THE COLLIDER DETECTOR (CDF) AT FERMILAB - AN OVERVIEW

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CDF, the Collider Detector at Fermilab, is a collaboration of almost 150 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 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 with CDF, lower energy processes can be extrapolated to these higher energies. One such example shown in Figure 1 is large $-p_t$ jet production predicted by QCD. Jets with p_t as large as 250-300 GeV are accessible to experimental study. Another example probing the same energy scale is that of W or Z pair production, shown in Figure 2. Again practical rates should exist for this process at 2 TeV. The increased energy also will yield higher cross sections for single W and Z production by approximately an order of magnitude compared to that now seen at 540 GeV.

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How did we design CDF around these considerations? 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.

What particles do we want to detect? 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 in a tower geometry to detect jets. One of the central calorimeter modules called a wedge is shown in Figure 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 calorimeter towers is sufficient to just 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 unit in y and between 5° and 15° in ϕ. A plot of this granularity is shown in Figure 4. Leptons are characterized by single particles which have different interactions in the various component detectors in 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. Neutrinos are observed by missing energy and momentum. Photon detection is achieved with finely segmented shower counters and the absence of a charged track.

An isometric drawing of CDF is shown in Figure 5. The detector is divided into three main pieces, the Central Detector and two Forward/Backward Detectors. All three pieces are centered on the Tevatron beamline at the B0 collision area at Fermilab. A vertical section through the Central Detector is shown in Figure 6. The heart of the Central Detector is a 1.5 Tesla, 3.0 m diameter, 5.0 m long superconducting solenoid magnet. 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 between 90° and 33° are made of a lead scintillator sandwich read out with wavelength shifter plates and light pipes. A strip proportional chamber has been inserted at a depth of five radiation lengths to provide fine grained information on the shower location. Between 33° and 10° the shower counters are a lead proportional pad chamber sandwich. These chambers are gas filled proportional counters fabricated out of resistive plastic tubes with cathode pad readout. A strip proportional chamber is also provided in these detectors at the shower maximum to provide precision information about shower location. Outside the shower counters are located the hadron calorimeters. In the region between 90° and 30° these calorimeters are made of steel and scintillator read out by wavelength shifter bars and light pipes. Between 30° and 10° the hadron calorimeters are steel and proportional pad chambers. Outside the hadron calorimeters in the region between 90° and 50° 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 penetrating particles. The return legs of the magnet are located above and below the central calorimeters. These central calorimeters are assembled into four arches which surround the magnet cryostat. One of these arches is shown in the photograph labeled Figure 7.

A detailed section of one quadrant of the core of the central detector is shown in Figure 8. The beam pipe is 5 cm in diameter composed of 2 mm Be. Surrounding this in the vicinity of the interaction region are seven small atmospheric pressure VTPC's which have a good r - z tracking ability. The principal roles of the VTPC's are to record the occurence 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. A drawing of one of the VTPC modules is shown in Figure 9. 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 each contain 12 sense wires. These five axial layers are separated by four superlayers of "stereo" wires each containing 6 sense wires. Both axial and stereo superlayers are divided into cells similar to the JADE detector. Each cell is tilted 45° with respect to the radial direction so that the drift direction is predominately circumferential when the magnetic field is 1.5 Tesla. 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.

Located outside the central tracking chamber is the cryostat of the superconducting solenoid magnet. This magnet is being produced in Japan by Hitachi as a collaboration between physicists from the University of Tsukuba and Fermilab. 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 magnets of this type. A detail of this arrangement is shown in Figure 10. The coil was originally wound on a large mandrel. The bobbin which is used to propogate a quench was then slipped over the coil in a shrink fitting operation in which the bobbin was heated then allowed to cool in order to achieve a tight fit. The mandrel was then removed from the coil. This operation was successfully carried out in January of this year.

An elevation view of half of the detector is shown in Figure 11. Particles produced between 2° and 10° pass out of the central detector through a hole in the end plug and enter the forward and backward detectors. The first layer of these detectors is a shower calorimeter composed of alternate layers of lead and proportional pad 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 range as well. Located behind the shower calorimeter is the forward hadron calorimeter. This calorimeter is composed of steel plates instrumented with proportional pad chambers. Small angle muons originating between 2° and 17° will be detected and momentum analysed by the magnetized iron toroids and muon tracking chambers of the forward muon detector located immediately behind the hadron calorimeter.

Overall there are more than 60,000 channels of detector information 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 as close as possible to the detector components. In the case of the central wedges on the actual wedges themselves 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 B0 counting rooms. FASTBUS will be used in the data acquisition system.

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 or 7 microseconds whether to keep the event for digitization. This trigger is derived from analog signals provided by the front end electronics about energy deposited in the shower counters and hadron calorimeters. 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 may 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 level. The three levels are expected to reduce the original rate to approximately 1 Hz. The control, monitoring, calibration, and data logging for CDF will be handled by a system of VAX computers.

A plan view of the B0 experimental area is shown in Figure 12. The collision hall is an underground enclosure 30 m long and 15 m wide located around the Tevatron beam line approximately 15 m below the surface. This is shown in the lower part of Figure 12. 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 of CDF. The assembly hall is a 75 m x 30 m surface building containing a 23 m x 30 m pit at Tevatron elevation where CDF is actually assembled, a 50 ton crane, counting rooms, offices, and shops. An elevation view of the facility is shown in Figure 13. 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 control rooms are located over the tunnel connecting the collision hall and the assembly hall. The detector will be connected to the control room by a flexible cable tray not shown in the figure.

Currently, Fermilab has CDF scheduled for a test run in June 1985 with another run in January 1986. The experimental area at B0 is essentially complete. The low beta quads for the interaction region have been installed and are expected to undergo testing this spring. The coil has been wound, is currently being installed in the cryostat, and is scheduled to be cooled down in April with shipment to the United States expected in June. The assembly of the magnet yoke will begin in the B0 assembly hall pit in April. Production lines for the various assemblies that go into the central wedge modules have been running for almost two years now. Some of these lines have actually finished their work and are beginning to shut down. Assembled wedges are beginning to go to the beam line for final calibration. A diagram showing the assembly pit sequence is shown in Figure 14. We expect to have most of the central detector and parts of the backward detector ready for the June 1985 run. The central tracking chamber and the end plugs cannot be used in this run because two beam pipes will still go thru B0 at that time. The entire detector will be in place for the January 1986 run. The electronics production will be complete by the end of 1986. At that time, we expect to begin sharing beam time with the fixed target experimental program at a fraction that will approach 50%.

Given the time limitations of this talk and the space limitations for the proceedings I have chosen to give an overview of CDF in order to acquaint many of you who are not familiar with the project with the main goals and general design. If you seek more details on various aspects I refer you to the appended bibliography which has served as the source of most of this talk and paper.

CDF Bibliography

1) Design Report for the Fermilab Collider Detector Facility (CDF), CDF Collaboration, August, 1981, Fermilab Internal Document.

2) CDF, Roy Schwitters, Fermilab Reports, September, 1983.

3) Charged Particle Tracking in CDF, M. Atac, et al., CDF Note #178, August 11, 1983.

4) A Radial Drift Chamber, M. Atac and G. Chiarelli, CDF Note #193.

5) Title I Design Report: Colliding Beam Experimental Area at B0 Straight Section, August 28, 1981, Fermilab Internal Document.

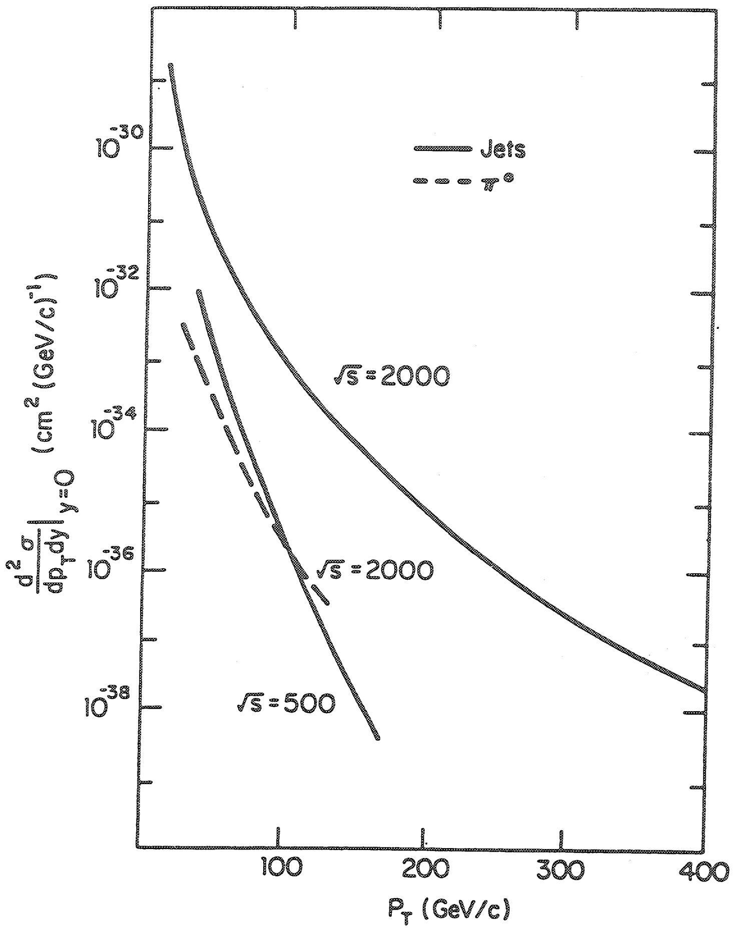
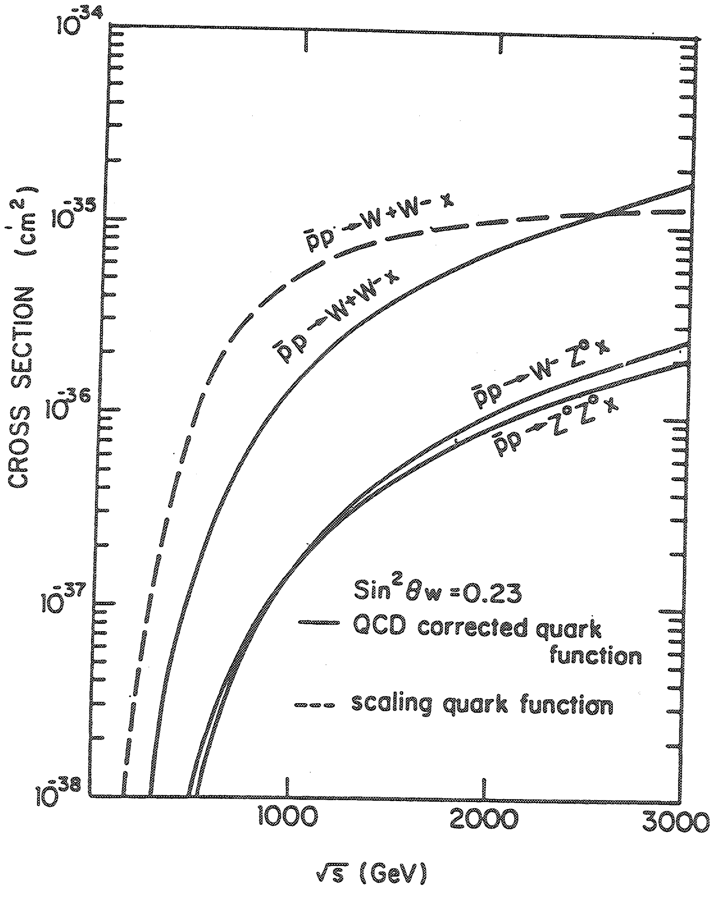


Figure 1: Large p_t jet production predicted by QCD for the Tevatron Collider energy compared with the cross section for lower energy collisions

Figure 2: Predicted production of W and Z pairs



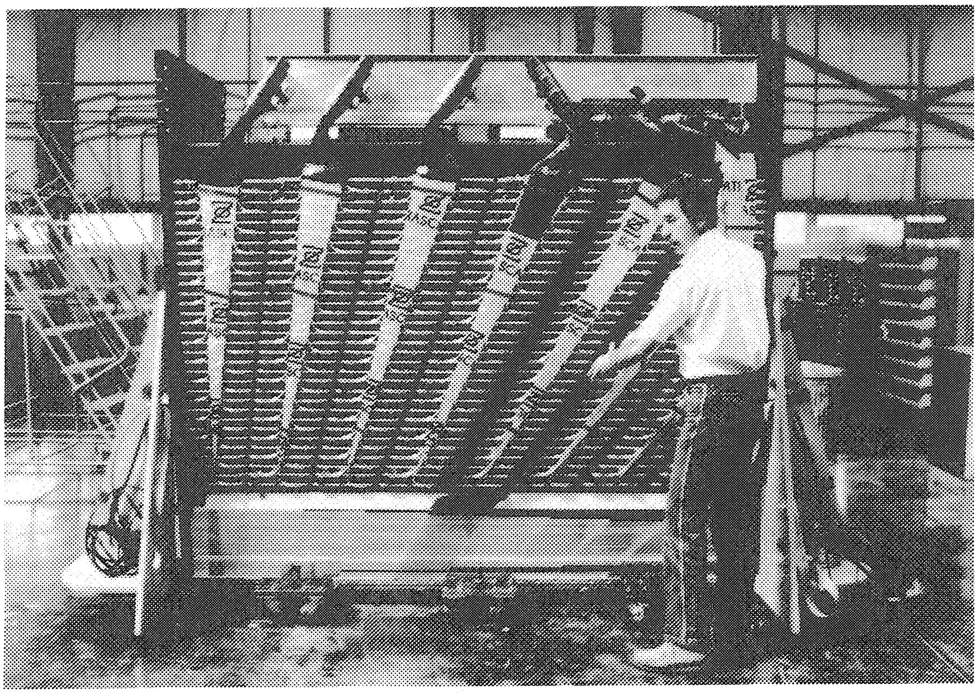


Figure 3: Side view of one wedge module with side skin removed exposing the tower structure

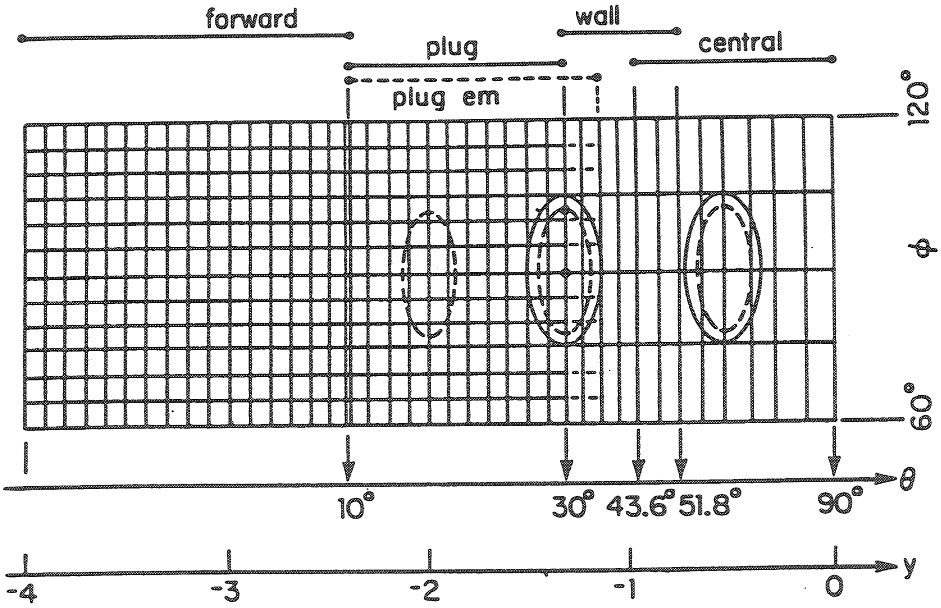


Figure 4: Granularity of the shower counter and hadron calorimeter system

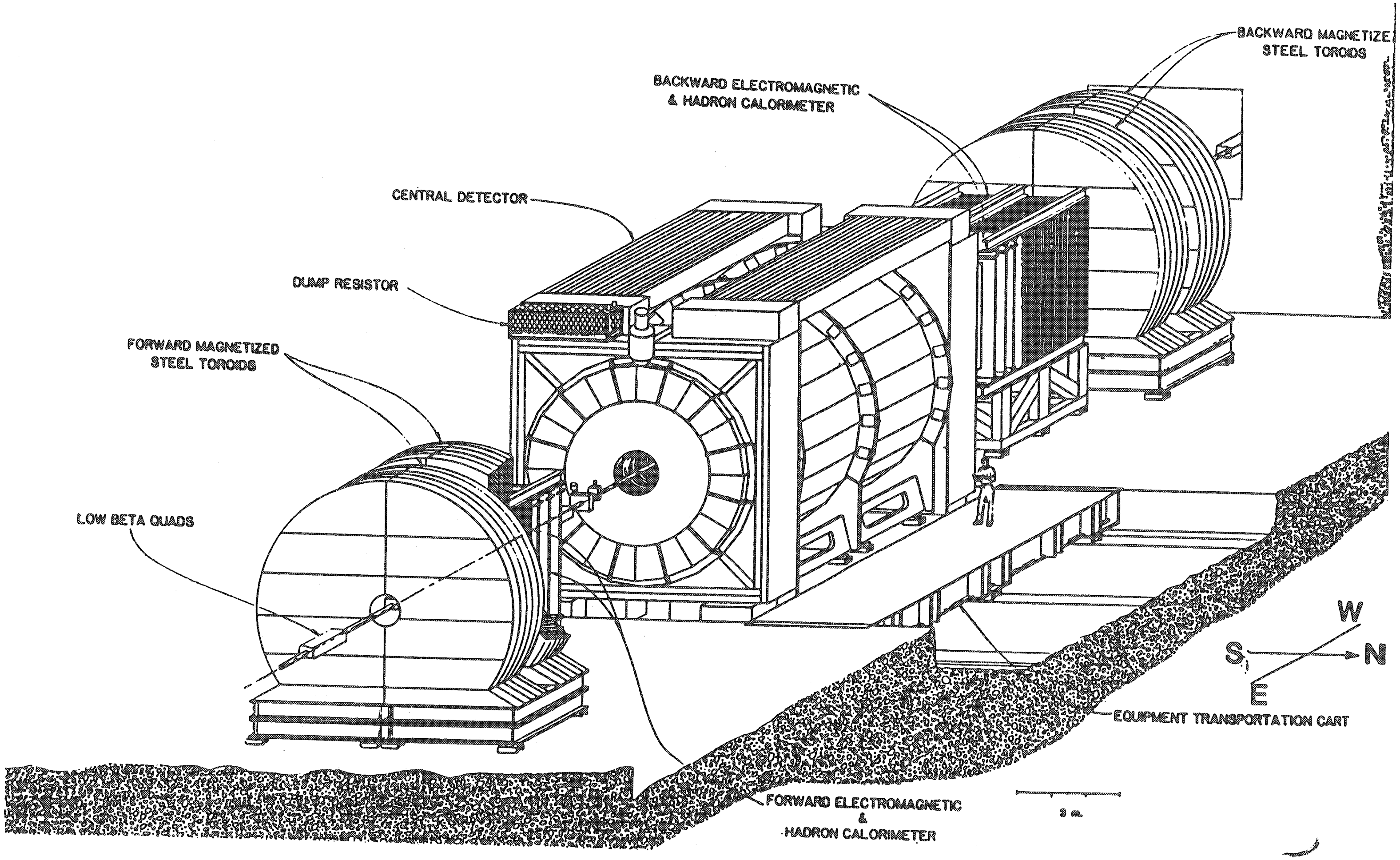


Figure 5: An isometric drawing of CDF

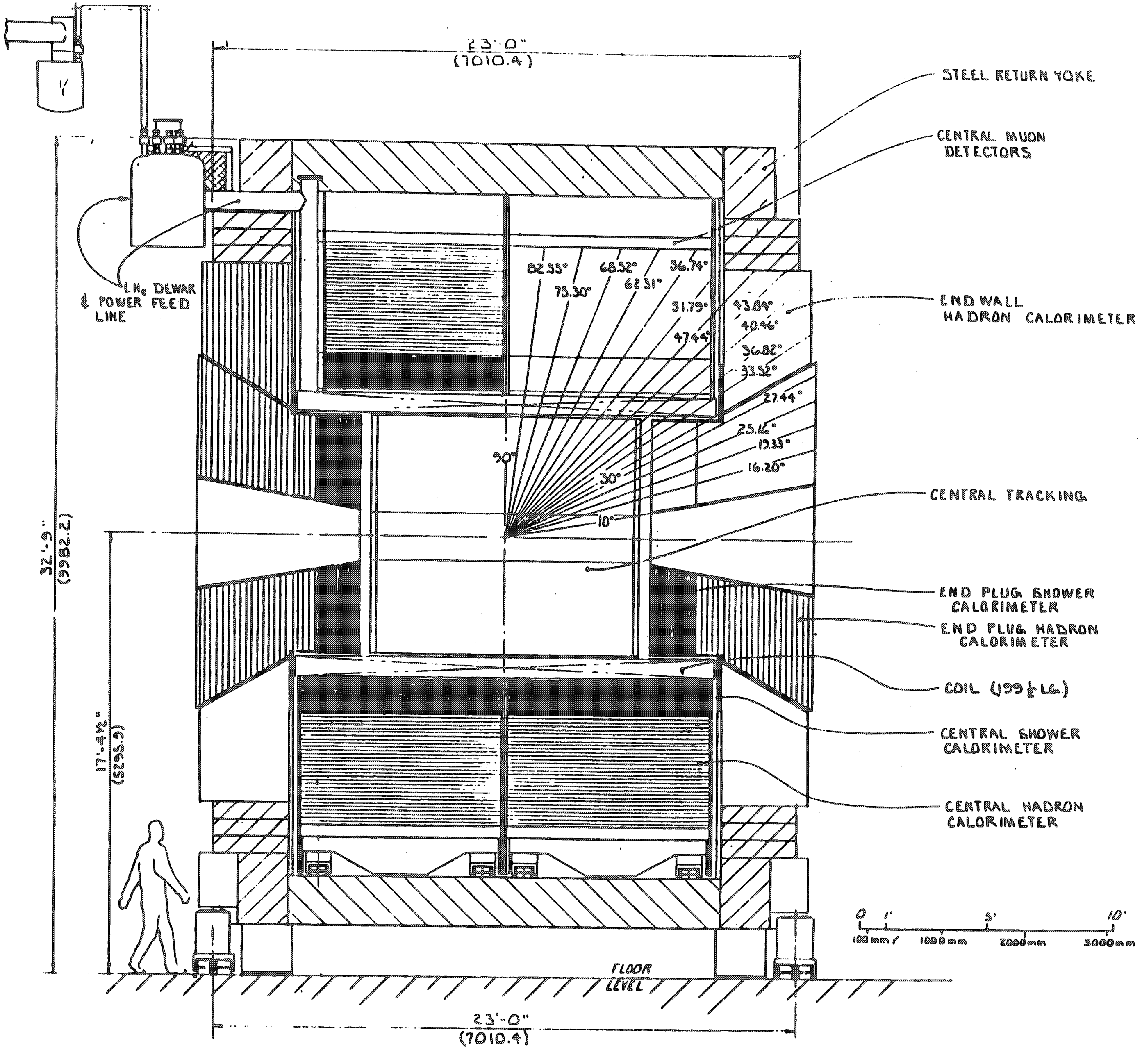


Figure 6: Vertical section through the Central Detector of CDF

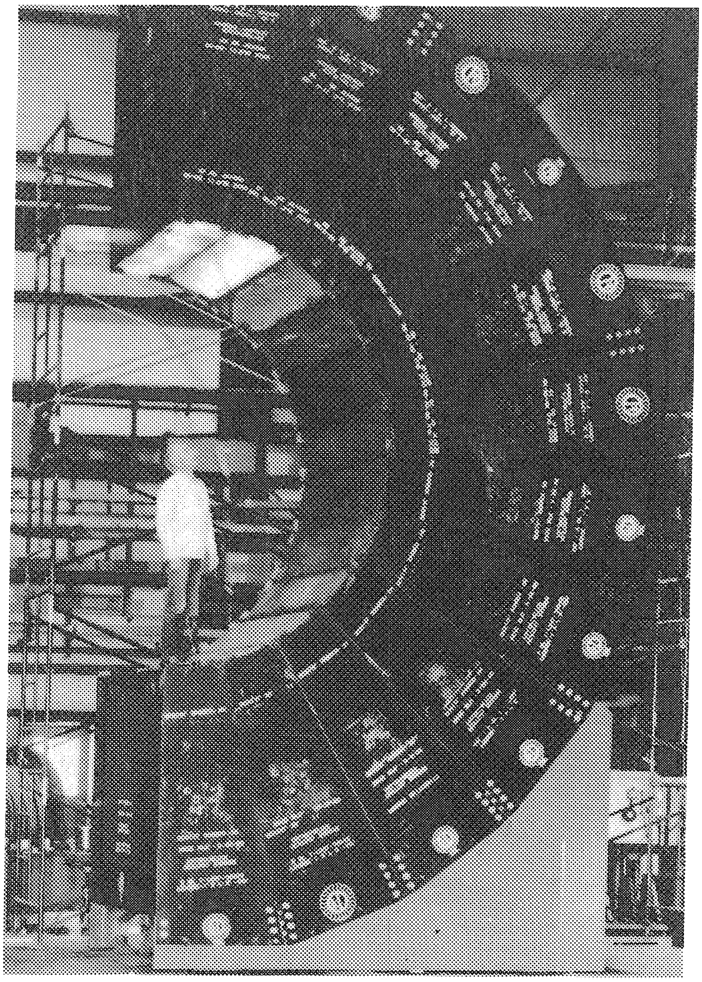


Figure 7:

One of the four central calorimeter arches during a test assembly using partially completed wedge modules

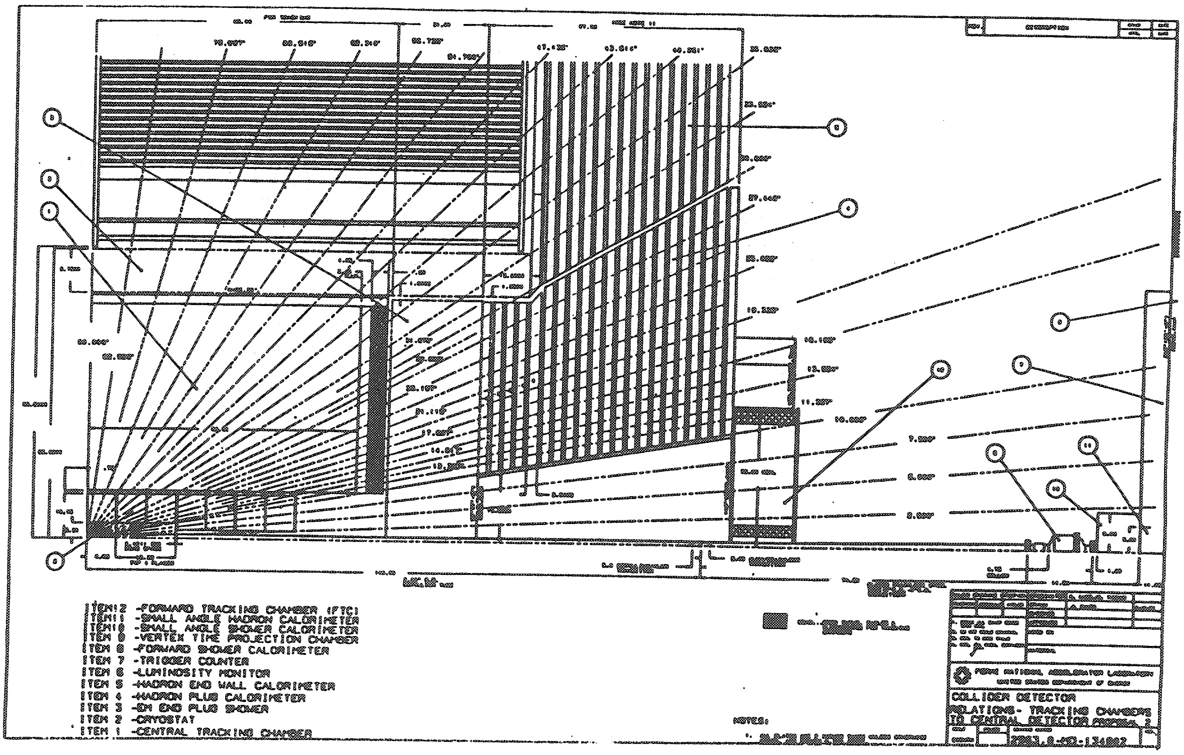


Figure 8: One quadrant of the core of the Central Detector of CDF showing the relationship

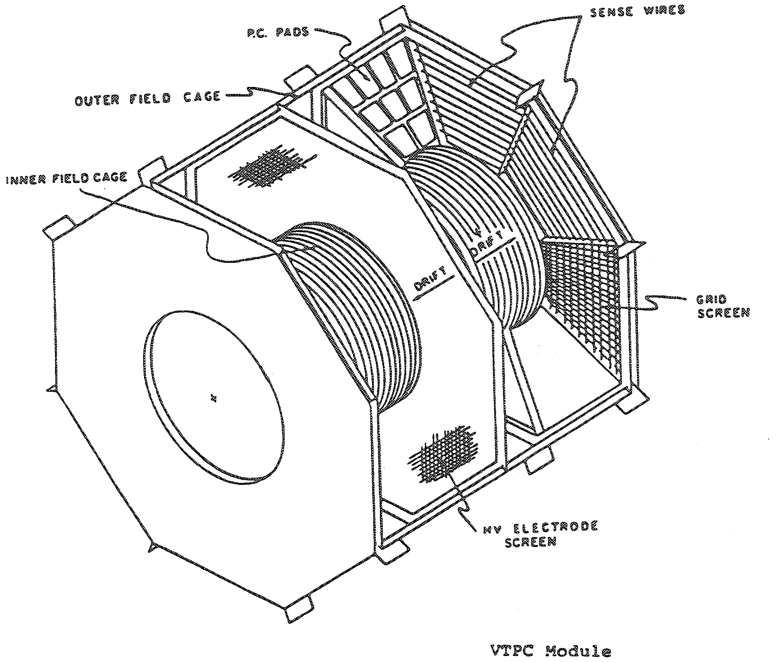


Figure 9: VTPC module of CDF Tracking System

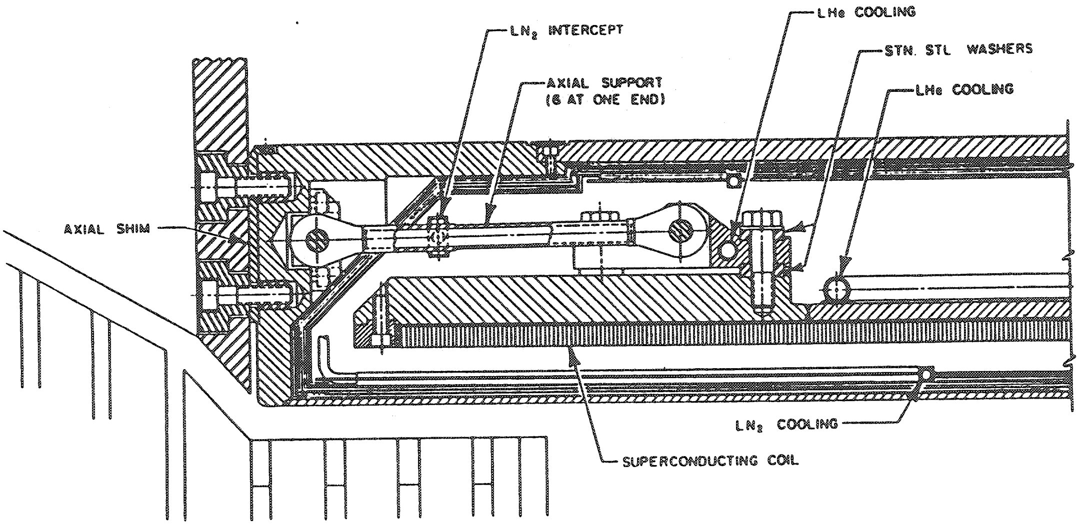


Figure 10: Detail of one end of CDF solenoid magnet

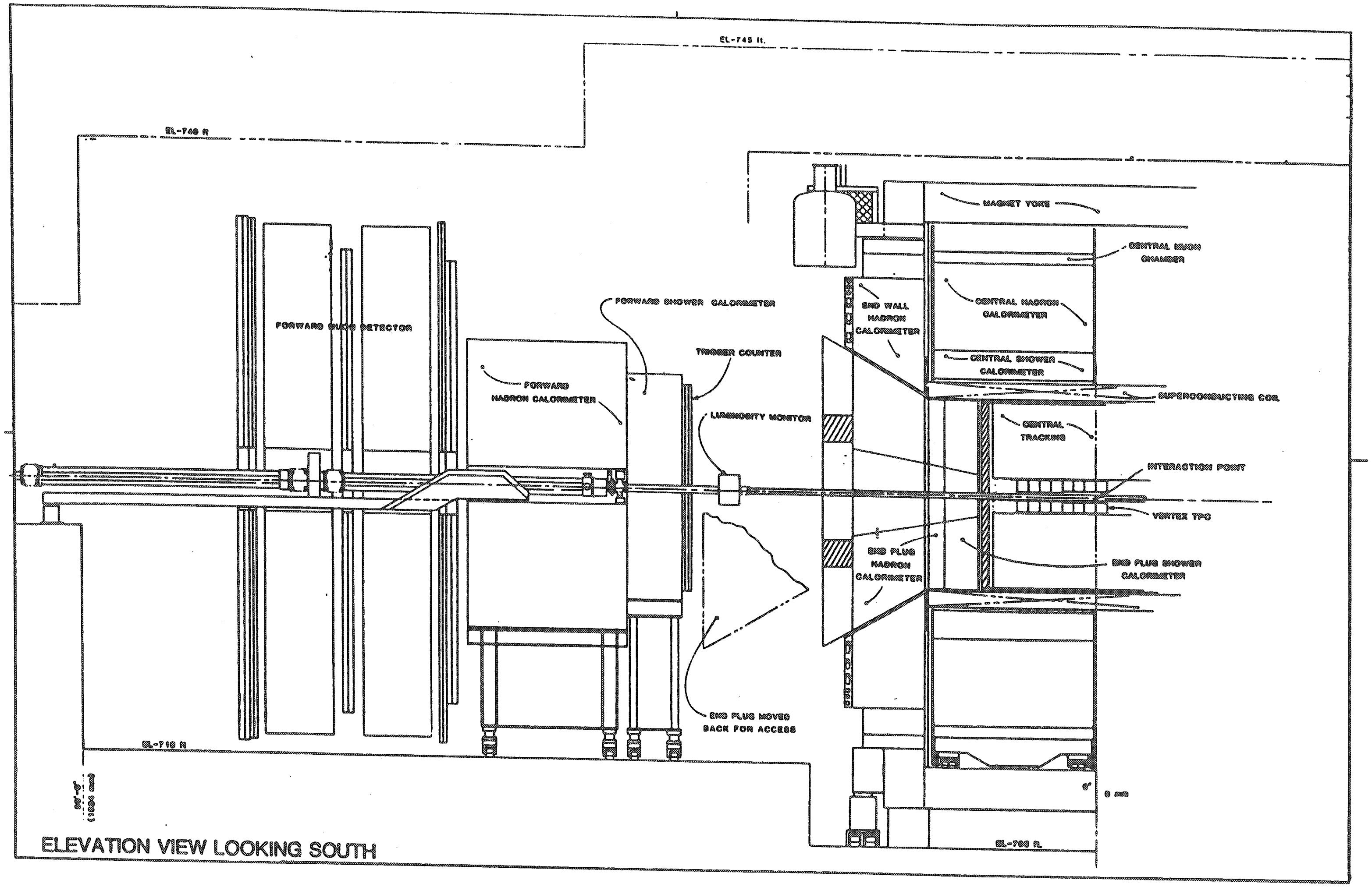


Figure 11: Elevation view of half of the CDF detector

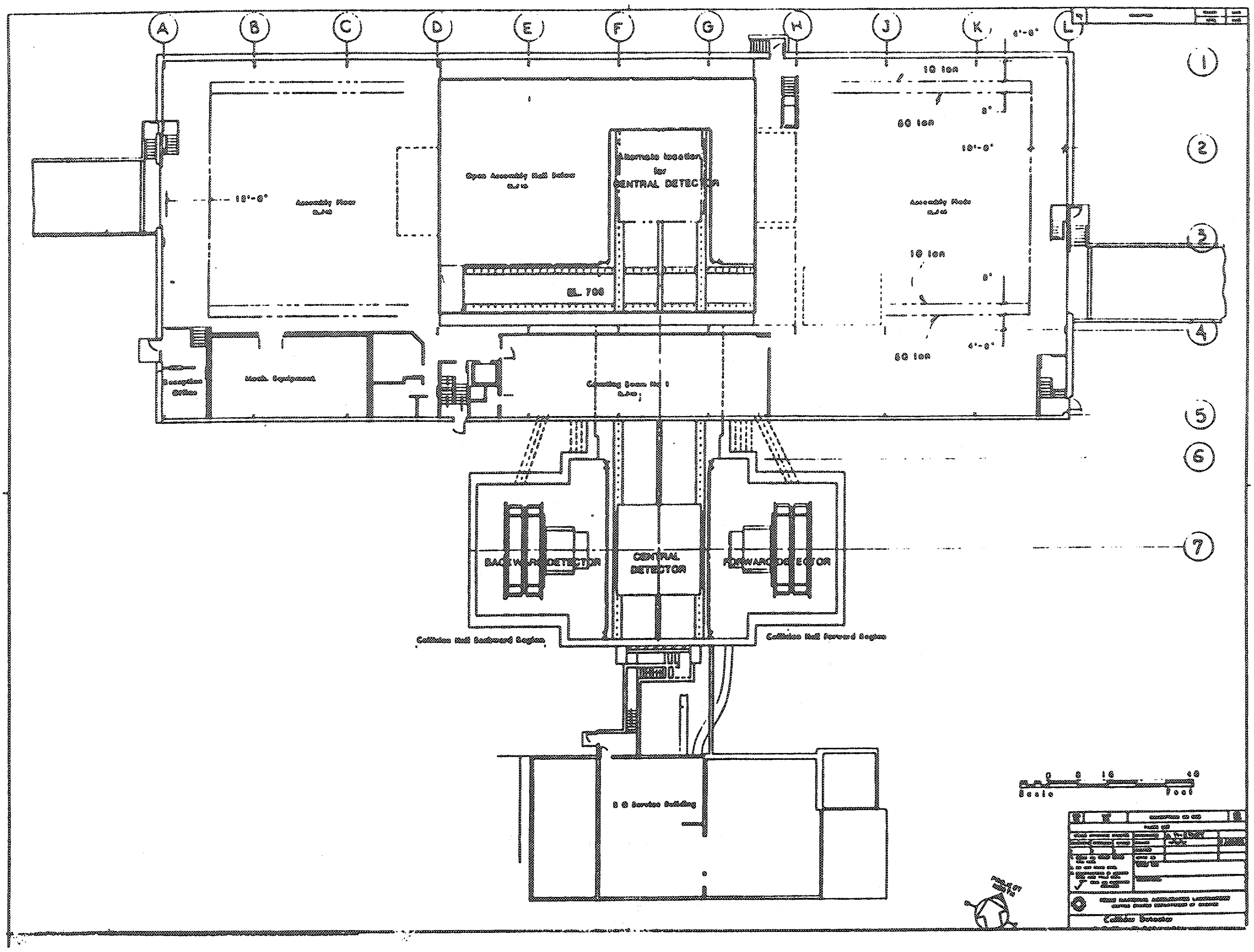


Figure 12: A plan view of the B0 Experimental Area at Fermilab

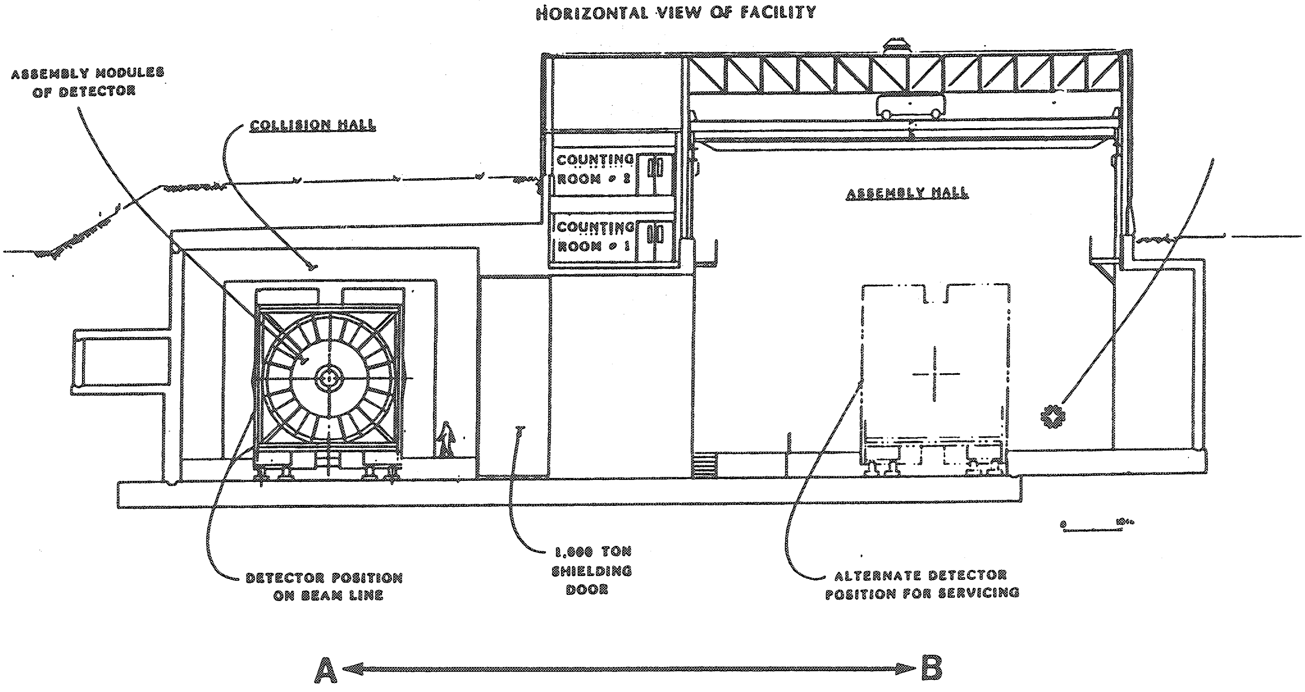


Figure 13: An elevation view of the B0 Experimental Area

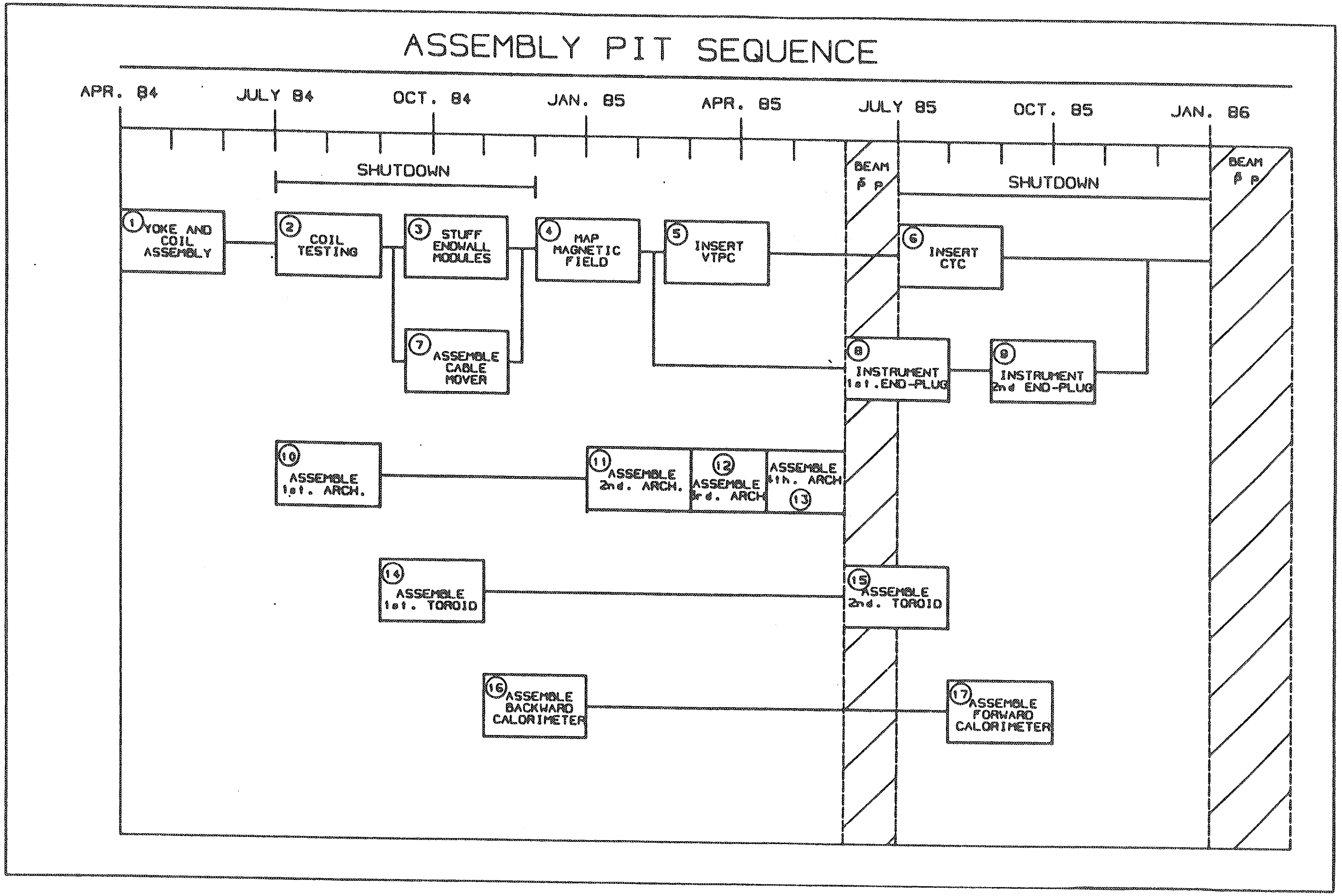


Figure 14: Assembly Sequence and Timetable for mechanical assembly of CDF components in the B0 Assembly Hall