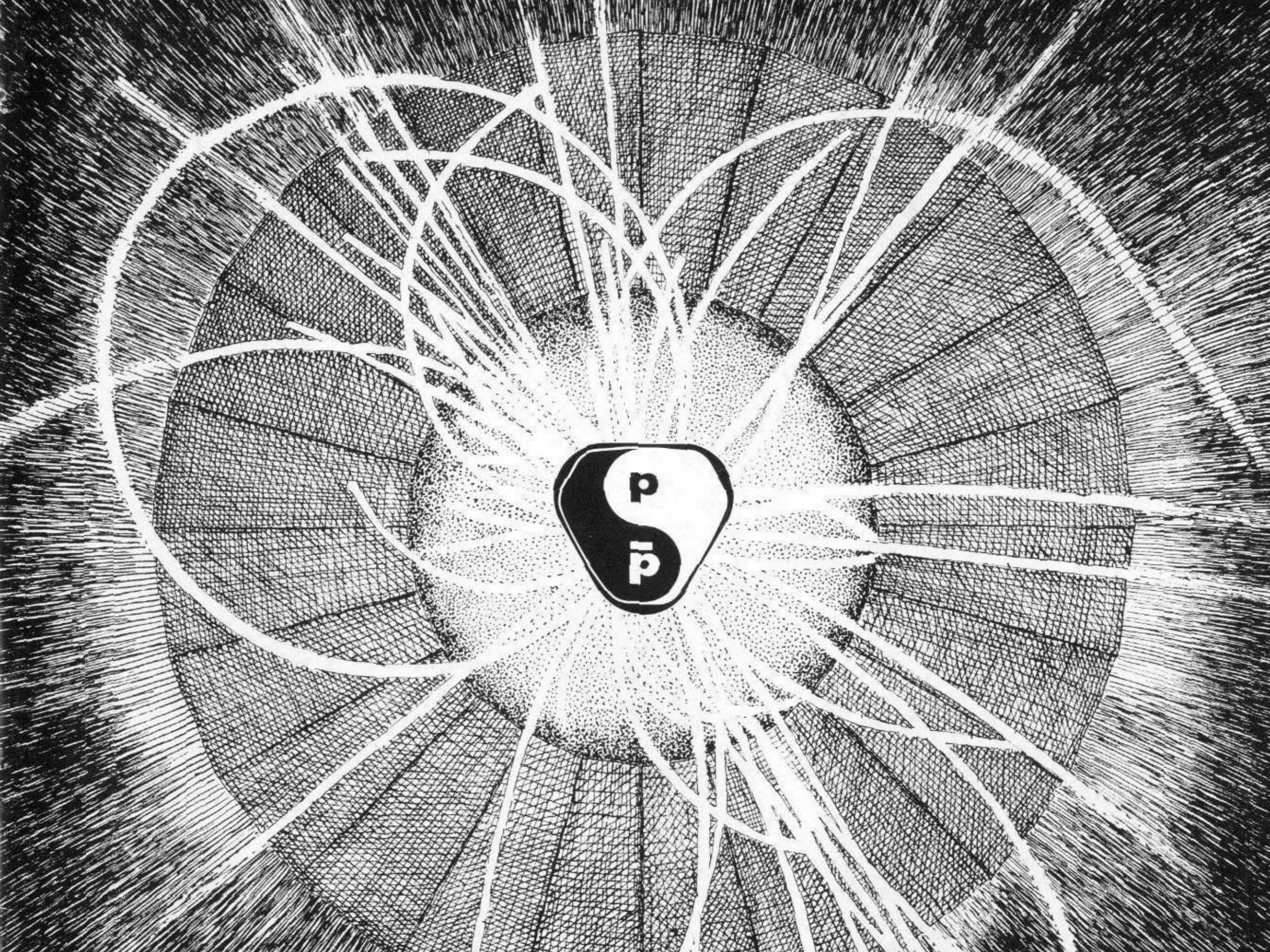
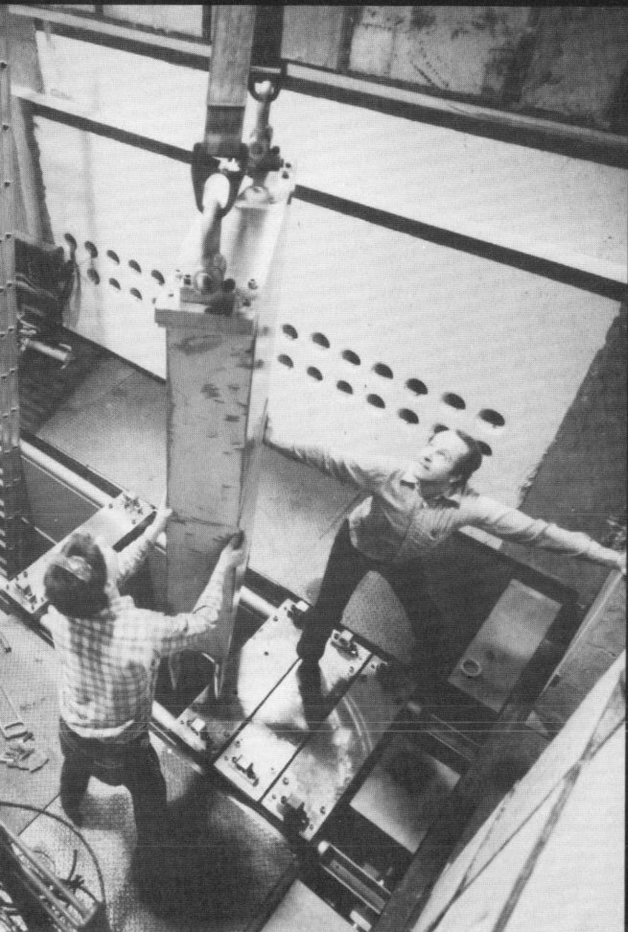
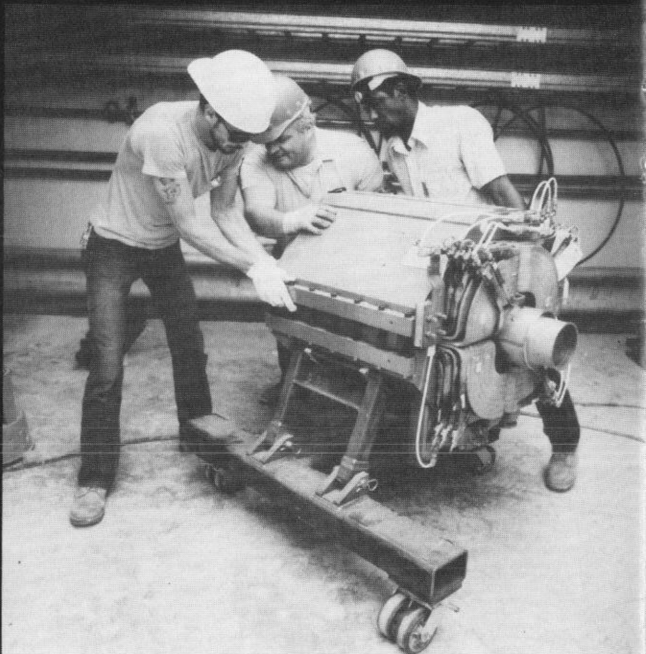
Dedication
Of the Proton-Antiproton Collider
Tevatron I, Fermilab

October 11, 1985



Fermi National Accelerator Laboratory





THE COLLIDER AT FERMILAB

PREAMBLE

High-Energy Physics goes about its business by the observation of collisions between subnuclear particles. The debris of these violent collisions is studied by a wide variety of detectors in order to compile data on the existence and the quantitative properties of the particles that exist in nature, as well as the properties of the forces which act between these particles. Synthesis of these data go into establishing a valid theory which attempts to understand, in the simplest possible way, the workings of the physical universe. The lessons of the past indicate that the more violent the collision, the more incisive the data that is extracted. The road to more violent collisions is to increase the energy of the colliding particles.

It has recently become possible to generate head-on collisions of very energetic particles moving in opposite directions - these are vastly more productive of high energy than more conventional collisions of accelerated particles with fixed targets. The penalty of head-on machines (colliders) is the relative rareness of collisions.

THE FERMILAB PROTON-ANTIPROTON COLLIDER

This is designed to provide an intense source of **antiprotons** and to arrange head-on collisions of **protons** and antiprotons at a total energy of 2000-billion volts (GeV) in the TEVATRON.

Fermilab's accelerator complex consists of a series of accelerators, each designed to increase the energy of protons over a specific domain of energies. Thus we have the **Cockroft-Walton** electrostatic accelerator which raises the energy from zero to 750,000 volts. This is followed by a **Linear Accelerator** (750 KeV to 200 MeV) and the **Booster Ring** (200 MeV to 8 GeV). The Booster feeds protons into the **Main Ring** which brings them to 150 GeV for injection into the TEVATRON. This provides the final push to 800 GeV (soon to be raised to nearly 1000 GeV). In all of these rings one should think of bunches of protons circulating many tens of thousands of circuits per second in a highly evacuated pipe, constrained by magnets to roughly circular orbits while electromagnetic forces cause them to stay concentrated and to gain energy.

PRODUCTION OF ANTIPROTONS

In the Collider mode, protons are accelerated in the Main Ring to 120 GeV and, by strategic manipulation of radio frequency fields, the protons are grouped to be optimally organized for producing antiprotons. The protons are extracted at location F17 and are incident upon a specially constructed target where collisions generate a large flux of nuclear particles including antiprotons (one per 30,000 incident protons). A fraction of the antiprotons, those near 8 GeV, are focussed by a "lens" made of a cylinder of lithium through which flows a pulse of 600,000 amperes. The large current creates a magnetic field which concentrates the valuable antiprotons. Their forward momentum carries them in a highly evacuated pipe to the Debuncher.

COOLING

A key invention which makes an antiproton source practical is called "cooling." This technique, invented by Simon Van der Meer of CERN, compresses a large number of antiprotons into a small volume and reduces the random motions of antiprotons relative to a "standard antiproton orbit." This process makes it possible to store and accumulate large numbers of antiprotons without having them overflow their storage device. The trick is to sense the location of a deviant particle as the group of particles is circulating around a ring and to transmit this information across the ring so that a correction impulse may be applied at the time the errant particle has arrived. In detail, a complex mathematics and very sophisticated signal handling is required to carry out this process.

DEBUNCHER

This is a 1700-ft circumference ring of 345 magnets. Here, a combination of magnetic fields and radio-frequency impulses cools and compresses the antiprotons into a smaller and smaller sausage-shaped volume as these circulate around the ring at an energy of 8 GeV. When the sausage is properly prepared (about 2 seconds) it is passed on to the Accumulator ring.

ACCUMULATOR

This ring of 176 magnets is concentric with the Debuncher and has the task of further compressing the antiproton sausage and gradually accumulating these in a core "stack." As each pulse of antiprotons enters the Accumulator, it is treated with high-frequency electromagnetic forces and repositioned within the magnet aperture to add to the core. An accumulation time of several hours yields enough antiprotons to proceed to the next step.

ACCELERATION

About half the core of antiprotons is extracted into a beam line towards the Main Ring. Since antiprotons carry a negative charge, they enter the Main Ring rotating in a sense counter to the sense of protons. After acceleration to 150 GeV, the antiprotons are transferred to the TEVATRON ring where protons are already stored in circulating bunches. Both groups of particles are now accelerated to the maximum energy, rotating in opposite directions and passing each other in bunches that are still too tenuous for significant collisions to take place. At full energy, they are stored for many hours and new, powerful focussing magnets ("low beta quads") are energized to greatly increase the density of the beams at two places around the TEVATRON ring. All of this required radical modification of the accelerator complex under the direction of Helen Edwards.

COLLISIONS

At location B-zero and D-zero, the two sharply focussed beams cross each other about 50,000 times per second. At each crossing there is a good chance (50-50) that one antiproton will collide with one proton. Thus, at the design specification, about 50,000 collisions will take place at each location (interaction point) per second. The vast majority of these collisions will not be of major interest because protons and antiprotons, on the microscopic level, are mostly empty space. It is the constituents of these particles, **quarks** and **gluons**, whose collisions are to be observed.

CDF AND D-ZERO

In 1980, Fermilab, upon the advice of its Advisory Committee, organized the Collider Detector at Fermilab (CDF) group to construct a major particle detector for proton-antiproton collisions. At present, the consortium consists of ten universities, three national laboratories, and institutions in Japan and Italy. The co-leaders of this project are Roy Schwitters of Harvard University and Alvin Tollestrup of Fermilab. The schedule for CDF calls for a first physics run to begin in September of 1986 at the end of our 1985-86 construction shutdown. In July of 1984, DOE approved the construction of a second proton-antiproton detector under the management of Paul Grannis of SUNY-Stony Brook and Peter Koehler of Fermilab. This detector, designed to be complimentary to CDF, will occupy the D-zero location; construction of the interaction and assembly hall will take place during the 1985-86 shutdown.

The Fermilab Proton-Antiproton Collider will provide the highest energy for the study of particle science until at least well into the 1990's.

HISTORY

I. In Olden Times (1955 - 1970)

Thirty years ago, the antiproton was discovered at the Berkeley 6-billion electron-volt (GeV) particle accelerator thus confirming one of the more spectacular predictions of theoretical science, the symmetry of matter and antimatter.

Antiparticles were identified theoretically in 1927 as peculiar and unexpected consequences of the mathematical equations describing electrons. These equations, the first to incorporate both Einstein's theory of relativity and the new quantum theory, were discovered by an English physicist, Paul Dirac. It was realized that not only do the equations predict the existence of positively charged electrons symmetric to the familiar negative electron, but that all particles should have corresponding antiparticles, particles of the opposite charge, magnetism, and, more profoundly, capable of annihilating with their "mirror" twins to produce pure energy.

The crucial test was the discovery of the existence of the antiproton in 1955. Following on the euphoria of this discovery, physicists quickly put the particle to work as an especially sensitive tool to probe subnuclear processes. One of the problems with this very effective probe is that antiprotons are rare; they are produced only in energetic collisions of protons with targets.

II. The Middle Ages (1970 - 1983)

In the mid-1970's, it became feasible to think about accumulating sufficient numbers of antiprotons to organize head-on collisions of protons and antiprotons, each group of particles circulating (in opposite directions) in a magnetic storage ring.

Electron accelerators had long been using this trick to greatly enhance the violence of the collisions, allowing more incisive measurements of the collision products. Protons and antiprotons would vastly increase the energy of the collisions, and both CERN (European Council for Nuclear Research in Geneva) and Fermilab began to consider the problem. The breakthrough came at CERN where Simon Van der Meer's invention of "stochastic cooling" was adopted. This made it possible to compress large numbers of antiprotons into small "volume" in a magnetic storage device. By 1979, CERN was well on its way to building a source designed to collect, store, and accumulate antiprotons until enough were available for injecting into their 400-GeV superproton synchrotron (SPS). At that time, the Fermilab effort was concentrated in building the TEVATRON, a superconducting accelerator designed to reach 1000 GeV and operate in two modes: conventional fixed-target mode, and colliding mode. A Fermilab collider would release 2000 GeV of energy - over three times the energy of the CERN device.

In 1983, the CERN work was crowned with success - the proton-antiproton collisions, as observed with two powerful detectors, resulted in the discovery of the W^+, W^-, and Z^0 particles. As with the discovery of the antiproton, this too was a triumph of pure reason. Theorists, having made a theory to account for all previous data, were able to predict the existence and precise properties of the W and Z particles.

III. The Fermilab Collider (1981 - 1985)

In 1981, the Department of Energy (DOE) successfully petitioned the Congress to authorize the construction of an antiproton source and collision facilities. The project was designated Tevatron I. The Fermilab design, based on CERN's experience and on several years of R&D at Fermilab, was radically modified as a result of new ideas and new technological possibilities. Late in 1981, John Peoples became the Project Manager for Tevatron I and assembled the new design. The scheme was carefully reviewed by DOE and approval came in May of 1982. The new project had all of its components in-place by June of 1985.

Let's see what this involved. It required the construction of 700 magnets ranging from small, precision trim magnets to 50-ton monsters built to Swiss-watch tolerances. It involved very precise electrodes to sense the position of particles, and electrodes to correct these motions. The technology of signal and power handling involves superconducting filters, 2-4 gigahertz Travelling-wave Tubes, ultra-sensitive diagnostic equipment, and an exquisite mathematics that guides the entire process. Fabrication of much of this was under the direction of Richard Lundy and Paul Mantsch.

It is important to point out that the Proton-Antiproton Collider depends on an intimate and synchronized cooperation of all of the existing accelerator rings as well as the new Antiproton Source rings. Operating conditions in the Main Ring and in the TEVATRON are radically altered in the collider mode. In late September, significant numbers of antiprotons had been collected, stored, and accumulated. The entire choreography of five rings, with their diverse radio-frequency and stochastic cooling systems, managed by hundreds of microcomputers, satisfied stringent engineering tests.

On October 6, the machine complex was shut down in order to carry out the last phase in the TEVATRON program: the civil construction of an "overpass" and the second collision hall (D-zero).

The Proton-Antiproton Collider is scheduled to begin its scientific epoch on September 1, 1986.

DEDICATION OF THE COLLIDER
Ramsey Auditorium

"A CELEBRATION OF SCIENCE"

Prelude:	*"Abstract"* and *"Proposal"*	Music synthesis by Walter Kissel
Chair:	Harry Woolf	Director, Institute for Advanced Studies, Princeton University; Chairman of the Board, Universities Research Association, Inc.
Speakers:	Leon M. Lederman	Director, Fermilab
	Lewis M. Branscomb	Vice President for Research, IBM
	Daniel J. Terra	U.S. Cultural Ambassador-at-Large
	Norman Hackerman	President Emeritus, Rice University
	James R. Thompson	Governor of Illinois
	John S. Herrington	Secretary of Energy
Platform Group:	Lewis M. Branscomb	John Peoples
	Helen T. Edwards	Joseph F. Salgado
	Norman Hackerman	Roy F. Schwitters
	John S. Herrington	Daniel J. Terra
	Edward A. Knapp	James R. Thompson
	Leon M. Lederman	Alvin V. Tollestrup
	Richard A. Lundy	Alvin M. Trivelpiece
	Paul M. Mantsch	Harry Woolf
	J. Richie Orr	Donald E. Young
Postlude:	*"Celebration"*	Music synthesis by Walter Kissel

COLLIDER DETECTOR AT FERMILAB (CDF)
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University of Chicago
Fermi National Accelerator Laboratory
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Fukui University, Japan
Harvard University
University of Illinois
KEK, Japan
Lawrence Berkeley Laboratory
University of Pennsylvania
INFN--University of Pisa, Italy
Purdue University
Rockefeller University
Rutgers University
Saga University of Japan
Texas A&M University
ICRR, Tokyo University, Japan
Tsukuba University, Japan
University of Wisconsin

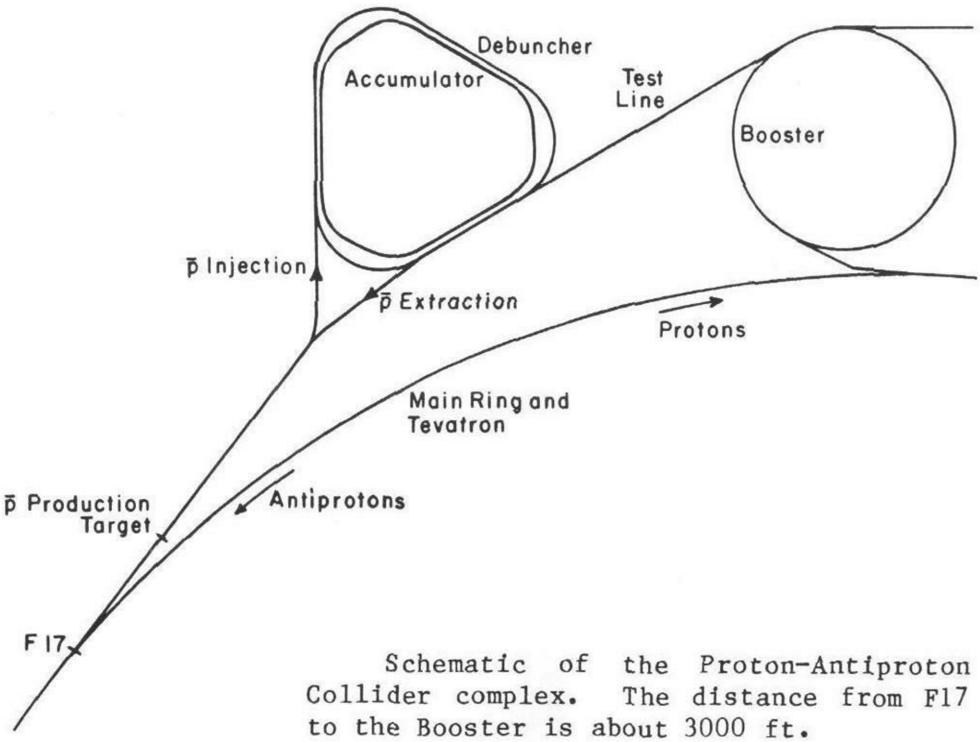
D-ZERO DETECTOR
Collaborating Institutions

Brookhaven National Laboratory
Brown University
Columbia University
Fermi National Accelerator Laboratory
Florida State University
Lawrence Berkeley Laboratory
University of Maryland
Michigan State University
Northwestern University
University of Pennsylvania
University of Rochester
CEN--Saclay, France
State University of New York at Stony Brook
Virginia Polytechnic Institute

TEVATRON I SECTION

Head: John Peoples
Deputy Head: Donald Young
Group Leaders: James Griffin, Carlos Hojvat,
Ernest Malamud, Jack McCarthy, Frederick Mills

We gratefully acknowledge the contributions of :
Argonne National Laboratory,
Lawrence Berkeley Laboratory,
and The Institute of Nuclear Physics, Novosibirsk, U.S.S.R.



Schematic of the Proton-Antiproton Collider complex. The distance from F17 to the Booster is about 3000 ft.

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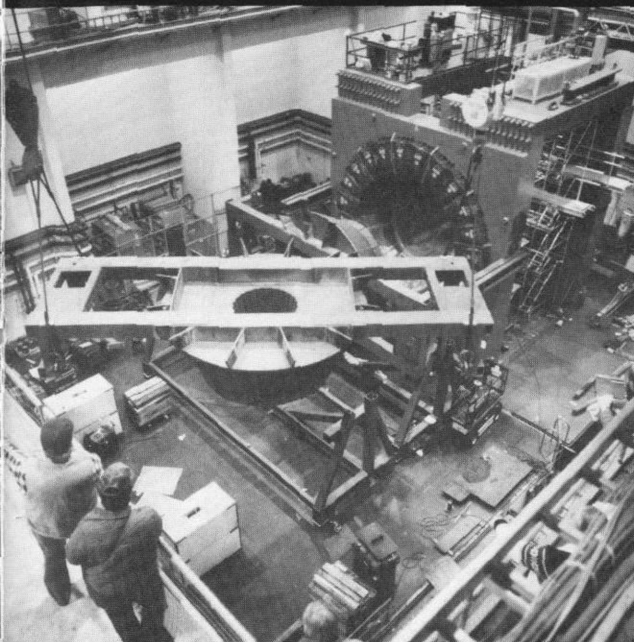
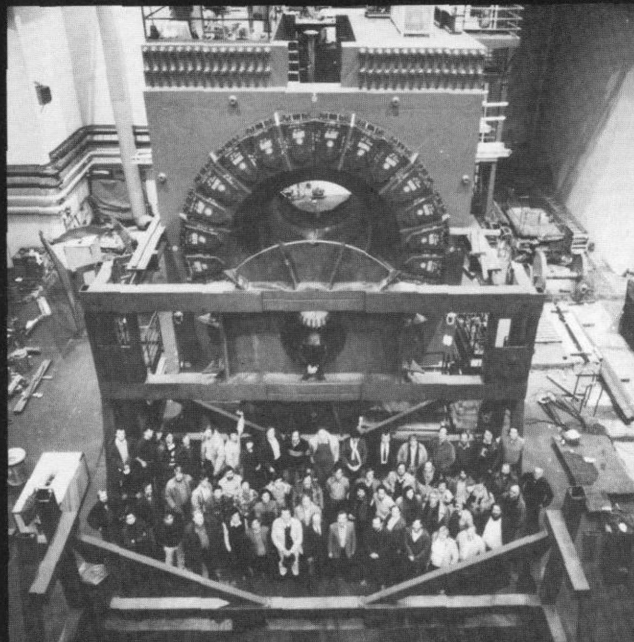
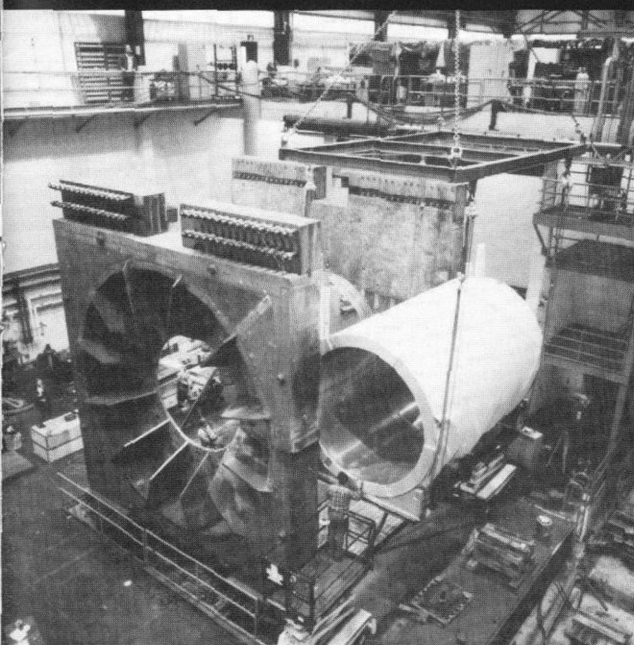
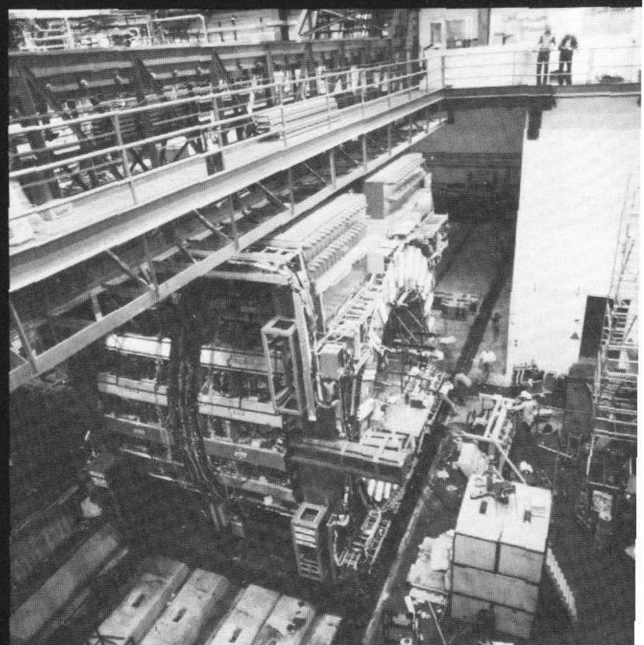

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