6156



Detector view showing the magnet with the end-wall hadron calorimeter in place, and one arch of the central calorimeter withdrawn to the side. Parts of the apparatus for measuring the magnetic field are visible in the foreground. *(Fermilab photograph 85-202-9)*

CDF COLLABORATION†

R. Diebold, E. May, L. Nodulman, J. Proudfoot, J. Schlereth,
P. Schoessow, N. Solomey, D. Underwood, R. Wagner,
and A. Wicklund
Argonne National Laboratory

J. Bensinger, L. DeMortier, L. Kirsch, W. Lewis, R. Poster,
L. Spencer, and S. Tarem
Brandeis University

D. Amidei, M. Campbell, H. Frisch, C. Grosso-Pilcher, T. Liss,
G. Redlinger, M. Shochet, R. Snider, S. Somalwar, and Y. Tsay
University of Chicago

M. Atac, E. Barsotti, P. Berge, M. Binkley, A. Brenner,
T. Carroll, C. Day, T. Droege, J. Elias, B. Foster, J. Freeman,
I. Gaines, D. Hanssen, H. Jensen, D. Johnson, R. Kadel,
H. Kautzky, R. Kephart, C. Newman-Holmes, J. Patrick,
R. Perchonok, D. Quarrie, D. Theriot, A. Tollestrup, K. Turner,
C. van Ingen, R. Vidal, R. Wagner, G.P. Yeh, and J. Yoh
Fermi National Accelerator Laboratory

S. Bartalucci, S. Bertolucci, M. Cordelli, M. Curatolo,
P. Esposito, P. Giromini, M. Pallotta, and A. Sansoni
INFN--Frascati, Italy

M. Kawaguchi
Fukui University, Japan

C. Blocker, G. Brandenburg, D. Brown, R. Carey, M. Eaton,
E. Kearns, R. Schwitters, and R. St. Denis
Harvard University

G. Ascoli, S. Cihangir, R. Downing, S. Errede, L. Holloway,
I. Karlinger, H. Keutelian, U. Kruse, R. Sard, D. Smith,
and T. Westhusing
University of Illinois

Y. Fukui, S. Mikamo, and M. Mishina
KEK, Japan

W. Carithers, W. Chinowsky, R. Ely, M. Franklin, J. Siegrist,
and E. Wood
Lawrence Berkeley Laboratory

D. Bauer, D. Connor, J. Cooper, S. Hahn, N. Lockyer, M. Miller,
M. Newcomer, T. Rohlay, R. VanBerg, and H. Williams
University of Pennsylvania

F. Bedeschi, G. Bellettini, L. Bosisio, F. Cervlli,
R. Del Fabbro, M. Dell'Orso, A. Di Virgilio, E. Focardi,
S. Galeotti, P. Giannetti, M. Giorgi, A. Menzione,
D. Passuello, L. Ristori, A. Scribano, A. Stefanini,
and G. Toneli
INFN--University of Pisa, Italy

V. Barnes, K. Chadwick, R. Christian, A. Garfinkel, S. Kuhlmann,
A. Laasanen, and J. Simmons
Purdue University

S. Belforte, T. Chapin, K. Goulianos, S. White, and C. Young
Rockefeller University

A. Beretvas, A. Caracappa, T. Devlin, K. Krueger, L. Scott,
T. Watts, and T. Yang
Rutgers University

A. Murakami
Saga University of Japan

A. Giordana, P. McIntyre, T. Meyer, M. Shepko, and R. Webb
Texas A&M University

Y. Muraki
ICRR, Tokyo University, Japan

Y. Asano, Y. Hayashide, M. Ito, T. Kamon, Y. Kikuchi, S. Kim,
K. Kondo, S. Miyashita, H. Miyata, S. Mori, Y. Morita,
H. Sekiguchi, M. Shibata, Y. Takaiwa, K. Takikawa, A. Yamashita,
and K. Yasuoka
Tsukuba University, Japan

D. Cline, R. Handler, R. Loveless, L. Pondrom, D. Reeder,
J. Rhoades, and M. Sheaff
University of Wisconsin

The E-605 collaboration trying on their spectrometer analyzing magnet.
(Fermilab photograph 82-42-27)

LEPTONS AND HADRONS AT HIGH TRANSVERSE MOMENTUM--EXPERIMENT 605

Charles N. Brown

J. Crittenden, Y. Hsuing, Columbia University; W. Cooper, D. Finley, A. Jonckheere, H. Jostlein, D. Kaplan, L. Lederman, G. Moreno, R. Orava, S. Smith, K. Sugano, K. Ueno, Fermilab; M. Adams, H. Glass, D. Jaffe, R. McCarthy, SUNY-Stony Brook; R. Gray, K. B. Luk, R. Plaag, J. Rutherfoord, B. Straub, K. Young, University of Washington; Y. Hemmi, K. Miyake, J. R. Hubbard, Ph. Mangeot, Saclay; G. Charpak, F. Sauli, CERN

Introduction

In 1979, E-605 was proposed and approved to extend to Tevatron energies the measurements of the previous Proton Area Experiments 288 and 494. Now, in 1985, E-605 is the first large new facility designed and built specifically for Tevatron energies to reach the end of its approved program. In the last few years this experiment has impinged directly or indirectly on most departments at Fermilab. The successful completion of our approved program despite the conflicting demands of the Tevatron construction programs is a testimony to the cooperation and diligence of the Fermilab staff. Although there is not room in this article to personally thank all those who have helped, their efforts are appreciated.

Physics

In 1977, E-288 reported the existence of an unexpected family of narrow resonances, the Upsilon family, in the dimuon mass spectrum from 400 GeV proton-nucleus collisions. Before the experiment was dismantled in 1979, it had mapped out the production of massive dimuons by the Drell-Yan mechanism and had observed the three narrow upsilon states. Experiment 494 had converted the E-288 spectrometer for dihadron measurements by adding threshold Cherenkov counters. Both experiments were limited in their ultimate luminosity by the copious flux of muons emanating from the beamstop between the spectrometer arms. Experiment 288 was further limited by the 2 % resolution of the spectrometers. The 500-MeV splittings of the three upsilon states, combined with a poor resolution, tend to obscure the whole region from 8.5 GeV to 11 GeV. Nevertheless, both experiments opened new vistas in quark-quark scattering, quark-quark annihilation, and lepton production at high transverse momenta.

There remained many questions that could be better addressed at Tevatron energies. Did the anomalous atomic-number dependance of hadron yields at high p_T persist to higher energies? Did the energy dependance of quark scattering and lepton production follow QCD predictions? Were there more narrow states in the high-mass region hidden beneath the dominant S-state upsilon resonances? The E-605 spectrometer and the new M-East (ME) external proton beam (ME) were optimized to answer these questions.

Apparatus

A high intensity, clean, carefully focussed external proton beam was the first requirement of the proposed experiment. The new ME beam uses a dozen 3Q120 quadrupoles and sixteen Energy Saver dipoles to transport beams of up to 1 TeV to the E-605 spectrometer in the Meson Detector Building. The quads form a FODO channel with a final-focus section yielding a 0.01-in. high by 0.1-in. wide spot at the spectrometer target. The beam has proven very reliable and stable, and has a halo of less than 10^{-6} outside a 3-in. beam pipe. It has transported 4×10^{12} protons/pulse at 800 GeV. The beam is somewhat unique in the experimental areas as it has no windows and a sub-micron vacuum for its entire length.

The backbone of the E-605 spectrometer is two large analyzing magnets. These magnets were assembled from iron salvaged from the Nevis Cyclotron at Columbia University. The first magnet, 50 ft long with a horizontal gap of 36 in. and a vertical pole width of 48 in., has 65-ft long aluminum coils which were fabricated at Fermilab (TM-1034 Fermilab). The second, a re-analyzing spectrometer magnet, has a horizontal gap of 59 in., a vertical pole width of 66 in., and a length of 13 ft. The coils for this magnet were assembled from the same aluminum conductor by Sumitomo Corporation of Japan under the aegis of the Japan/US Collaboration.

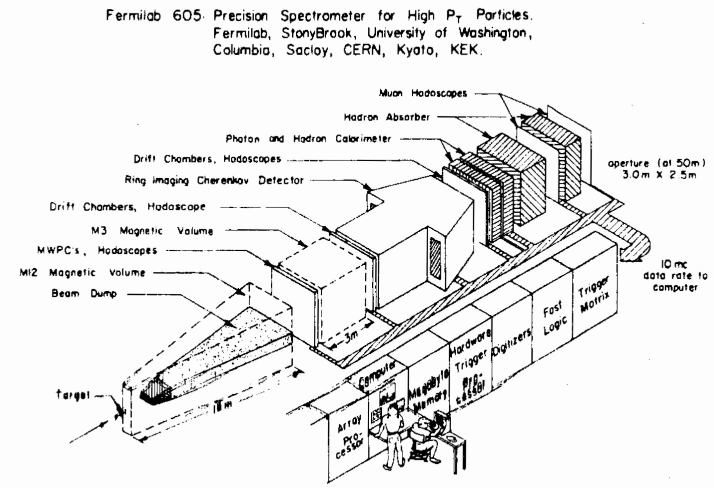
The beamline and the water-cooled copper beam dump in the first spectrometer magnet are designed to accept the full intensity of the slow-extracted proton beam from the Tevatron.

The spectrometer shown schematically at right is instrumented to detect and identify all charged hadrons and leptons. The small-cell drift chambers (16 planes, 2500 wires) and the MWPC system (6 planes, 5000 wires) were built by the Fermilab Physics Department. The proportional-tube muon detectors were built at the University of Washington. The electronics for the chambers were built by Columbia University and the Japan/US Collaboration.

The scintillator hodoscopes and the fast-matrix electronics comprising the first-level trigger were built by Stony Brook and Washington. The second-level trigger system involved a large electron-hadron calorimeter built by Kyoto, and a sophisticated trigger processor built by Columbia (IEEE, N531, 5 (1984), 1028.)

and the Japan/US Collaboration. This processor searched for tracks in the chambers which pointed to the target and not the beam dump.

Particle identification is completed by the ring-imaging Cherenkov counter. The counter employs a radiator of ultra-pure helium gas and two multi-step photon detectors sensitive to far ultra-violet Cherenkov protons which photoionize triethylamine (TEA). This detector was developed by CERN, Saclay, and Stony Brook (FN-375 Fermilab). It has a 90-GeV threshold for protons and can separate pions and kaons up to 300 GeV over an input angular acceptance of ±100 mrad.



Schematic view of the E-605 spectrometer.

The 10 MHz data acquisition "Transport Bus" developed at Columbia University deposits data during the spill into a 4-Megabyte dual-port memory developed at the University of Washington. Data logging to tape, equipment monitoring, experiment control, and the link to a VAX 780 are handled by the University of Washington PDP 11/45 Data Acquisition System. The full system can handle 4 Megabytes of data in a 20 second spill with negligible deadtime.

Data Taking

The spectrometer was assembled in the new ME area of the Meson Detector Building during the first four months of 1982. The old, conventional M1 beam was upgraded for 400 GeV high-intensity operation and commissioned during a spring 1982 shutdown. During April and May the beamline and spectrometer were debugged.

Initially, the background rates through the open aperature into the detectors were much higher than design estimates. Nevertheless, after careful work on collimation of secondary sources within the large analyzing magnet, two weekends of data were recorded at an intensity of 2×10^9 protons/sec. The atomic-number dependence of hadron yields was studied and the analysis of these results will be published shortly. The 1982 test run was successful and uncovered the design modifications necessary for high-intensity Tevatron operation.

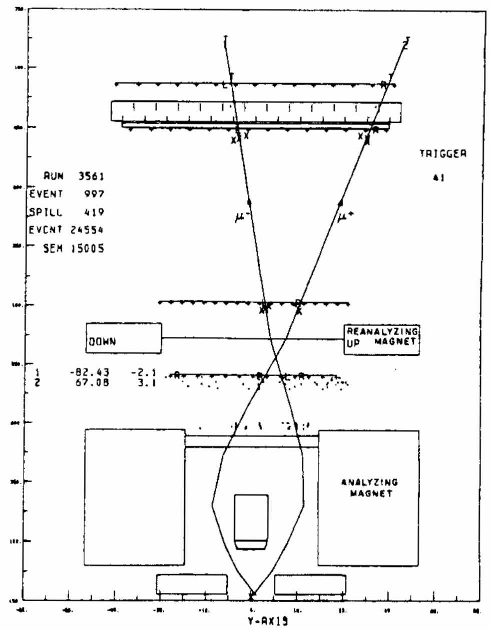
During the 1983 Tevatron installation shutdown, many design modifications were made to the E-605 spectrometer. In addition, the new ME beamline was assembled. Extensive work was done changing the configuration of the production target and tungsten absorber teeth in the large analyzing magnet. These changes included moving the target upstream and adding a small (BM105) pre-analyzing magnet in anticipation of 800 GeV operation.

In January and February of 1984, data taking on the production dynamics of hadron and dihadron yields at 400 GeV was completed using the newly commissioned Tevatron accelerator. In the spring of 1984 these measurements were extended to 800 GeV. In addition, a liquid hydrogen/deuterium target was installed along with the beryllium, copper, and tungsten targets allowing a full investigation of A-dependance effects. Even at 800 GeV, the many collimation improvements allowed operation at an intensity of 10^{10} protons/second in the open aperature configuration.

Preliminary results from this huge collection of open aperature data should be available this summer. Meanwhile, tests in June 1984, and modifications during the subsequent months, have led to a new maximum luminosity, closed aperature configuration.

During the present FY85 accelerator operations, the spectrometer has been optimized for the detection of dimuons. A 4-ft thick wall of lead has been added at the exit of the first spectrometer magnet, followed closely by a precision, high-rate proportional-tube detector. This allows a separation of the momentum determination in the second spectrometer magnet from the plane of multiple scattering in the Pb wall. Both a resolution of 20 MeV in mass at 10 GeV and a large increase in luminosity can be obtained.

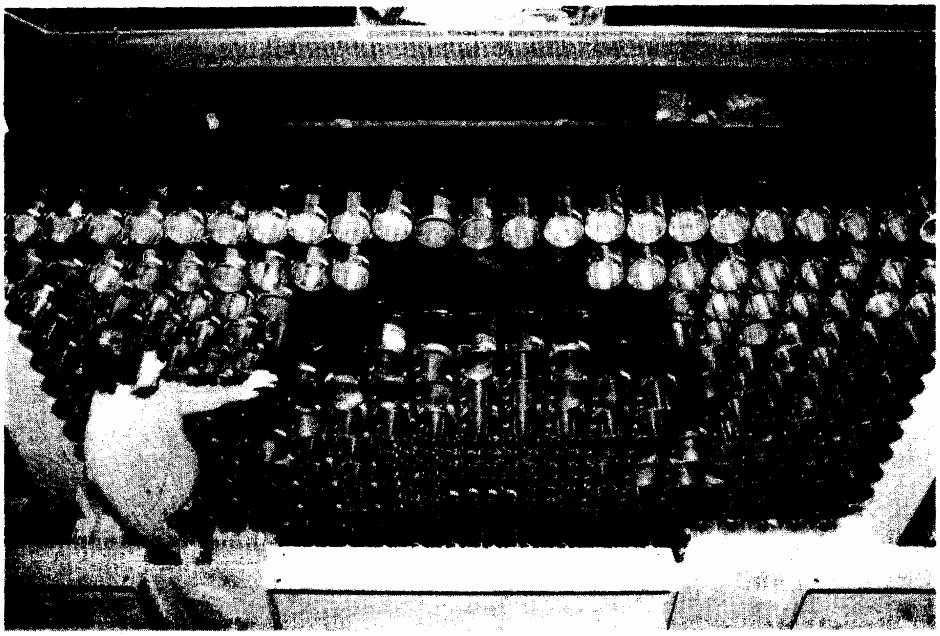
As this article is being written, the apparatus is recording dimuons produced by 800 GeV protons at intensities up to 2×10^{11} protons/sec. The events are surprisingly clean and easy to analyze, as shown at right. Any narrow states between 8 GeV and 20 GeV will be observed if their production cross section times branching fraction into dimuons is greater than 1% of the upsilon 1S resonance. Data on the systematics of dimuon production at 800 GeV via quark-antiquark annihilation (the Drell-Yan mechanism) are a byproduct of the measurement.



On-line computer display of a dimuon event from 1985 run.

Future

The original E-605 proposal included discussions of repeating all the above measurements with an incident pion beam. The design of a high-intensity pion beam in ME does exist. The E-605 collaboration plans on completing most of the analysis of the present data set before proposing further data taking. What is already clear is the beautiful performance of the ME beam and the E-605 spectrometer. The apparatus has been able to detect and identify hadrons and leptons almost up to the transverse momentum kinematic limit as originally proposed. The analyzed data set will surely suggest many future measurements.



Chuck Serritella (Physics Department) admires the just-completed stack of 576 glass blocks that make up the electromagnetic calorimeter for E-705. The shorter blocks on the outside of the array are made of lead glass; the longer blocks on the inside are made of a new scintillating glass which has superior resolution. The array, which weighs 30 tons, sits on a movable table that can position each of the individual blocks onto the beam line. (Fermilab photograph 85-161-18)

US/CERN JOINT SCHOOL ON PARTICLE ACCELERATORS

Marilyn Paul

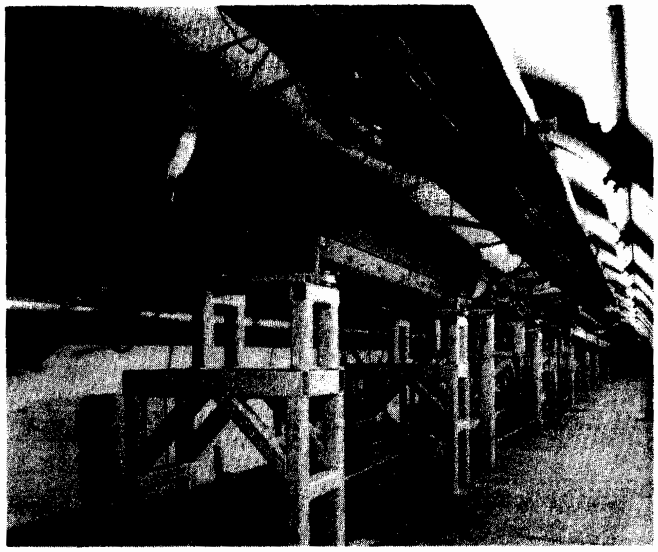
The first US/CERN Joint School on Particle Accelerators was held in Santa Marherita di Pula in southern Sardinia from January 31 through February 5, 1985. The Organizing Committee welcomed nearly 100 students and 21 lecturers; 9 lecturers representing the US, 7 from CERN, and 5 from other European institutions.

The course was constructed to teach the mathematical tools used in the study of nonlinear dynamics, to describe the application of these tools to accelerators, and to assess the role to be played by computers and state-of-the-art nonlinear theory in solving accelerator problems. Emillo Picasso of CERN said he hoped the understanding of non-linear phenomena would one day allow the exploitation of solitons for accelerators, an exciting prospect that surely needs more work.

The success of this first School owes a lot to the generous help of the Italian Physical Society, and the warm hospitality shown by the Government of the Region of Sardinia and the local tourist authorities. The participants were honored by addresses from the Mayor of the local town of Pula, Mr. G. Piredda, and from the President of the Council for the region of Sardinia, the Honorable Mr. M. Mellis, as well as by a special Sardinian dinner and entertainment sponsored by President Mellis.

Mel Month, Chairman of the US School on High-Energy Particle Accelerators, stated in his closing remarks that one of the most difficult aspects of this School was the necessity to overcome what has been called the "transatlantic barrier"; finding support for a significant number of young accelerator physicists to cross the Atlantic is very, very difficult. Nevertheless, it is hoped that this is the start of a long and fruitful series of joint schools to be held annually on alternate sides of the Atlantic.

The proceedings of the school will be published in a few months' time in the Springer-Verlay series "Lecture Notes in Physics."



A view of the new, long straight-section (DO), showing the overpass which raises the Main Ring to a separation of some 80 in. from the Tevatron in preparation for the installation of the DO Colliding Beams Detector.
(Fermilab photograph 84-1243-9)

NOTES AND ANNOUNCEMENTS

Safety of Experimental Equipment. . .

Leon Lederman would like to remind users that certain kinds of experimental equipment are subject to Laboratory safety review and approval before being put into use at the Lab.

In order to better understand the safety implications of each experiment, a checklist provided by the Research Division Safety Group must be completed prior to the approval of the agreement by the Head of the Research Division.

If users anticipate using equipment which incorporates cryogenic devices, pressure vessels, hazardous chemicals, large amounts of inert gas, or radioactive substances, the design and application should be discussed with the Lab at the earliest possible stage. Experience has shown that for large or complicated systems, the safety review and approval can involve a lot of time and effort. Discussions early in the planning and fabrication phase can reduce this burden, particularly with regard to cryogenic systems and pressure vessels. The Laboratory will continue to insist that there is evaluation of personnel safety before allowing experimental equipment to be operated.

Drift Chambers Available. . .

Approximately 100 drift chambers from E-326 are available. Each chamber is a section of an octagon with a 47-in. outer radius and an inner radius which varies from 5 in. to 17 in. These chambers were built for a magnetized iron spectrometer. If you have use for these chambers, call Mel Shochet at the University of Chicago, (312) 962-7440 before May 1.

MANUSCRIPTS, NOTES, LECTURES, AND COLLOQUIA PREPARED OR PRESENTED FROM MARCH 18, 1985 TO APRIL 21, 1985

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

Experimental Physics

V. Suchorebrow
Experiment #565
Experiment #570

Inclusive K^+K^- Production in Reactions π^+p, K^+p, and pp at 200 GeV/c (Ph. D. Thesis, Massachusetts Institute of Technology, February 1985)

S. Palestini
Experiment #615

Forward Production of High Mass Muon Pairs in Pion-Nucleon Interactions (Ph.D. Thesis, Princeton University, December 1984)

D. L. Carlsmith
Experiment #617

A Measurement of the $K^0(890)$ Radiative Width (Ph.D. Thesis, the University of Chicago, December 1984)

H. W. M. Norton
Experiment #617

A Determination of the Branching Ratio of K_L to Gamma Gamma (Ph.D. Thesis, the University of Chicago, December 1984)

Theoretical Physics

A. Sen

Baryon Number Violation Induced by the Monopoles of the Pati-Salam Model (FERMILAB-Pub-84/130-T; submitted to Phys. Lett. B.)

T. Sjöstrand

A Model for Initial State Parton Showers (FERMILAB-Pub-85/23-T; submitted to Phys. Lett. B.)

C. T. Hill

Can the Hawking Effect Thaw a Broken Symmetry? (FERMILAB-Pub-85/28-T; submitted to Phys. Lett. B.)

Astrophysics

A. S. Szalay and
D. N. Schramm

Are Galaxies More Strongly Correlated Than Clusters? (FERMILAB-Pub-85/24-A; submitted to Nature)

D. J. Hegyi and K. A. Olive	A Case Against Baryons in Galactic Halos (FERMILAB-Pub-85/26-A; submitted to Astrophysical Journal)

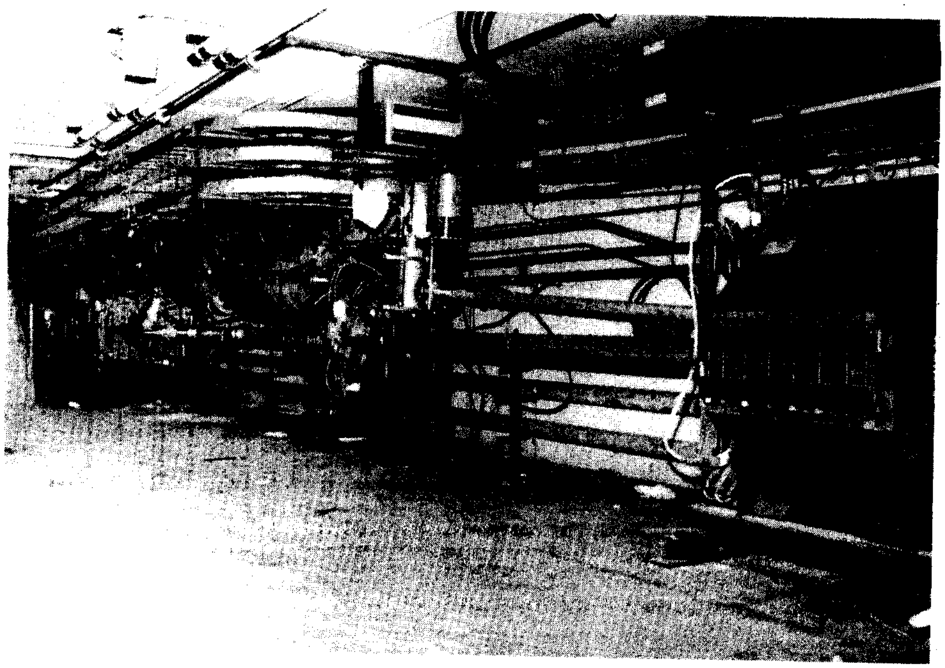
General

J. D. Bjorken	Heavy Quarks and CP: Moriond '85 (FERMILAB-Conf-85/45; presented at the Fifth Moriond Workshop on Heavy Quarks, Flavor Mixing, and CP Violation, La Plagne, France, January 13-19, 1985)

Colloquia, Lectures, and Seminars

R. Orr	"Accelerator Division Information Meeting" (Fermilab, March 19, 1985)
D. Johnson	"Commissioning the AP-2 Line with 8 GeV Protons" (Fermilab, March 21, 1985)
V. Bharadwaj and S. Holmes	"Commissioning the Debuncher" (Fermilab, March 21, 1985)
R. Yarema	"Surface Mount Technology-Are You Ready For It?" (Fermilab, March 27, 1985)
R. Johnson	"Tests of Orbital Dynamics Using the Tevatron" (Fermilab, April 2, 1985)
D. Young	"Comments on the Recent DOE Review" (Fermilab, April 4, 1985)
J. Peoples	"Installation Plan for April" (Fermilab, April 4, 1985)
D. Johnson and G. Dugan	"Status of AP-2 Commissioning" (Fermilab, April 4, 1985)
S. Parke	"Perturbative QCD Using Extended Supersymmetry" (Fermilab, April 9, 1985)
M. Johnson	"Super Damper Tune Measuring System" (Fermilab, April 9, 1985)
J. Peoples	"Plans for Commissioning and Maintaining the Antiproton Source" (Fermilab, April 11, 1985)

C. Hojvat and J. Krider	"First Operation of the Target Station" (Fermilab, April 11, 1985)
D. Anderson	"What's Happening in Europe in Detectors" D. Anderson's version (Fermilab, April 11, 1985)
G. Mulholland and B. Wands	"Cryogenic Pressure Vessels and Vacuum Vessels" (Fermilab, April 16, 1985)
R. Orr	"Accelerator Division Information Meeting" (Fermilab, April 16, 1985)
D. Johnson	"First Operation of the AP-2 Beam Line" (Fermilab, April 18, 1985)
S. Holmes	"Early Test of the Debuncher" (Fermilab, April 18, 1985)
J. Griffin	"Review of Recent Accelerator Status in the Main Ring" (Fermilab, April 18, 1985)
S. Majewski	"New Ideas in Transition Radiation Detection" (Fermilab, April 18, 1985)



The AP-2 line as it enters the Antiproton Source Debuncher.
(Fermilab photograph 85-267-7)

DATES TO REMEMBER

May 1-4, 1985	International Symposium on Particle Physics in the 1950s: Pions to Quarks, Fermi National Accelerator Laboratory. For more information, write L. Hoddeson, Fermilab, P. O. Box 500, Batavia, Illinois 60510
May 6-7, 1985	Workshop on the History of Particle Theory in Japan (1935-1960). Fermi National Accelerator Laboratory. For more information, write L. Brown, Northwestern University, Evanston, Illinois 60201.
May 6-7, 1985	Heavy Quark Workshop. For information, contact Phyllis Hale, Users Office, MS #103, Fermilab, P. O. Box 500, Batavia, Illinois 60510; (312) 840-3111
May 10-11, 1985	Annual Users Meeting
May 21-22, 1985	Fifth Annual Industrial Affiliates Meeting
June 15-21, 1985	Extended Summer Meeting of the Physics Advisory Committee
July 15-26, 1985	1985 U.S. Summer School on High Energy Particle Accelerators at SLAC