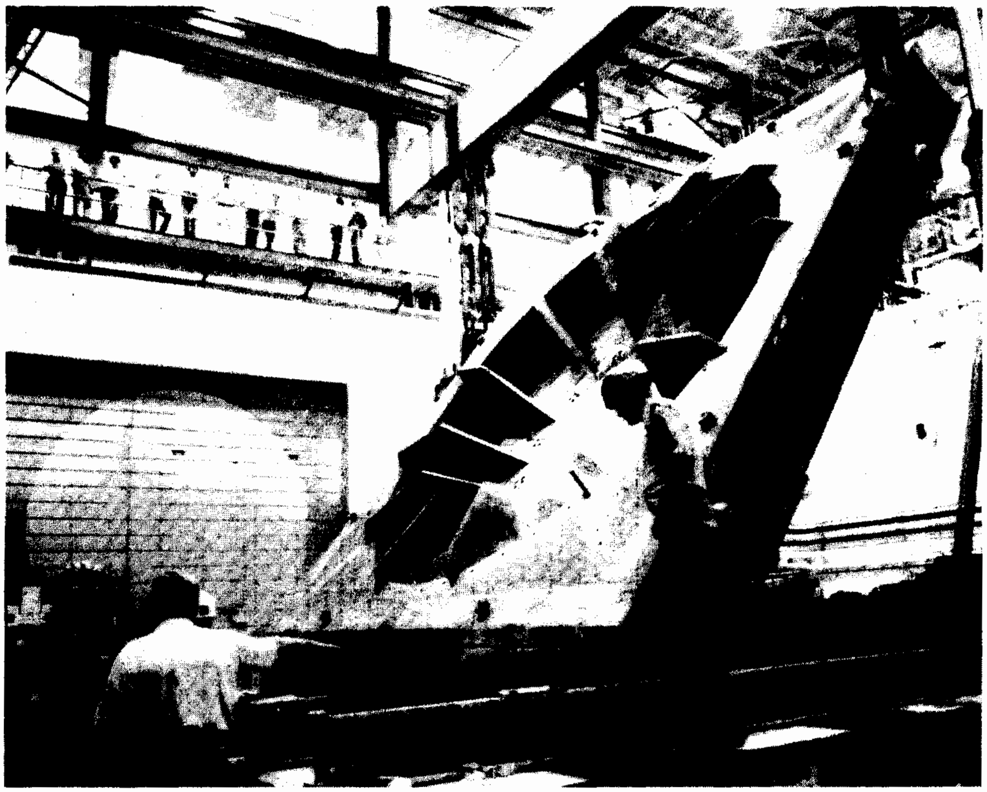
fermilab report

Fermi National Accelerator Laboratory Monthly Report

October 1984



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F. T. Cole, R. Donaldson, and L. Voyvodic, Editors

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Fermi National Accelerator Laboratory

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THE COVER: Collider Detector magnet end wall being raised into position in the pit of the assembly building.

(Photograph by Fermilab Photo Unit)

CONTENTS

COMMISSIONING OF THE BO LOW BETA INSERTION

Rolland Johnson

Introduction

One of the first steps towards using the Tevatron in its new role as a collider has been taken in the testing of the new low beta insertion at BO. Although it may be several months before proton-antiproton collisions take place in the BO collision hall, the new magnets and associated devices have been tested and are ready to play their part. Just as additional lenses can be used to improve the sensitivity of a microscope, the new magnetic lenses which make up the low beta insertion are expected to improve the power of the Tevatron as a collider by almost a factor of a hundred.

The arrangement of magnetic elements in the Tevatron, its **lattice**, was originally designed for slow resonant extraction. In order to fully exploit the machine as a proton-antiproton collider, the lattice must be modified by inserting a new subset of magnetic elements near the experimental collision area. An **insertion** of quadrupoles in this region can be used to change the size of the beam, proportional to the square root of the **beta function.** In the case of the CDF experiment at BO the quadrupoles must focus the beam tightly at the very center of the interaction region. The small beam size, or **low beta** function, increases the density of the particle beams and consequently the interaction rates.

The interaction rate R is the product of the machine luminosity L, and the interaction probability or cross section σ. The luminosity is a property of the machine, depending on the beam sizes and intensities, I_1 and I_2. The measurement of the cross section is usually the goal of the experiment.

$$R = L\ \sigma\ (s^{-1}),\text{ where the luminosity}$$

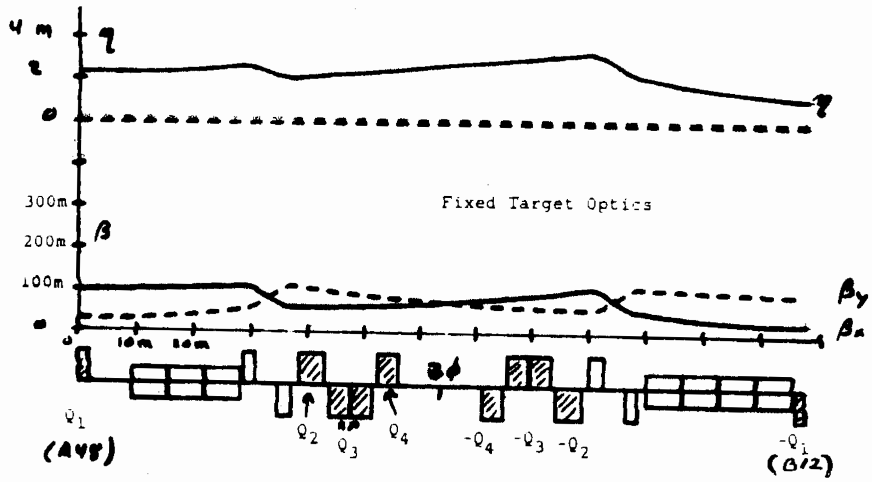
$$L = \frac{k\ I_1 I_2}{\varepsilon\ \beta}\ (cm^{-2}s^{-1});$$

k includes the longitudinal distribution of the beam or bunching factor, ε is the emittance, β is the beta function, and $\varepsilon\beta$ is the square of the beam size. Here ε and β are taken to be the rms averages of the horizontal and vertical values.[1] The highest possible luminosity is needed to see rare processes.

Details

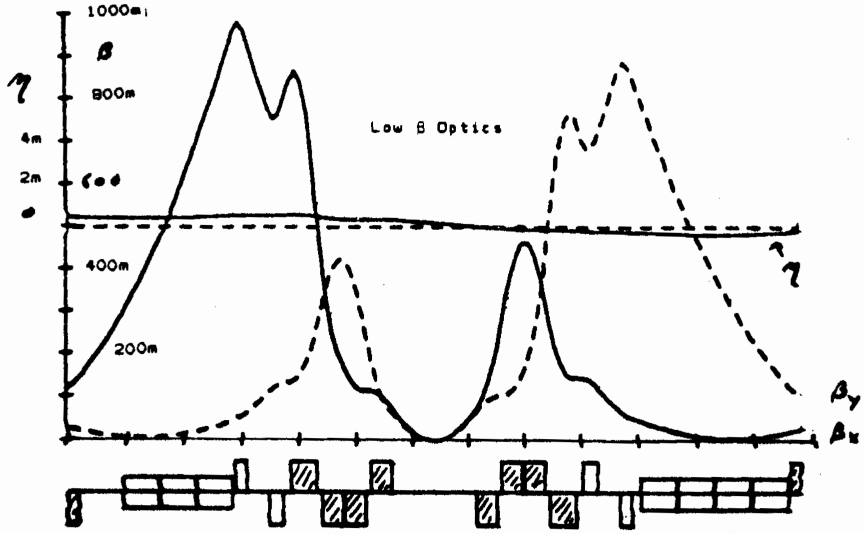
The original studies of low beta insertions in the Tevatron were made by Tom Collins and Dave Johnson.[2,3] Higher-current versions of the Tevatron quadrupoles, developed by Gene Fisk, determined the particular insertion which was installed this spring under the direction of Karl Koepke. This effort involved the collaboration of over 200 people from all parts of the Laboratory and a budget of about 8 million dollars. Besides the new superconducting quadrupoles and their associated power supplies, refrigeration, quench protection, and control circuitry, many other devices were needed. New beam position monitors, steering dipoles, a laser alignment system, and 6 flying wire scanner systems were also part of the effort.

The figure below shows the lattice of the Tevatron at B0 with the new quadrupoles indicated. Also shown are the horizontal and vertical beta functions and the momentum dispersion function. In the low beta configuration there are 4 new electrical circuits. All use quadrupoles which are similar to those of the Tevatron but with a superconducting cable capable of higher maximum currents (6 kA vs. 4.5 kA) and fields. The cable has 20 micron diameter NbTi filaments (compared to 8 microns) and Cu/NbTi of 1.3 (vs. 1.8) by volume.



Schematic of the low beta insertion at B0. The boxes above (below) the line represent horizontally focusing (defocusing) quads; the boxes which cross the centerline are normal Tevatron dipoles. The magnets which were added for the low beta insertion are shown shaded. Also shown are the lattice functions for the case of the fixed target configuration. The new quads at A48 and B12 replace the shorter quads of the normal Tevatron lattice. The new quads reduce the magnet-free region from 50 to 15 m.

The Q1 circuit has two 66 in. long quads which replace two of the 32 in. long quads in the regular Tevatron lattice. The Q1 circuit is the only one of the four which must be programmed during the operation of the Tevatron in the fixed-target mode. It is also unusual in that its polarity changes at one point in the transition to the low beta configuration.



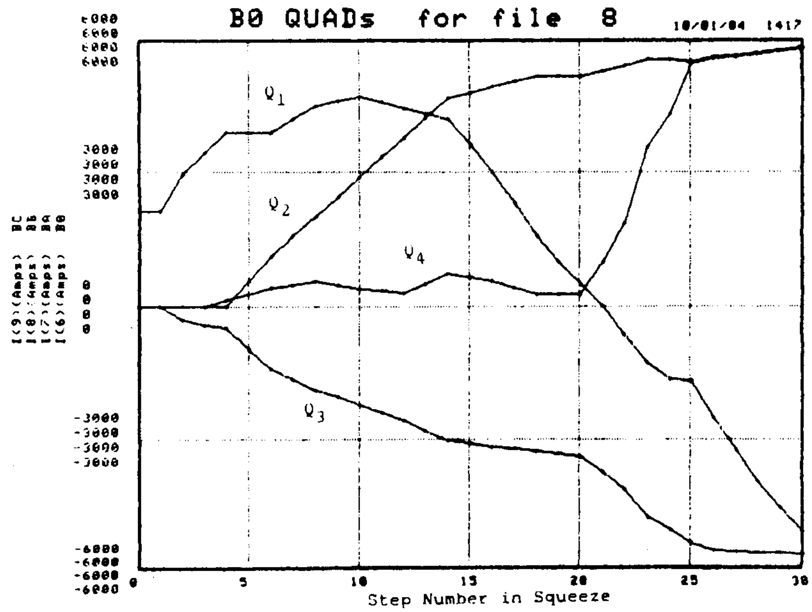
Schematic of the low beta insertion showing the lattice functions with all magnets energized. The beta values at the interaction point are approximately 0.85 m in each plane. The large beta values near the (unshaded) Collins' quads prohibit injection with the insertion energized; an adiabatic change from the fixed target or injection lattice to the low beta configuration while the beam is stored at high energy is necessary.

The Q2 circuit has two 180 in. quads, the Q3 circuit has four 144 in. quads, and the Q4 circuit uses two 144 in. quads. The number of circuits is of particular importance for a superconducting low beta insertion because each transition from the normal conductor to the cold region is an additional load on the refrigeration system. At the CERN SPS where this is not an additional constraint, a similar low beta insertion requires 15 independently controlled supplies.[4]

Refrigeration for the new magnets is provided by the satellite refrigerators at A4 and B1 which have each been upgraded to provide an additional 100 Watts of cooling at 4.2°K.

The installation of the superconducting quadrupoles and the additional beam position monitors and correction dipoles took place during the three week shutdown in February. Most of the commissioning studies took place during April and May.

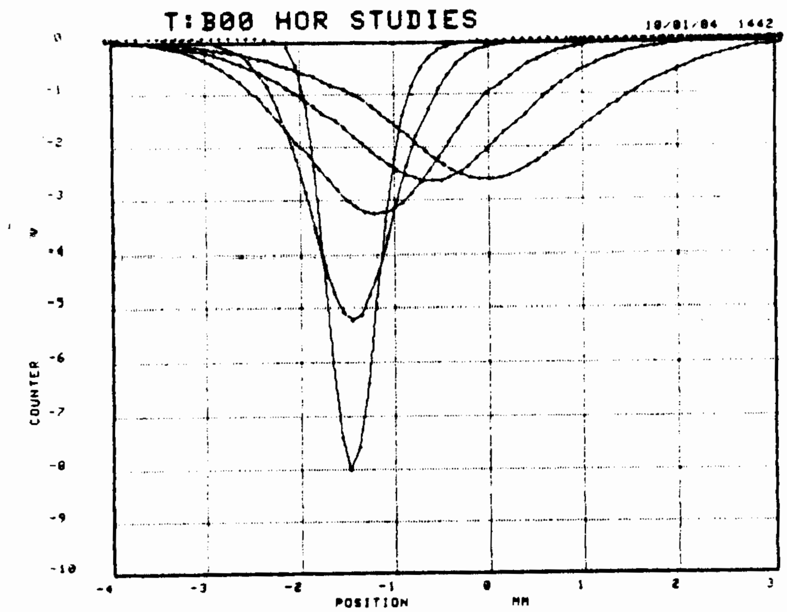
A design criterion for the insertion was to be able to start with stored beam at high energy (where the beam is smaller than at injection energy) with the Tevatron in its fixed-target lattice configuration and to continuously vary the lattice until the low beta is reached. This requirement manifests itself in 28 separate configurations or steps, each a lattice solution. Each step needs values for the new quad currents and the correction elements which are affected by the changes in the insertion. The figure below shows how the currents in the four new circuits change for these steps:



Current programs for the 4 new quad circuits in the adiabatic change from the fixed-target lattice to the low beta configuration at 1 TeV. There are approximately 30 steps in the process. Each step takes about 2 seconds and includes the simultaneous change of correction element power supplies which control the tunes, chromaticities, skew quad setting, and 20 dipole steering magnets. The total time for the "squeeze" is less than 2 minutes.

Dipole steering corrections are needed because the strong quadrupoles of the insertion magnify errors in the closed orbit. The extra focusing of the quads also causes changes in the betatron tunes which are compensated using the regular Tevatron correction quads. Including the skew quad and chromaticity-correcting sextupole circuits, some 29 function generators need to be changed together for each of the 28 steps between the initial and final configurations.

To test that the machine behaved as predicted a flying wire scanner was used to measure the evolution of the beam size at each step in the squeeze. The flying wire scanner is a thin (0.002 in.) beryllium wire which is moved quickly through the beam (5m/s) while a downstream scintillation counter records some of the particles scattered out of the beam. The figure below shows the horizontal profile of the beam measured this way at the very center of the B0 interaction region at successive steps in the squeeze. When amplifier resolution corrections are applied, the predicted and actual beam profiles agree quite well.



Flying wire scanner measurements of the horizontal beam profile at steps 16, 18, 20, 22, and 24 in the squeeze. As the power supplies go through the steps in the squeeze and the lattice is modified, the predicted beam size can be compared with the measured values. Because of a problem with amplifier saturation the detailed comparisons at the smallest beam sizes were made directly from oscilloscope traces. The shifts of the profile centers are due to the changes in the closed orbit caused by the steering of the new quads. The first 20 steps are used to effectively turn off the Q1 circuit so that its polarity can be reversed.

Preliminary Conclusions and Future Activities

Final conclusions on the success of the low beta insertion will have to wait until proton-antiproton collisions are producing new physics results at B0. So far, however, things look very promising. The hardware and software for the low beta insertion all seems to work as predicted. Some questions about the alignment accuracy and physical stability of the magnet supports have preliminary answers. Judging by the original closed orbit distortions and subsequent variations in the closed orbit during the two months of commissioning, the quads were all placed to better than 0.007 in. and have moved less than 0.002 in. This is particularly impressive considering how the magnets have to be supported over the B0 detector pit.

The next beam studies, besides verifying that all systems work well at the highest possible energy, will be devoted to studying coasting beam while the low beta is working. Computer studies imply that there should be no degradation of the beam lifetime, although there may be unknown effects which were not in the simulations and can only be seen using the Tevatron itself.

References

[1] See the March 1984 **Fermilab Report** article by C. Ankenbrandt for a more comprehensive review of these relations. Basically, lowering the beta value at the interaction region is the most effective way to increase the luminosity. This is true up to the point where the beta value is smaller than the longitudinal beam dimension or the large beam at a corresponding high beta region encounters regions of poorer field quality leading to a diminished beam lifetime.

[2] D. E. Johnson, "A Low-β Insertion Design for 1981," TM-1035, March, 1981.

[3] D. E. Johnson, "Tevatron B0 Low Beta Tuning Report," TM-1106, May 1982.

[4] P. E. Faugeras, A. Faugier, A. Hilaire and A. Warman, Proc. of XII Int. Conf. on High Energy Accelerators, Fermilab, 1983.

The TeV I project. Beyond the ring service buildings is the Target Station Service Building.
(Photograph by Fermilab Photo Unit)

SNOWMASS 84

John Peoples

Two hundred fifty-one scientists participated in the Summer Study on the Design and Utilization of the Superconducting Super Collider (SSC) held in Snowmass Village, Colorado, from June 23 to July 13. The participants effort was directed largely at three subjects: a study of the phenomenology that current theoretical models of elementary particles will exhibit in hadron collisions at 40 TeV in the center of mass, an evaluation of today's detector technology and its use in detectors for the SSC, and an examination of certain aspects of the SSC accelerator design, with particular emphasis on the requirements that experiments place on the design. Although the pp reaction at 40 TeV in the center of mass was given the greatest amount of attention, the use of the SSC for ep and $p\bar{p}$ collisions and fixed-target physics was also considered.

The participants collectively arrived at the conviction that a deeper understanding of elementary particles and their interactions requires an exploration of masses of 1 TeV and beyond. They concluded that the rich phenomenology associated with the mass scale predicted by some theoretical models of elementary particles can be tested with a 40-TeV center-of-mass proton-proton collider. Moreover, the detailed calculations done at Snowmass established that the general features of the 1-TeV mass scale can be explored initially with a luminosity of 10^{32} cm^{-2} sec^{-1}. In order to make a detailed exploration, experiments will have to be designed that can make use of power which a luminosity of 10^{33} cm^{-2} sec^{-1} can provide.

The consensus of the participants was that today's detector technology can be extrapolated to design large 4π detectors which can observe the products of pp collisions at 40 TeV in the center of mass. It was concluded that such a detector will operate at a luminosity of 10^{32} cm^{-2} sec^{-1}. Certain types of present-day detector technology can probably be used at 10^{33} cm^{-2} sec^{-1}, for example, calorimetry. Other examples of present-day detector technology cannot be extrapolated to operation at a luminosity of 10^{33} cm^{-2} sec^{-1}, for example, vertex detectors. In such cases new ideas are needed. The participants, noting that detector construction now takes as long as accelerator construction, recommended that a research and development program be initiated in the very near future in order to develop detectors that are well matched to the initial operation of the SSC and that can ultimately exploit the high luminosity capability of the SSC.

The aspects of accelerator design that were examined included dynamic aperture, injector performance, and interaction-region design. The participants concluded that a major computational effort based on tracking calculations should be initiated to determine the dynamic aperture of an SSC based on each of the three reference-design magnets. In addition, it was recommended that an accelerator-studies program be initiated on the Fermilab Tevatron in order to compare its performance with tracking calculations. Although the participants were unable to reach quantitative conclusions on the definition of the dynamic-aperture requirements, they did agree on its importance. They noted that computational and experimental studies must be completed before a final magnet design is chosen.

The participants re-examined projected performance of the Reference Design injector and proposed improvements that would provide the required brightness. It was concluded that current accelerator technology could achieve a luminosity of 10^{33} cm^{-2} sec^{-1}. In addition, the requirements for test beams to calibrate the experimental detectors were specified. Clustered interaction regions were found to be feasible with one qualification and several specific designs were developed. The qualification was linked to the dynamic aperture. In particular, some of the participants believed that the breaking of symmetry implied by clustered interaction regions would aggravate the effect of nonlinear elements and thus reduce the dynamic aperture.

The Study was characterized by many detailed investigations of problems anticipated at the SSC. Although much of the work was not fully completed, the intention of the participants was to see the analyses through to the end and to publish the results in the proceedings. The early indications of the Study are that the SSC will be beautifully matched to the physics goals and technical capabilities of our field.

SUMMARY OF THE VERTEX DETECTION WORKSHOP
September 21-22, 1984

David Christian
Fermilab

and

Jean Slaughter
Yale University

One of the ideas to come out of the Fermilab Fixed Target Workshop (June 9, 1984) was that there be a series of workshops on the role of Tevatron II experiments in heavy quark physics. The idea was re-iterated by the Physics Advisory Committee in its June 1984 meeting. Such a series would examine the physics opportunities, the experimental techniques and problems, and the strengths and weaknesses of fixed-target experiments as compared to e^+e^- experiments.

The first of these workshops, on vertex detectors, was held at Fermilab on September 21 and 22, 1984. The meeting was orginally conceived of as an intimate workshop, but generated such interest that it quickly blossomed into a short conference attended by approximately two hundred people.

Friday morning was devoted to silicon strip detectors and their associated readout electronics. Gerhard Lutz's (Max Planck Institute-Munich) overview of the state-of-the-art was followed by a description of an on-going program at Stanford of custom IC design and fabrication. In addition, Steve Shapiro (SLAC) presented a novel idea for a silicon pad detector. Five talks were then given on working experience with specific silicon strip detectors and strategies for their best use.

On Friday afternoon, the general heading could have been "optical detectors" and an extremely wide range of devices was presented. Both LEBC, which has produced a large fraction of the existing data on hadronically-produced charm using a small fiducial volume and conventional optics, and the much larger holographic bubble chambers to be used at the Tevatron were discussed. Progress was reported on the development of high resolution streamer chambers which would combine the pattern recognition advantages of optical detectors with the trigger-ability of the electronic detectors. The last talks of the afternoon described scintillating optical fibers, which might be used in an active target or in miniature "wire" chambers.

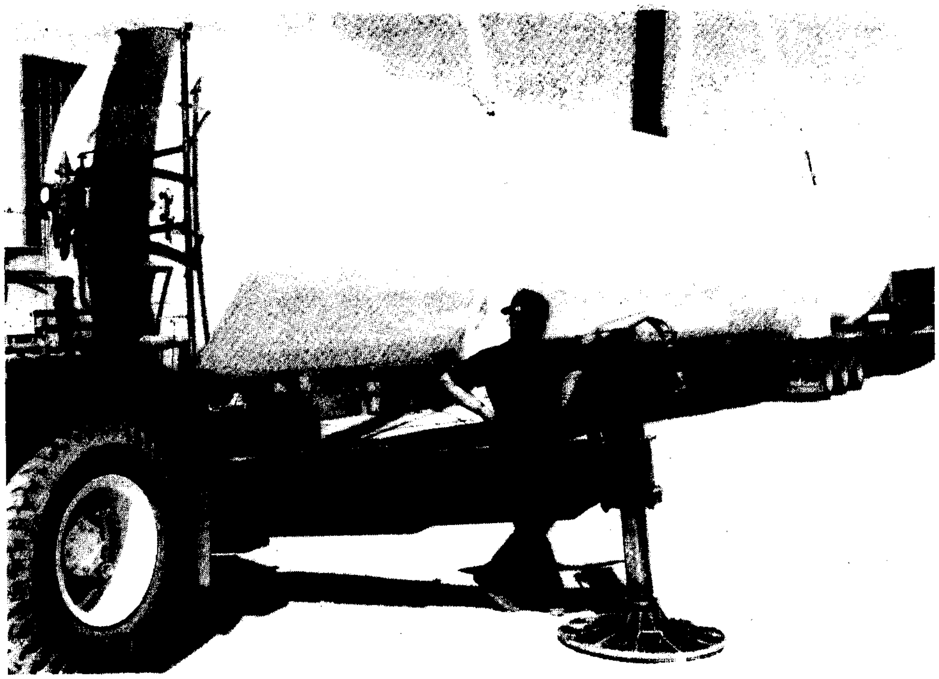
On Saturday, Stan Majewski (Fermilab) presented a review of some of the ideas being pursued to increase the resolution of drift chambers (such as the use of "cool" gases in which drifting electrons suffer very little diffusion). His talk was followed by three others describing specific projects, two of which were added to the agenda at the last minute. There was great interest expressed in the subject of high resolution wire chambers and this section of the conference could easily have taken much more time than was allotted to it.

The focus of the talks then shifted back to solid-state detectors. Pavel Rehak (Brookhaven National Laboratory) and Lutz presented data on impressive first results obtained with silicon drift devices. Muzaffer Atac's (Fermilab) presentation of results obtained by Taka Kondo (KEK) et al. on radiation damage to solid-state devices provoked a lively discussion of the prospects for improving device lifetimes and the extent to which these problems have already been solved by military suppliers.

Finally, David Buchholz (Northwestern University) reviewed some of the pattern recognition problems which were faced by NA11 in their analysis of charm production. This talk had originally been planned as an introduction to a discussion of pattern recognition and the integration of vertex detectors into spectrometers. However, there was not enough time to cover this part of the agenda. This discussion will hopefully become part of another workshop.

The attendance and the enthusiastic discussions at the workshop certainly demonstrated a lively interest in vertex detectors for charm and beauty experiments. The wealth of ideas presented should provide useful input both to the rest of the workshops and to plans for the next generation of heavy quark experiments. A limited number of copies of a volume containing sets of the transparencies from the workshop will be available from the Users Office at Fermilab.

Plans are underway for the next workshop, "Physics Topics: Charm and Beauty II," to be held in the next few months.



A new 20,000 liter liquid nitrogen dewar is delivered to the Central Helium Liquefier.

(Photograph by Fermilab Photo Unit)

REORGANIZATION

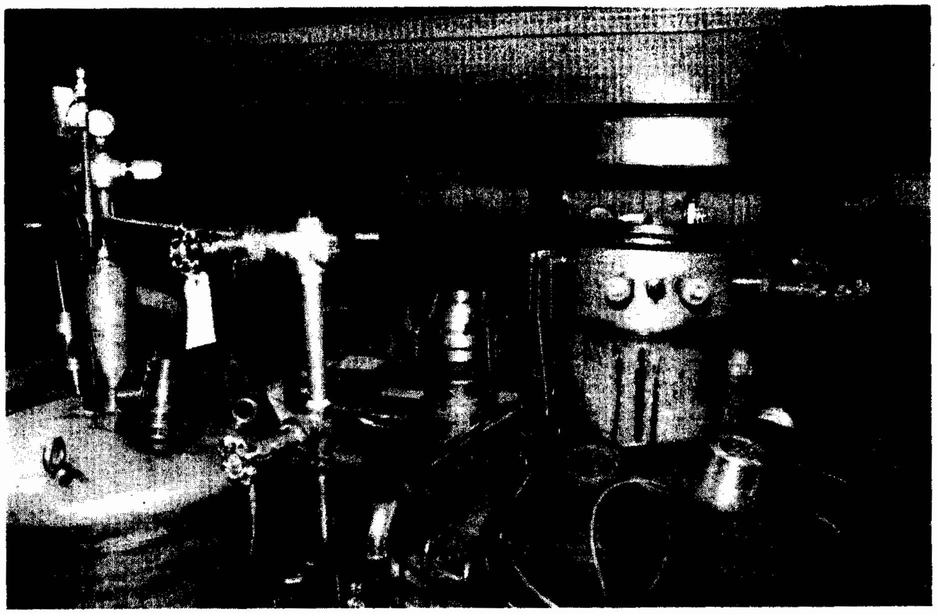
Since the primary goal of Fermilab is now to exploit TeV I and II and their associated detectors for physics, Director Leon Lederman announced a reorganization, effective October 1, to strengthen the Laboratory for this new period.

Three new Associate Directors have been named: James (Bj) Bjorken for Physics, Bruce Chrisman for Administration, and Dick Lundy for Technology. Phil Livdahl will continue to serve as Acting Deptuty Director but will devote much of his time to technical problems in the Accelerator Division.

Peter Koehler, formerly head of the Research Division, will join the Accelerator Division as Associate Division Head, responsible for providing support for the D0 project and the other (non-CDF) Main-Ring tunnel experiments in that division. Ken Stanfield, formerly Head of the Business Office, will take Koehler's place as Head of the Research Division. Jim Finks has been appointed Business Manager.

Tom Kirk will succeed Drasko Jovanovic as Head of the Physics Department, in addition to continuing as Manager of the TeV II project. Kirk's Deputy Head will be Dan Green.

Paul Mantsch will replace Dick Lundy as the head of the Technical Support section. Mantsch has been concentrating recently on the design of prototype magnets for the Superconducting Super Collider (SSC). In his new role, he will have responsibility for all conventional magnet work, drafting service, the machine shop, and magnetic measurements as well. Gene Fisk will head the continuing SSC magnet work.



Experiment 636 dewars.
(Photograph by Fermilab Photo Unit)

MANUSCRIPTS, NOTES, LECTURES, AND COLLOQUIA PREPARED OR PRESENTED FROM FROM SEPTEMBER 16, 1984 TO OCTOBER 14, 1984

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

D. J. Summers Experiment #516	Reconstruction of a Strip Geometry Calorimeter Using Stepwise Regression (Submitted to Nucl. Instrum. Methods)
V. K. Bharadwaj et al. Experiment #516	A Large Area Liquid Scintillation Multiphoton Detector (Submitted to Nucl. Instrum. Methods)

Theoretical Physics

C. Quigg	SSC Parameters: What Physics Demands (FERMILAB-Conf-84/73-T; submitted to the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider, Snowmass, Colorado, June 23-July 13, 1984)
C. N. Leung et al.	Low Energy Manifestations of a New Interaction Scale: Operator Analysis (FERMILAB-Pub-84/74-T; submitted to Phys. Rev.)
E. Eichten et al.	Higgs Bosons at the SSC: Supplement to EHLQ (FERMILAB-Conf-84/76-T; submitted to the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider, Snowmass, Colorado, June 23-July 13, 1984)
C. H. Albright et al.	Search for Horizontal Bosons at the SSC (FERMILAB-Conf-84/77-T; submitted to the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider, Snowmass, Colorado, June 23-July 13, 1984)

C. DeTar et al.	Axial Gauge Propagators for Quarks and Gluons on the Polyakov-Wilson Lattice (FERMILAB-Pub-84/79-T; submitted to Nucl. Phys. B)
L. McLerran et al.	Hidden Spurious Sources in Axial Gauge Propagators (FERMILAB-Pub-84/80-T; submitted to Nucl. Phys. B)
K. M. Bitar et al.	Renormalization Flow of SU(3) Lattice Gauge Actions (FERMILAB-Pub-84/82-T; submitted to Phys. Rev. D)
T. Sjöstrand	On the Separation of Quark and Gluon Jets in High-p_T Events (FERMILAB-Conf-84/83-T; submitted to the 1984 Summer Study on the Design and Utilization of the Superconducting Super Collider, Snowmass, Colorado, June 23-July 13, 1984)
L. D. McLerran and T. Toimela	Photon and Di-Lepton Emission from the Quark-Gluon Plasma: Some General Considerations (FERMILAB-Pub-84/84-T; submitted to Phys. Rev. D)

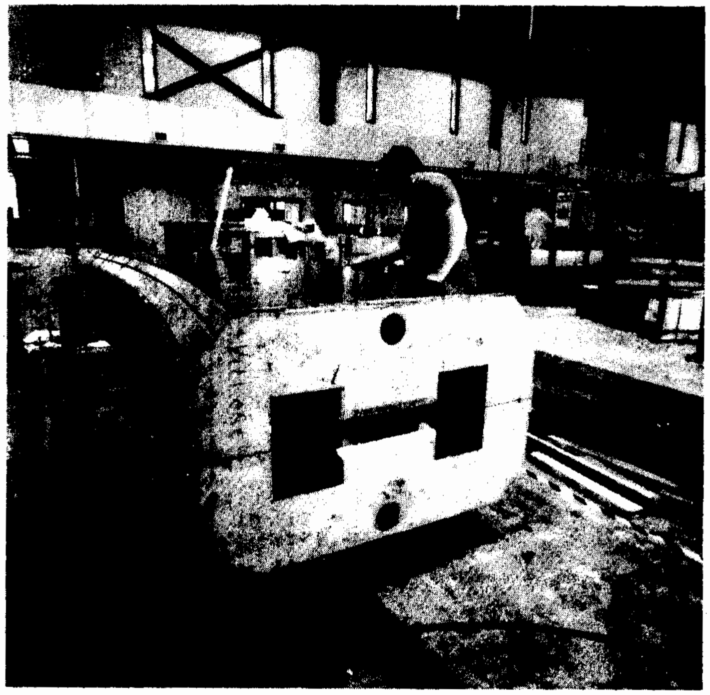
General

J. A. Carson and F. W. Markley	Mechanical Properties of Superconducting Coils (Submitted to the Applied Superconductivity Conference, San Diego, California, September 9-13, 1984)
A. D. McInturff et al.	I_c (H, T) Measurements for Multi-Kiloampere Superconducting Magnet Conductor (Submitted to the Applied Superconductivity Conference, San Diego, California, September 9-13, 1984)
M. Kuchnir et al.	SQUID Based Current Meter (Submitted to the Applied Superconductivity Conference, San Diego, California, September 9-13, 1984)

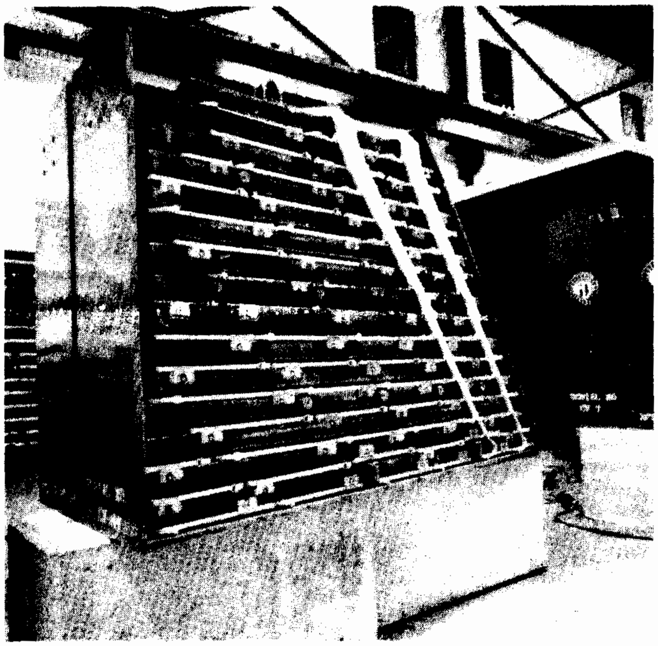
Colloquia, Lectures, and Seminars

A. Lennox	"Programs for Training Science Teachers" (Argonne National Laboratory, September 14, 1984)
F. T. Cole	"Programs for High School Students" (Argonne National Laboratory, September 14, 1984)
F. Mills	"Progress on TeV I Components" (Fermilab, September 18, 1984)
E. Malamud	"TeV I Installation and Commissioning" (Fermilab, September 18, 1984)
M. Notarus	"Booster Office Buildings--Out of the Portakamps and into the Palace" (Fermilab, September 20, 1984)
E. Malamud	"A Status Report on the TeV I Controls System and the Requirements for Application Programs" (Fermilab, September 20, 1984)
A. Szalay	"Where Do Galaxies Form?" (Fermilab, September 24, 1984)
S. Ohnuma	"5 Weeks with the Texas SSC" (Fermilab, September 25, 1984)
C. Hojvat	"Status of the Target System and Life Tests of Lithium Lens" (Fermilab, September 27, 1984)
J. Hangst	"Status of the C-Magnet" (Fermilab, September 27, 1984)
L. Sauer	"Magnet Installation Plan" (Fermilab, September 27, 1984)
B. J. Carr	"Pre-Galactic Stars and the Dark Matter Problem" (Fermilab, October 1, 1984)
R. Orr	"Accelerator Division Information Meeting" (Fermilab, October 2, 1984)
E. Malamud	"Applications Programs for TeV I Source Commissioning" (Fermilab, October 4, 1984)

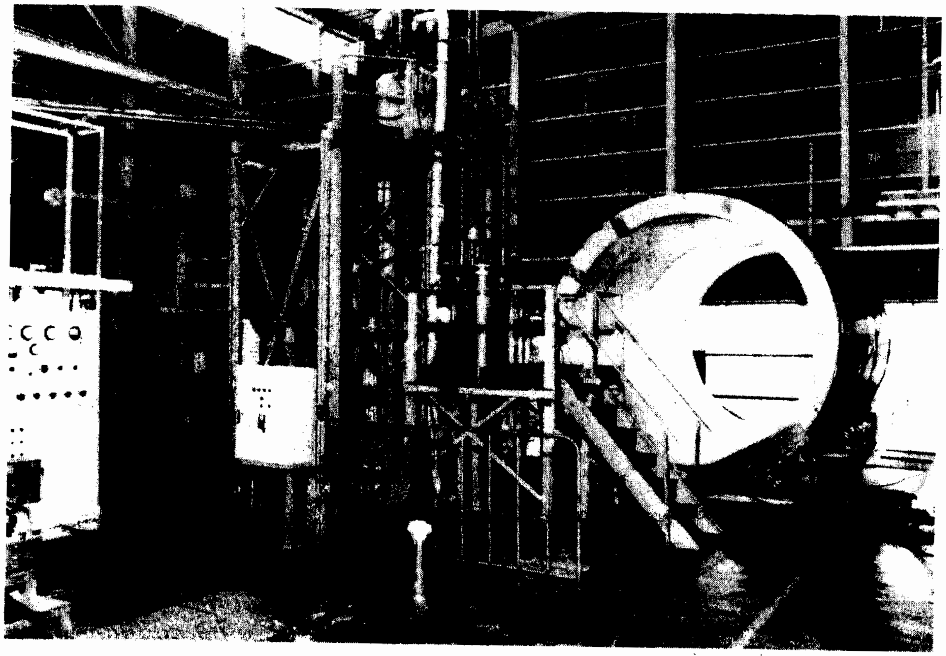
G. Mayer	"Applications Programming on the HP-[illegible] (Fermi-lab, October 4, 1984)
S. Holmes	"Applications Programs for Orbit Dynamics" (Fermilab, October 4, 1984)
B. Kells	"Accelerator Physics at the Seattle 0.5 eV Synchrotron" (Fermilab, October 9, 1984)
S. Rao	"Superconducting Strings" (Fermilab, October 10, 1984)
R. Peters	"Summary of Modifications and Measurements ot the Accumulator Quadrupoles (Fermilab, October 11, 1984)
S. Holmes	"Significance of the Field Measurement of the Accumulator Quadrupoles and the Anticipated Performance of the Accumulator" (Fermilab, October 11, 1984)



A large-aperture dipole core for Tevatron I.
(Photograph by Fermilab Photo Unit)



Endwall calorimeter module for Collider Detector being instrumented with plastic scintillators and light pipes.
(Photograph by Fermilab Photo Unit)



The superconducting solenoid coil for the Collider Detector under power tests in Japan prior to shipment to the United States.

(Photograph by Fermilab Photo Unit)

DATES TO REMEMBER

November 8-9, 1984	Physics Advisory Committee Meeting