Tevatron Antiproton Source

Presentee by J. Peoples, Fermilab

No written contribution received.

THE COLLIDER DETECTOR AT FERMILAB - CDF A PROGRESS REPORT

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CDF, the Collider Detector at Fermilab, is a collaboration of almost 180 physicists from ten U. S. universities (University of Chicago, Brandeis University, Harvard University, University of Illinois, University of Pennsylvania, Purdue University, Rockefeller University, Rutgers University, Texas A&M University, and University of Wisconsin), three U. S. DOE supported national laboratories (Fermilab, Argonne National Laboratory, and Lawrence Berkeley Laboratory), Italy (Frascati National Laboratory and University of Pisa), and Japan (KEK National Laboratory and University of Tsukuba). The primary physics goal for CDF is to study the general features of proton-antiproton collisions at 2 TeV center-of-mass energy. On general grounds, we expect that parton subenergies in the range 50-500 GeV will provide the most interesting physics at this energy. Work at the present CERN Collider has already demonstrated the richness of the 100 GeV scale in parton subenergies.

To set the scale for physics at CDF, the lower energy processes can be extrapolated to these higher energies. One such example shown in Fig. 1 is large p_t jet production predicted by QCD. Jets with p_t as large as 250-300 GeV are excessible to experimental study. Another example probing the same energy scale is that of W and Z pair production, shown in Fig. 2. Again, practical rates should exist for these processes at 2 TeV. The increased

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energy also will yield higher cross sections for single W and Z production by approximately a factor of three compared to that now seen at CERN.

Since CDF will be observing hadron collisions, the natural coordinates to use are rapidity, y, azimuthal angle, ϕ, and the transverse momentum, p_t. As a very crude guide, the events of interest can be pictured as being produced uniformly in y up to a cutoff given by energy conservation, uniformly in ϕ, and with a steeply falling p_t dependence. To see most of the events at the 100 GeV scale, such as W and Z production, the detector must cover a y range from -3 to +3. If we allow for the decay products as well, another unit in y must be added. Thus, the acceptance for the full calorimetry and tracking of CDF was chosen to be $-4 < y < +4$, $0 < \phi < 2\pi$. The y acceptance translates into a polar angle acceptance of $2° < \theta < 178°$. Events at higher masses are well contained by this acceptance.

Since the basic processes are expected to involve quarks, gluons, leptons, and photons, we want to measure as much about these particles as possible within practical constraints of available technology and money. Since quarks and gluons manifest themselves as clean narrow jets of hadrons, CDF has chosen shower counters and hadron calorimeters arranged in a projective tower geometry to detect jets. One of the central calorimeter modules called a wedge is shown in Fig. 3. The shower counter composed of lead and scintillator is at the bottom. The hadron calorimeter made of steel and scintillator is above. The projective tower geometry is obvious. The granularity of the calorimetry towers is sufficient to resolve the jets without being able to measure reliably every particle within the jet. Since hadrons in a typical high p_t jet will form a circular pattern in $y - \phi$ space with a diameter of roughly one unit, the calorimeter towers were chosen to be 0.1 units in y and between 5° and 15° in ϕ. Leptons are characterized by single particles which have different interactions in the various particle detectors of CDF. Charged particle tracking in a magnetic field, shower counter and hadron calorimeter response, and penetration through several interaction lengths of material are the techniques planned for detecting electrons and muons. Photon detection is achieved with a finely segmented shower counter and the absence of a charged track.

An isometric drawing of CDF is shown in Fig. 4. The detector is divided into three main parts, the central detector and two forward/backward detectors. All three parts, when running, are centered on the Tevatron beamline at the BØ collision area at Fermilab. A vertical section through the central detector is shown in Fig. 5. The heart of the central detector is a 1.5 Tesla, 3.0 m diameter, 5.0 m long superconducting solenoid magnet. This magnet was designed by a collaboration of Fermilab, University of Tsukuba, and Hitachi Heavy Industries and was manufactured by Hitachi. The total thickness of the coil and its cryostat is less than one radiation length. This small thickness was achieved by locating the support bobbin outside the superconducting coil rather than inside as in previous coils of this type. The coil was wound on a large mandrel and the bobbin, which is used to help propogate a quench, was then slipped over the coil in a shrink fitting operation. The mandrel was then removed from the coil. The coil was shipped to the United States last July and is currently undergoing full current testing at Fermilab. This magnet and the central tracking chamber are used to measure individual particles with p_t less than 40 GeV. It gives information that is complementary to that of the calorimeters and provides a pictorial representation of the event. The choice was a solenoid to provide maximum efficiency in the study of large p_t events. Surrounding this magnet are the shower counters and hadron calorimeters. The shower counters in the region betwen 90° and 33° are made of a lead scintillator sandwich readout with wavelength shifter plates and a light pipe. A proportional strip chamber has been inserted at a depth of five radiation lengths to provide fine grained information on the shower location. The scintillator for these detectors was produced here in Japan and is especially good in its radiation resistance properties. Between 33° and 10° the shower counters are a lead pad proportional chamber sandwich. These chambers are gas proportional counters fabricated out of resistive plastic tubes with cathode pad readout. A strip proportional chamber is also placed in these detectors at the shower maximum to provide precision information about the shower location. This endplug shower calorimeter is one of the many contributions of our Japanese colleagues and is being produced entirely by KEK and the University of Tsukuba. The resistive plastic tubes were developed here in Japan and are being used elsewhere in the detector as well. Outside the shower counters are located the hadron calorimeters. In the region between 90° and 30° these calorimeters are made of steel and scintillator readout by wavelength shifter bars and light pipes. Between 30° and 10° the hadron calorimeters are steel and pad proportional chambers made of resistive plastic tubes. Outside the hadron calorimeters in the region between 90° and 55° are located the central muon detectors. These detectors are composed of four layers of drift chambers and a hard wired trigger which provides precision information on the direction of the penetrating particles. All of these central wedge calorimeter modules as well as the endwall calorimeters which complete the central hadron calorimeters in the angular region between 45° and 30° have been fabricated.

Twelve of the central wedges have already been calibrated and have been assembled into the final arch configuration of the detector. The remainder of the central wedges are currently being calibrated in the test beams at Fermilab. The endwall modules have already been installed in the yoke.

A detailed section of one quadrant of the core of the central detector is shown in Fig. 6. The beam pipe is 5 cm in diameter. The plan is to make the pipe out of a carbon fiber epoxy composite lined with a thin shell of aluminum. This technique has been developed here in Japan and is currently undergoing prototyping at KEK. Surrounding this in the vicinity of the interaction region are eight small atmospheric pressure VTPC′s which have a good r - z tracking ability. The principal roles of the VTPC′s are to record the occurrence of multiple events and to provide three dimensional information about the general event topology for use in pattern recognition by the calorimetry and the central tracking chamber. Prototyping on the VTPC′s is complete and the production of the eight modules is starting. Surrounding the VTPC′s is a large cylindrical drift chamber which provides the precision momentum measuring instrument in CDF. The central tracking chamber is an axial wire chamber with 84 layers arranged into 9 superlayers. Five of the superlayers are axial each containing 12 sense wires and four are stereo layers each containing 6 sense wires. Both axial and stereo superlayers are divided into cells tilted 45° with respect to the radial direction so that the drift direction is predominately circumferential when the magnetic field is 1.5 Tesla. The machining is complete on the two large endplates of the central drift chamber. The entire gas vessel is currently being assembled at the manufacturing plant to check dimensional tolerances. Wiring is scheduled to start this summer. Completing the tracking system is a radial wire drift chamber which covers the angular range of 2° to 10° in the forward direction. This chamber is composed of twenty layers of sense wires arranged in 72 radial cells each covering 5° in ϕ tipped at a 2° angle to provide ambiguity resolution. Wiring is underway on the first of four of these chambers.

An elevation view of half of the detector is shown in Fig. 7. Particles produced between 2° and 10° pass out of the central detector through a hole in the endplug and enter the forward/backward detectors. The first layer of these detectors is a shower calorimeter composed of alternate layers of lead and pad proportional chambers. Again a strip chamber giving fine grained information about shower location is located at shower maximum. The projective geometry used in the central detector is continued into this angular region as well. Production has started on these chambers and production modules are currently being calibrated in the test beams at Fermilab. Located behind the shower calorimeter is the forward hadron calorimeter. This calorimeter is composed of steel plates instrumented with pad proportional chambers. We are still at the prototyping stage on this system. The first chambers will go into the test beams this spring. The steel modules have already been produced and are currently being assembled into the final detector configuration. Small angle muons originating between 4° and 17° will be detected and momentum analyzed by the magnetized steel toroids and muon tracking chambers of the forward muon detector which is located immediately behind the hadron calorimeter. The steel for the first toroid is currently being fabricated and the production line for the chambers has been started.

Overall there are more than 60,000 channels of electronics in CDF. The job of acquiring and recording all of this information is not trivial. We have chosen to mount the front end amplifiers and the sample and hold circuits directly on the detector components. A redundant multiplexed ADC system will read out the analog signals locally and transmit the digital results to the data acquisition electronics located in the counting rooms. In the counting rooms a local intelligence will subtract pedestals, compact data, and, in general, prepare the raw data for further transmission. All of the required modules have gone through several prototyping stages and production has started on the final versions. The signals from the drift chambers go through discriminator circuits on the detector which transmit shaped pulses to TDC's located in the counting rooms. FASTBUS is used in the subsequent stages of data acquisition. All of the necessary FASTBUS modules have completed the prototyping stage and many are currently being manufactured commercially.

A multilevel trigger is planned for CDF. The basic interaction rate is expected to be 50,000 Hz. Three trigger levels are planned. Level 1 must decide within one beam crossing of 7 microseconds whether to keep the event for digitization. This trigger is derived from fast analog signals provided by the front end electronics of the energy deposited in the shower counters and hadron calorimeters in each event. Level 2 looks for patterns of energy deposition, high p_t tracks associated with muon hits, large missing p_t, and other similar inputs. Level 2 will take several beam crossings to make its decision. The final stage, Level 3, is made when fully digitized event information is available to the data acquisition system and dedicated processors will make software cuts to reduce the trigger rate to the data logging rate of a few Hz. The control, monitoring, calibration, and data logging for CDF will be handled by a system of VAX computers.

A plan view of the BØ experimental area is shown in Fig. 8. The collision hall is an underground enclosure 30 m long and 15 m wide located at the BØ straight section of the Tevatron approximately 8 m below the surface. The collision hall is accessed by means of a 10.5 m x 10.5 m tunnel which connects it to the assembly hall which serves as the assembly and service area for CDF. The assembly hall is a 75 m x 30 m surface building containing a 23 m x 30 m x 12 m deep pit where CDF is actually assembled, a 50 ton crane, counting rooms, offices, and shops. An elevation view of the facility is shown in Fig. 9. The central detector is provided with heavy duty rollers so that it can be moved easily between the beam line and the assembly area. The detector will be connected to the counting rooms by a flexible cable tray not shown in the figure. Construction was started on this experimental area in July, 1982. Initial occupancy was begun in November, 1983. Actual detector assembly began in April, 1984. Figure 10 shows the main endwalls of the detector while they were being fabricated on the floor of the pit in the assembly area. Figure 11 shows the completed coil being unloaded from the airplane after its shipment from Japan. Figure 12 shows the coil being inserted between the upright endwalls. Figure 13 shows the completed magnet yoke with the Endwall Hadron Calorimeters inserted. Figure 14 shows the detector as it was just before I left for this conference. The endplugs have been mounted completing the flux return in preparation for the magnet tests and the first of the central calorimeter arches has been stacked.

The current Fermilab schedule has CDF scheduled for three runs with antiprotons in the near future. In August or September, 1985, we expect to have our first run. The antiproton source will be complete and hopefully operational by that time. CDF will have completed the stacking of all four central calorimeter arches and will have sufficient electronics to instrument the scintillation calorimeters in both the central arches and the endwalls. Between four and eight of the VTPC modules will be available and operational. A crude Level 1 trigger will be available. There will be no magnet or central tracking chamber since the Main Ring beam pipe will still run through the detector. There will be no forward calorimeters or forward muon detectors. This run will mainly serve as a systems test although at the expected luminosity of 10^{28} it is possible to extend the cross-section beyond the CERN results for high p_t jets. After that short run Fermilab will go into a long construction shutdown to build the BØ overpass which moves the Main Ring out of the CDF detector and the DØ experimental area. A second run is scheduled for the summer of 1986. At that time CDF is expected to be approximately 95% complete. All major systems will be in place although we will be missing some of the forward hadron chambers and some of the electronics channels. The luminosity of the collider is expected to be close to 10^{30}. This is the major debugging run for CDF. In the fall of 1986 the first physics run is scheduled for three months duration. After that run we expect to began sharing beam time with the fixed target experimental program at a fraction that will approach 50%.

CDF Bibliography

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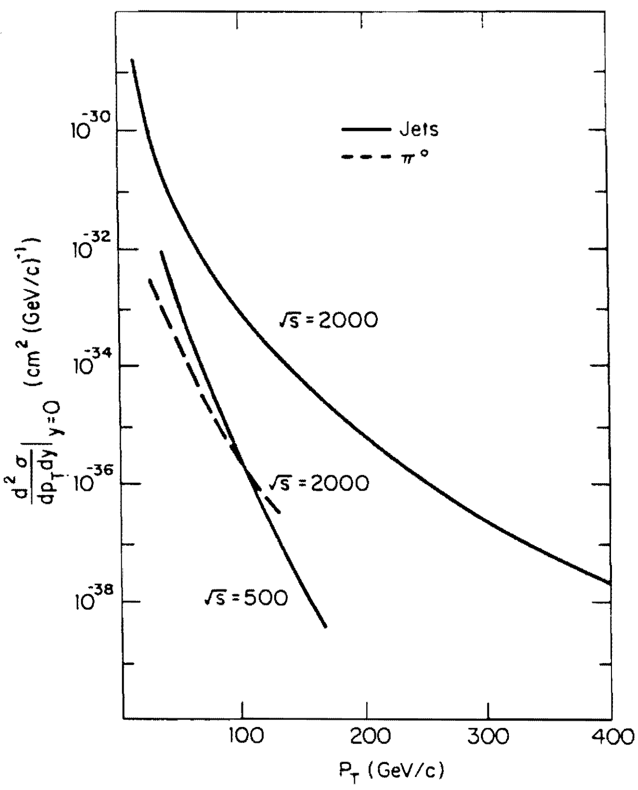

Fig. 1: Large p_t jet production predicted by QCD for the Tevatron Collider energy compared with the cross section for lower energy collisions

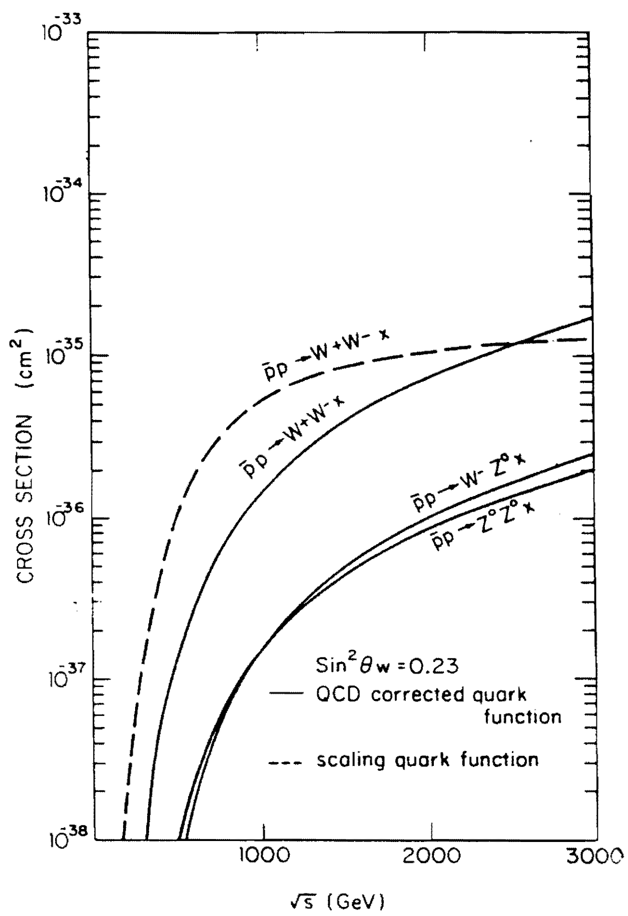

Fig. 2: Predicted production of W and Z pairs

Fig. 3: Side view of one wedge module with side skin removed exposing the tower structure

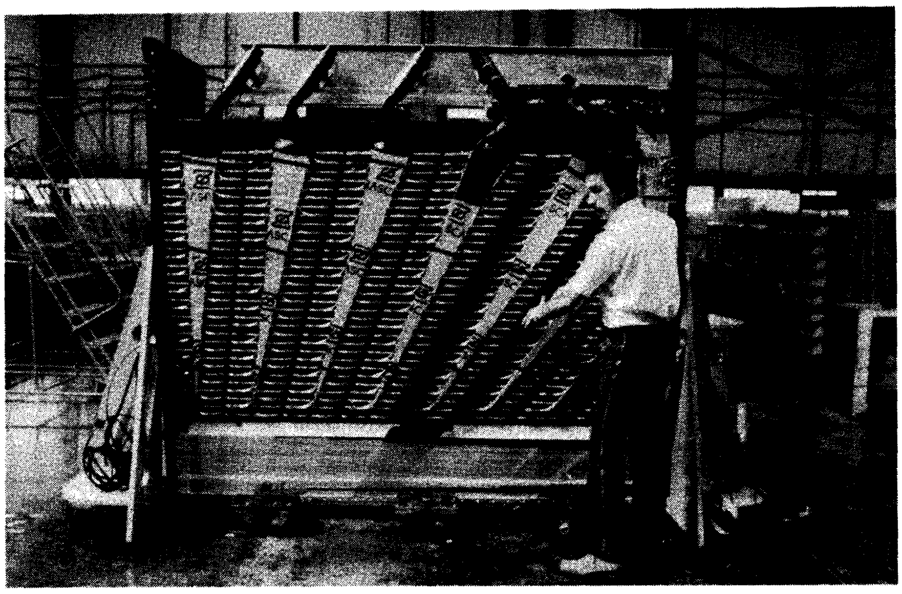

Fig. 4: An isometric drawing of CDF

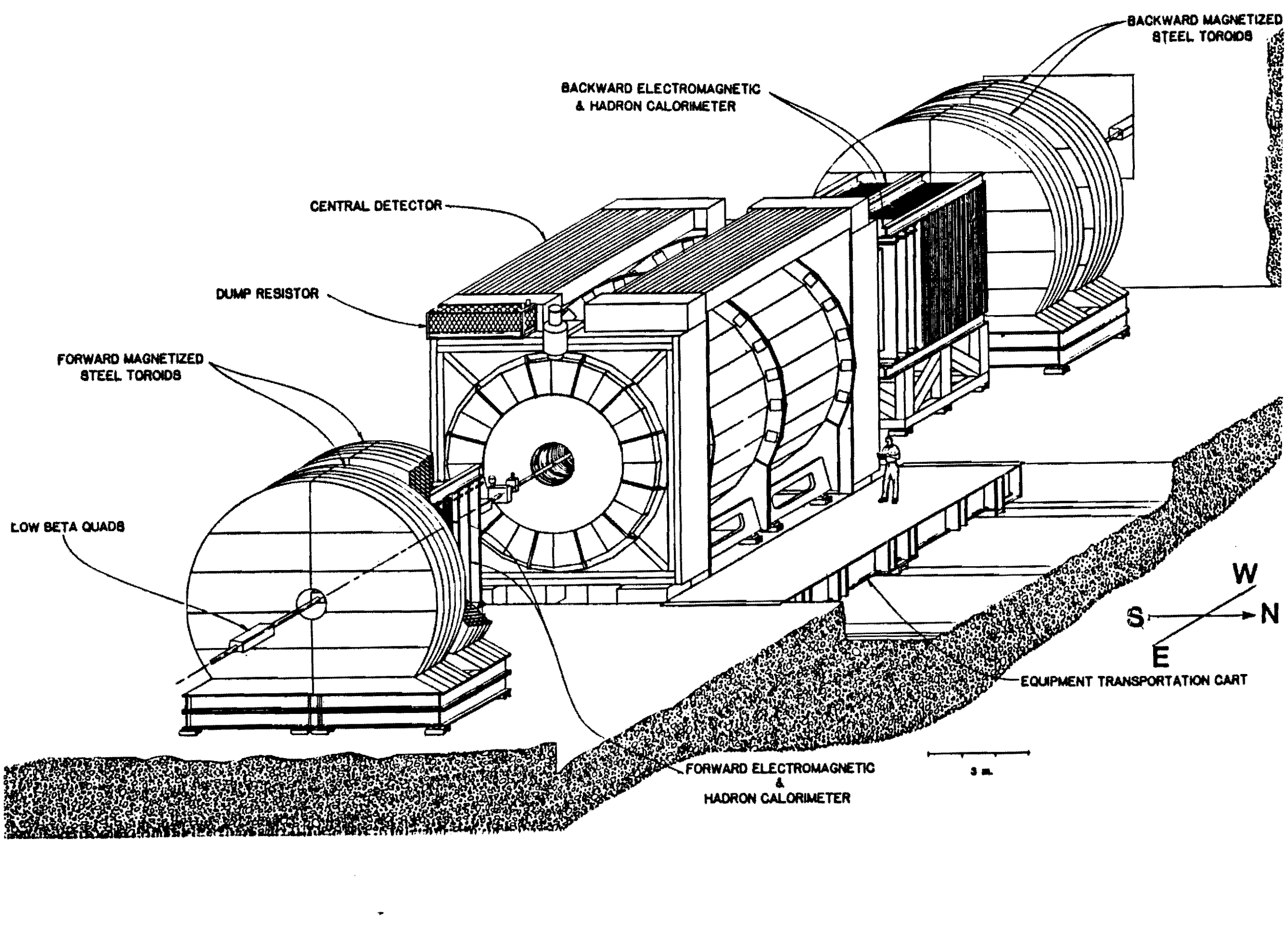

Fig. 5: Vertical section through the Central Detector of CDF

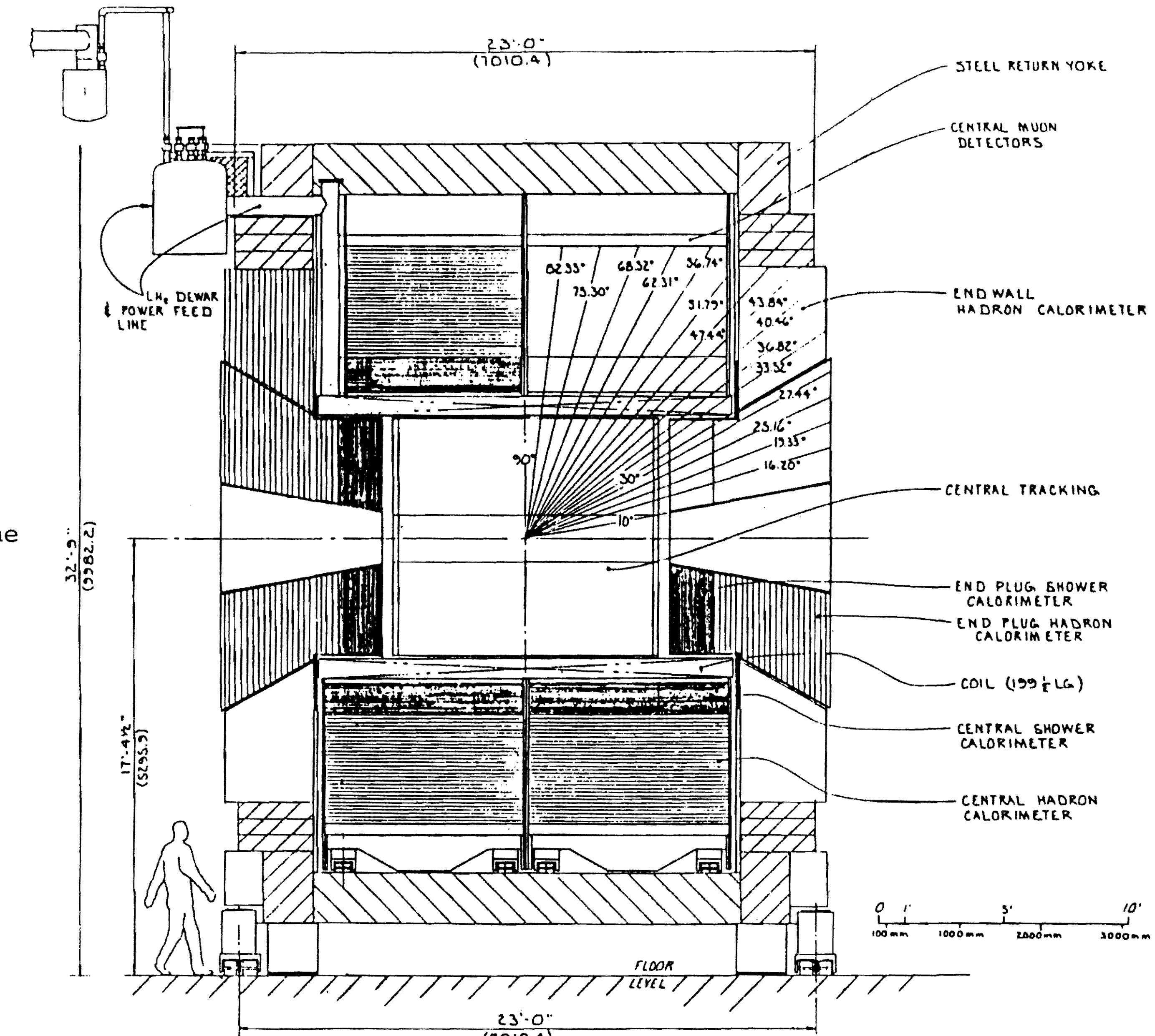

Fig. 6: One quadrant of the core of the Central Detector

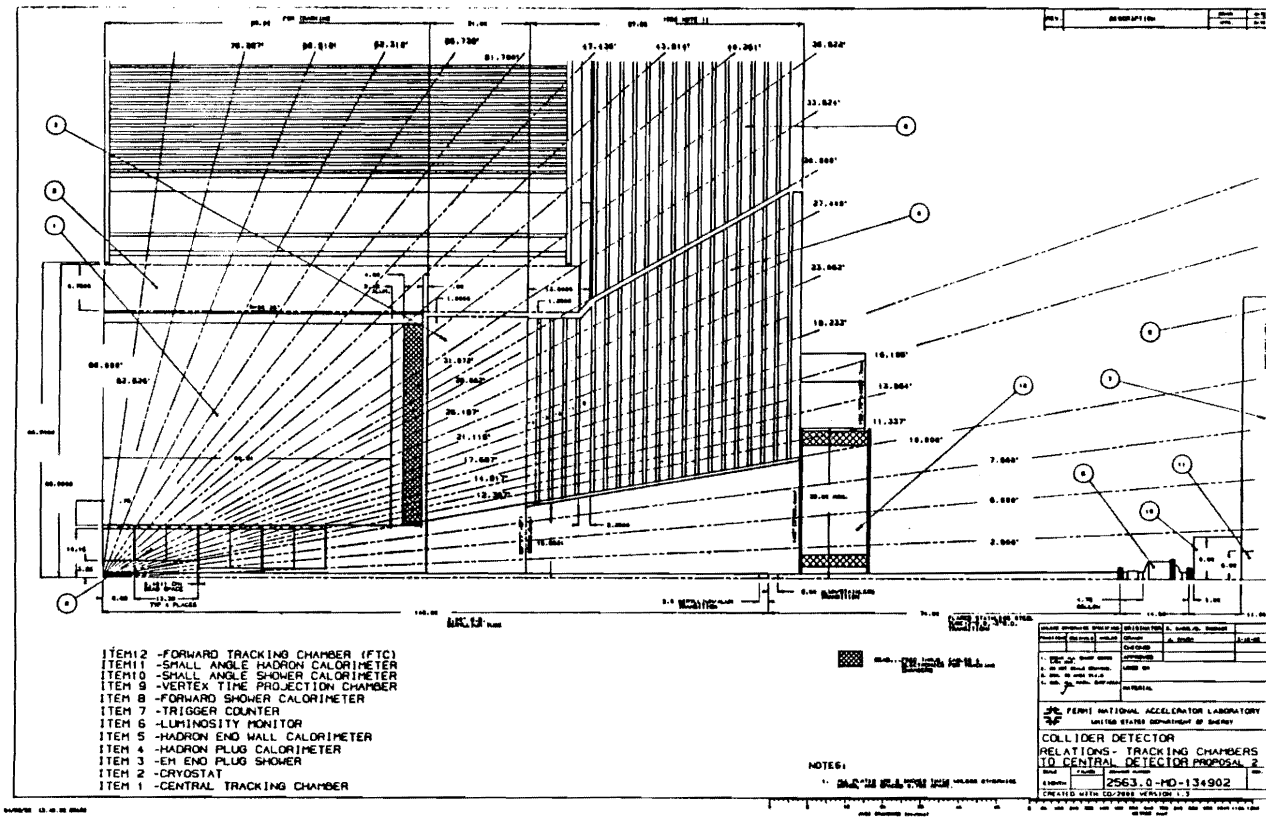

Fig. 7: An elevation view of half of the CDF Detector

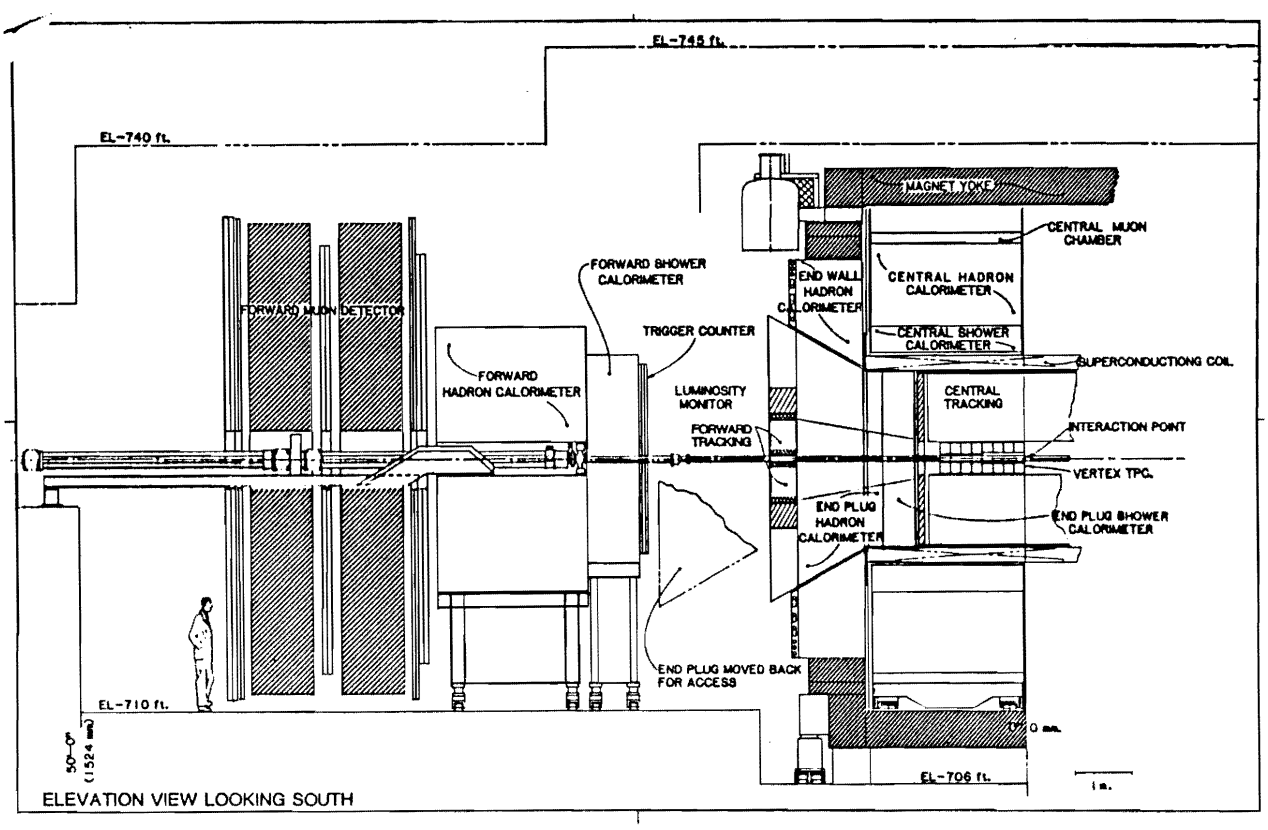

Fig. 8: A plan view of the BØ Experimental Area at Fermilab

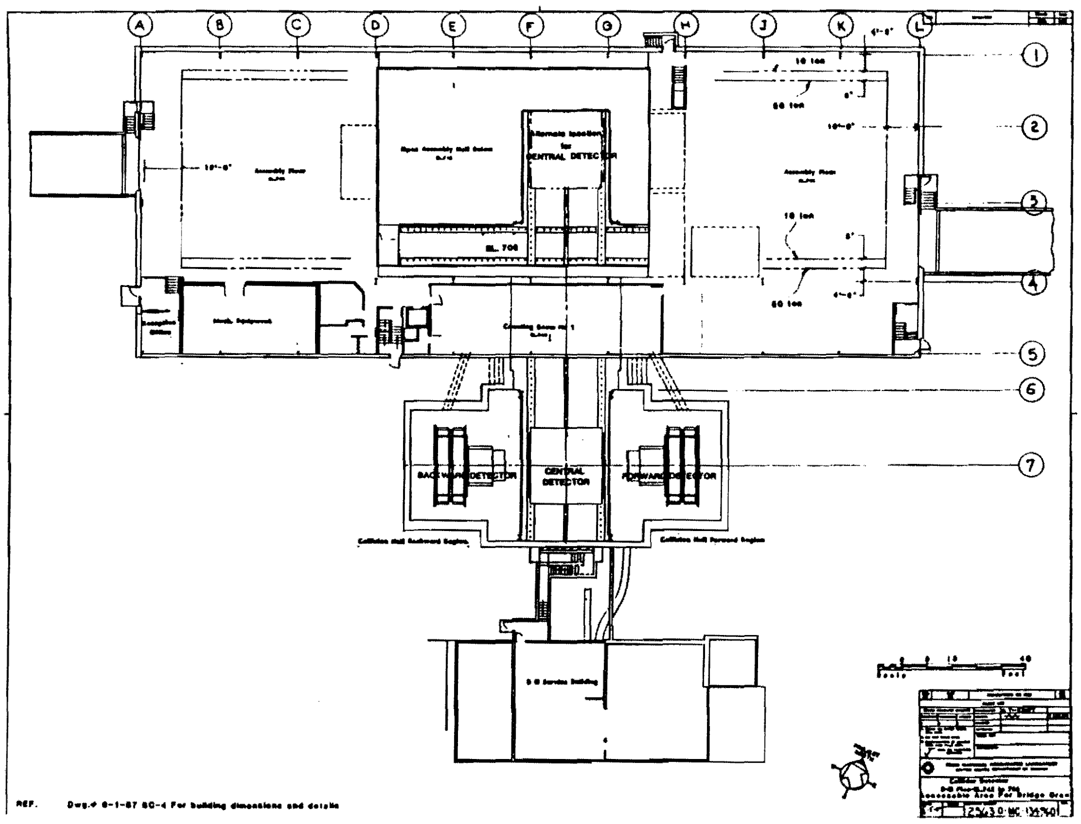

Fig. 9: An elevation view of the BØ Experimental Area

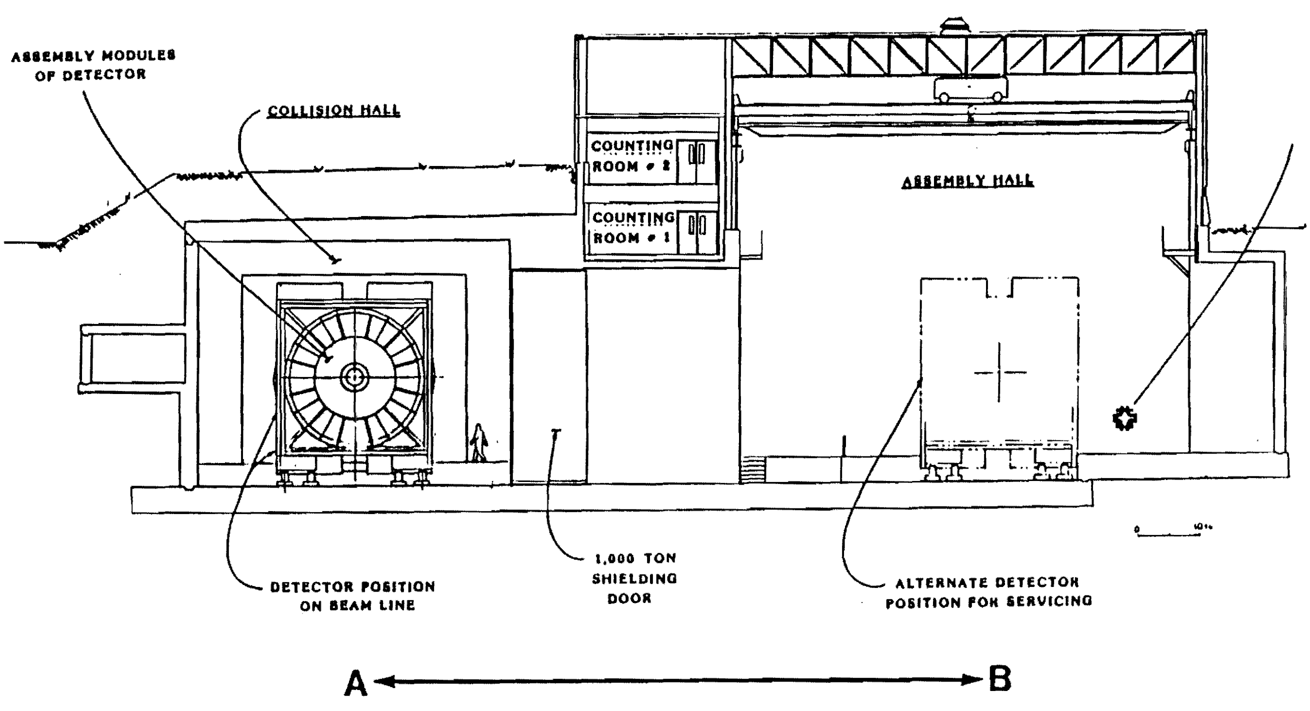

Fig. 10: Endwalls of the Central Detector being fabricated in assembly area - July, 1984

Fig. 11: Completed coil being unloaded from airplane after shipment from Japan - July, 1984

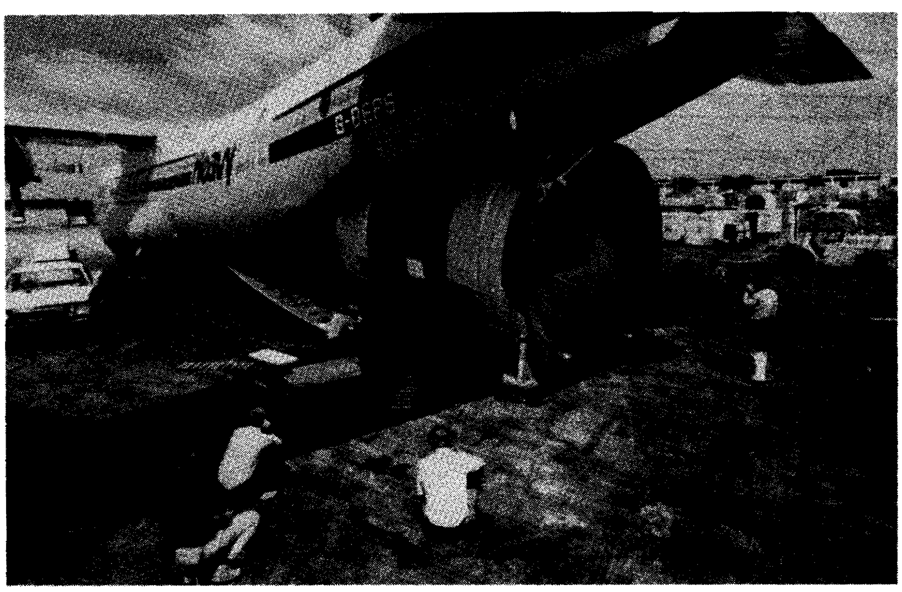

Fig. 12: Coil being inserted between upright endwalls - October, 1984

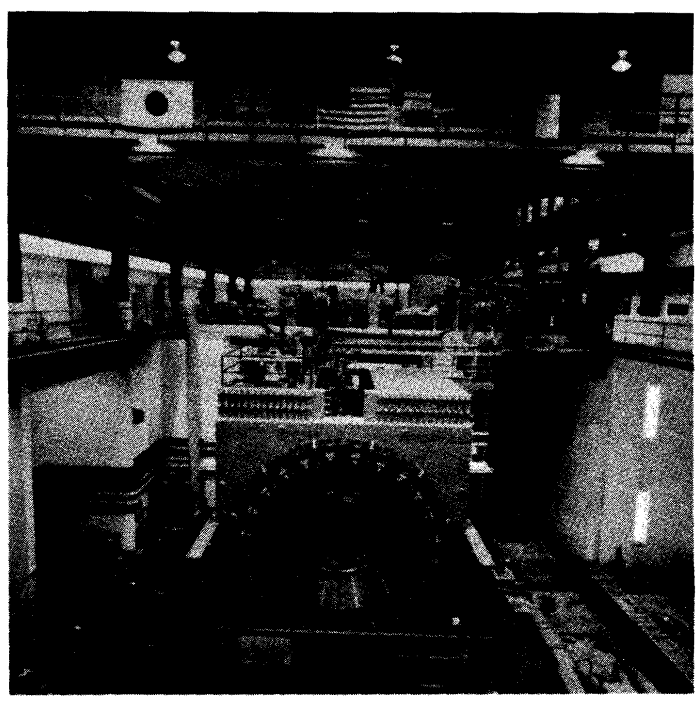

Fig. 13: Completed magnet yoke with endwall hadron calorimeters inserted - December, 1984

Fig. 14: Present state of CDF Detector - March, 1985