Status Report on CDF*

The CDF Collaboration

CDF Collaboration - June, 1987

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This was the first major run for the complete Collider Detector Facility (CDF) Detector. The object was to test and debug the data-acquisition system and to understand the characteristics of the tracking chambers and the calorimetry sufficiently well to do some preliminary physics measurements. In December of 1986 the CDF Detector was rolled into the collision hall, and the period between December 1986 and March 1, 1987, was spent in the testing and commissioning of the complete system. The major data-taking part of the run took place between March 1 and May 10.

The detector as installed, Fig. 1, was virtually complete in all of its systems with calorimetry and tracking covering the range from 2° to 178°. The central calorimetry system, both hadron and electromagnetic, is formed from scintillation plastic using shifter and phototubes for readout. The calorimetry forward

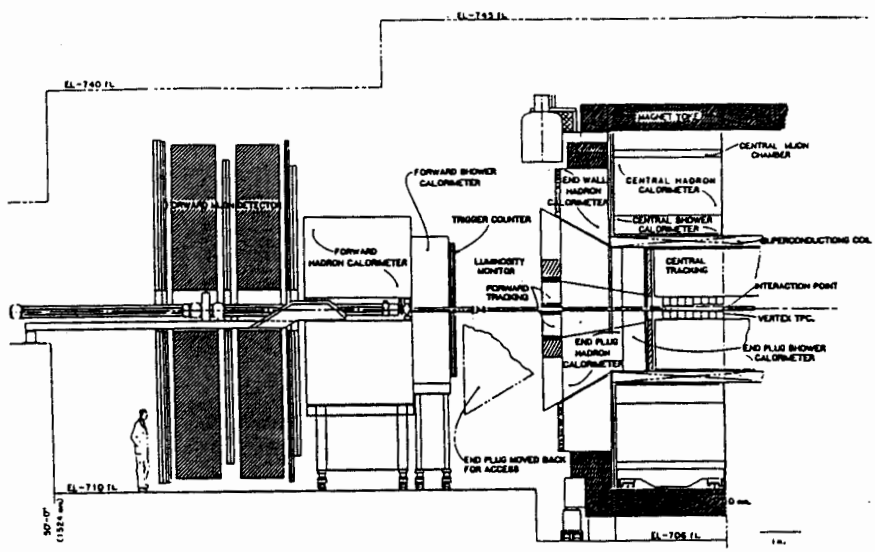

FIG. 1. Side view of the CDF Detector.

of 30° is based upon proportional chambers with resistive plastic walls and strip readout. In all cases the calorimetry is divided into towers in η and ϕ. The ϕ divisions are 15° in the central region and 5° forward of 30°. The division in η are .1 units over the whole range from -4.2 to +4.2. See Table I.

*Excerpted from an invited talk presented by A.V. Tollestrup at Rencontres de Physique de La Vallee d'Aoste on "Results and Perspectives in Particle Physics," La Thuile, Aosta Valley, Italy, March 1-7, 1987.

	Central		Endwall	Endplug		Forward	
	EM	Hadron	Hadron	EM	Hadron	EM	Hadron
$\lvert\eta\rvert$ - coverage	0-1.1	0-0.9	0.7-1.3	1.1.-2.4	1.3-2.4	2.2-4.2	2.3-4.2
Tower size, $\Delta\eta x\Delta\phi$	~.1x0.26	~.1x0.26	~.1x0.26	0.09x0.09	0.09x0.09	0.1x0.09	0.1x0.09
Longitudinal samples in tower	1*	1		1	3 1	2	1
Active medium	Polystyrene scintillator	acrylic scintillator	acrylic scintillator	Proportional tube chambers with cathode readout pads			
Scintillator thickness or proportional tube size	0.5cm	1.0cm	1.0cm	0.7x0.7cm^2	1.4x0.8cm^2	1.0x0.7cm^2	1.5x1.0cm^2
Number of layers	31	32	15	34	20	30	27
Absorber	Pb	Fe	Fe	Pb	Fe	94%Pb, 6%Sb	Fe
Absorber thickness	0.32cm	2.5cm	5.1cm	0.27cm	5.1cm	0.48cm	5.1cm
Typical phototube or wire high voltage	-1100V	-1500V	-1100V	+1700V	+2120V	+1900V	+2200V
Typical phototube or wire gain	$1.2x10^5$	$6x10^5$	10^6	$2x10^3$	$2x10^4$	$5x10^3$	10^4
Typical tower signal	-4pC/GeV	-4pC/GeV	-4pC/GeV	+1.25pC/GeV	1.3pC/GeV	+2pC/GeV	+0.7pC/GeV
Energy resolution $\left(\frac{\sigma}{E}\right)$ at 50 GeV	2%	11%	14%	3%	20%	4.5%	23%
Typical position resolution at 50 GeV	0.2x0.2cm^2*	10x5cm^2	10x5cm^2	0.2x0.2cm^2	2x2cm^2	0.2x0.2cm^2	3x3cm^2
Characteristic total width of azimuthal boundary region	3.5cm	4.1cm	3.8,8.9cm alternating	0.9cm	0.8cm	0.7cm;3.2cm**	1.3cm;3.2cm**

*An imbedded proportional tube chamber at shower maximum gives some additional information. The quoted position resolu tion is measured with this chamber.

**The first number is for the vertical boundary, the second for the horizontal.

Table I.

The tracking chamber, installed just before the detector rolled into the collision hall, performed beautifully. In addition to the central tracking chamber, which covers an angular region of about 30° to 150°, there is the vertex time projection chamber located close to the beamline, whose primary function is to identify the vertex and give an RZ view of the event tracks. There is also a forward tracking chamber located outside of the 10° hole in the forward end plug which provides track information between 2° and 10°. These various tracking chambers are all identified in Fig. 1.

In addition to testing the complete data-acquisition system and commissioning the tracking, it was hoped that enough luminosity from the run would be available to explore new regions in high-energy collider physics. Initially, it was determined that an integrated $\mathcal{L}$ of 100 inverse nanobarns would not only open up new areas in jet physics that had not yet been explored at CERN, but would also give a good sample of W's and Z's. The predicted counting rate in

the central plus end plug region of the detector for W's is a little bit more than 1 per inverse nanobar, and the acceptance for $Z^o \rightarrow e^+ e^-$ is only about 8% of this number. Finally, sufficient time to do a preliminary study of low p_T physics with good statistical accuracy was included in the run plan.

The detector was rolled into the collision hall during the week of December 12-15. The period from January 1 to March 1 was spent in commissioning both the machine and the detector. Operation required a crew of seven people who were scheduled in eight-hour shifts, and during this period we not only studied the various components of the detector, but we also did extensive training of physicists in the operation of all the systems.

After March 1 it was deemed that the detector and the machine were working well enough so that one should start on the data collection phase of the experiment. During this period we collected over 30 inverse nanobarns of data on tape. The trigger was varied during the run to accommodate the slowly increasing luminosity that the Accelerator was able to deliver. The simplest trigger was one in which all channels of the detector were read out in every beam crossing. This gave an unbiased data set for estimating luminosity and for studying any biases imposed when the beam-beam counters were included in the trigger. A number of runs triggered by simple coincidences between the arrays of beam-beam counters on the two sides of the experiment were taken for studying minimum bias events. About 40,000 such events were accumulated. Figure 2 shows the uncorrected single particle p_T spectrum from some of these runs.

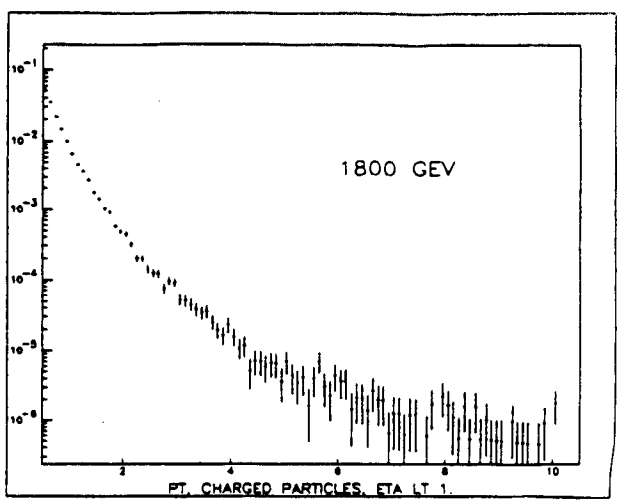

FIG. 2. Uncorrected single particle p_T spectrum obtained from a sample of minimum bias data.

Each calorimetry channel in the detector is equipped with a fast analogue readout; these are assembled into a trigger tower array for use in the level-1 and level-2 triggers. Most of the run was taken by simply setting a threshold level for E_t in a tower and a threshold on the sum of the E_t for those towers over threshold. These thresholds could be individually set for both electromagnetic and hadron calorimetry towers. Near the end of the run we started to commission the level-2 trigger which will enable one to trigger on clusters of energy rather than simply total E_t. This trigger, although installed, was not actually used during the data taking.

Complementing the calorimeter-based trigger was a fast track processor used for identifying high p_T particles and operated by defining roads through the central tracking chamber by means of prompt hits. These stiff tracks, once identified, could be placed in coincidence with the appropriate individual cell of the muon system located around the outside of the central calorimeter. This trigger was debugged and worked satisfactorily at the luminosities achieved in the present run. The forward muon system was also studied extensively, but its trigger rate was still too high during the run to include it in the trigger without prescaling.

It was observed that the gas calorimetry occasionally recorded a very large energy loss in a single tower. Further study indicated that the signal was being deposited in only a single layer of the calorimeter and was not associated with the high-energy track or a hadron shower. These large pulses were observed in all four of the forward gas calorimeters: the end plug electromagnetic and hadron, and the forward electromagnetic and hadron calorimeters. The electronic gains and the sensitivity of these chambers were all different, and the severity of the problem correlated with the individual characteristics of the system. The source of these pulses will be studied in the test beam this coming summer, and an attempt will be made to clarify the exact cause of the phenomena observed. It is postulated that the effect arises from the low-energy np collisions for which the cross section is approximately $4.4/\sqrt{E}$ barns. The energy loss of a proton in a typical gas calorimeter proportional tube can be 1 MeV compared to 1 or 2 kilovolts from a minimum ionizing particle crossing the tube. Thus, a proton can mimic several hundred track crossings and erroneously indicate a rather large shower energy. Since such effects occur only in a single layer of the calorimeter, it is not hard to identify such processes and eliminate them from the data, provided the calorimetry is subdivided in depth by connecting alternate layers to different digitizers.

The offline data-analysis programs exist and systematic analysis of the data is underway. Samplings of the data taken during the run have turned up a number of candidates for W and Z meson decays. In addition, a large number of QCD jet events were observed, some with E_t's of greater than 150 GeV.

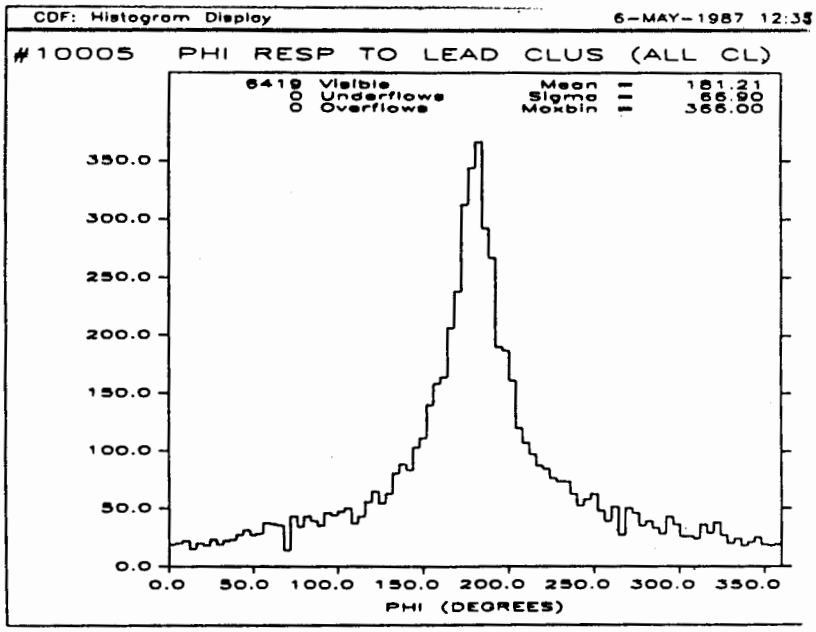

FIG. 3. ϕ distribution for all non-leading clusters relative to the leading cluster shown in Fig. 4.

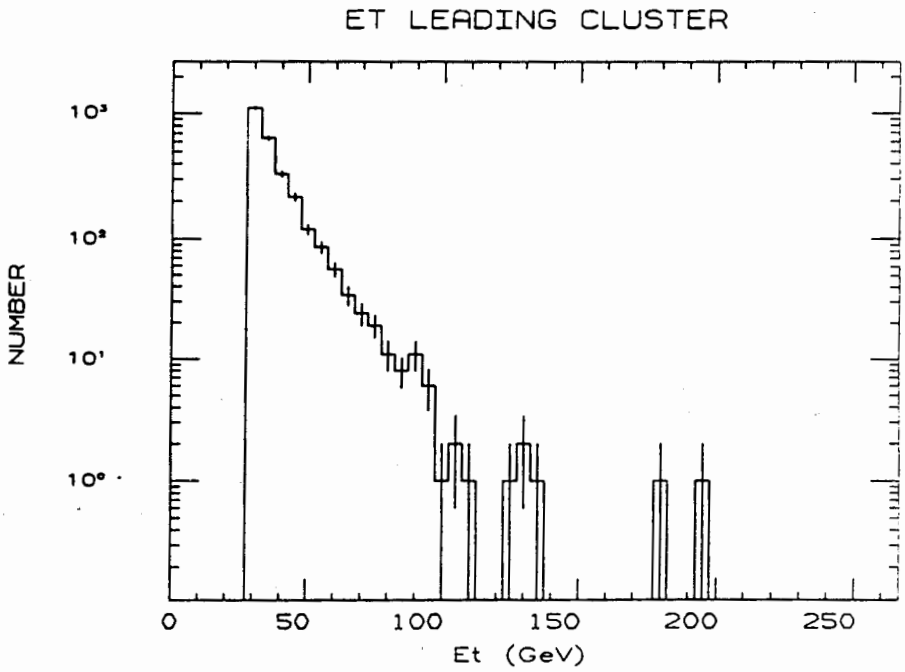

FIG. 4. Distribution of the observed E_t for the leading cluster in data about 1.5 nb^{-1}.

In Fig. 3 we show the azimuthal spectrum of all non-leading clusters relative to the leading one. The peaking in azimuth at 180° is clearly seen. Figure 4 shows the E_t spectrum of the leading cluster in a small sample of the data. The clusters are defined in a jet algorithm whose parameters are still being investigated. The spectrum is not corrected for acceptance, but it does give an indication of the quality and range of data that will eventually be available from this run.

The next run for colliding beams will start near the end of 1987 after the fixed-target running is finished. The improvements will involve installing the remaining chambers in the forward/backward hadron calorimeters and implementing the level-2 trigger. Additional work on shielding the detector from radiation from the Main Ring is necessary in order to completely commission the muon system.

The run was very successful, and this is perhaps an appropriate place to thank our colleagues in the Accelerator Division who helped make it possible.

Approved Fermilab Fixed-Target Experiments by Category

As compiled by the Fermilab Program Planning Office

Exp. #	Physics Objectives	Status
(Electroweak)		
E-632 (Morrison/Peters)	15-ft. Bubble Chamber exposure to wide-band neutrino beam.	Took 154K conventional pix and 111K holograms in 1985 run. Will run again in 1987 with improved holography.
E-665 (Kirk)	Target fragmentation in deep-inelastic muon scattering with proton and nuclear targets.	Beam and parts of detector were tested in 1985. Initial data run set to begin in 1987.
E-733 (Brock)	Weak neutral currents and same-sign dimuons in neutrino interactions in a fine-grained detector.	Took approx. one-half data in last run. Ready to continue in 1987.
E-745 (Kitagaki)	1-meter bubble-chamber exposure to wide-band neutrino beam.	Took 190K conventional pix last run and 60K holograms. Are installing new, larger B.C. for 1987 run.
E-770 (Smith)	High statistics study of nucleon structure functions and same-sign dimuons in neutrino interactions.	Had a data run in 1985 as E-744 and will continue in 1987.
(Decays and CP)		
E-731 (Winstein)	A precision measurement of the CP violating parameter ε'/ε in the neutral kaon system.	Ready for primary data run. Had initial tests and data in last run. Accumulated 15K events.

Exp. #	Physics Objectives	Status
E-756 (Luk)	Measurement of the magnetic moment of the Ω^- hyperon.	Installing experiment at present time. Should complete data run in 1987 run.
E-761 (Vorobyov)	Study of rare hyperon radiative decays.	To be set up in the P-Center hyperon beam on completion of E-756
E-773 (Gollin)	Measurement of the phase difference between η_{00} and η_{+-}.	Tentatively scheduled for 1989.
E-774 (Crisler)	Search for short-lived particles in an electron beam dump.	Tentatively scheduled for 1988.
(Heavy Quarks)		
E-653 (Reay)	Study of charm & beauty production in a hybrid emulsion spectrometer.	Took 5.2M triggers in the 1985 run. Ready to resume data-taking in 1987.
E-687 (Butler)	Photoproduction of charm and beauty in wide-band photon beam.	Beam was tested in 1985 run as well as some parts of the detector. Data-taking to start in 1987.
E-690 (Knapp)	High-rate study of charm and bottom production using pipeline trigger processor.	Recently moved from BNL to FNAL. Installation to begin in 1987.
E-769 (Appel)	Hadronic production of charm by kaons and pions in nuclear targets.	Modifying E-691 apparatus for data run in 1987.
E-771 (Cox)	Beauty production associated with dimuons.	First run scheduled for 1988.

Exp. #	Physics Objectives	Status
(Hard Collisions)		
E-672 (Zieminski)	Study of hadronic final states in association with high-mass dimuons.	Setting up with E-706 for first run in 1987.
E-704 (Yokosawa)	Polarized proton beam experiments to measure $\Delta\sigma_L$ among other things.	Ready for detector calibration and test at end of 1987 run.
E-705 (Cox)	A study of charmonium and direct photon production in antiproton, proton, and pion interactions.	Shakedown run in 1985. Set for data run in 1987.
E-706 (Slattery)	Direct photon production by hadrons yielding gluon structure functions of protons.	Setting up for initial run in 1987.
E-711 (Levinthal)	Constituent scattering in P+N collisions.	Initial shakedown run occurred in 1985. Primary data run to be in 1987.
E-760 (Cester)	Production of charmonium states in antiproton accumulator.	To begin testing in 1987. First data in 1988 fixed-target run.
E-772 (Moss)	Study of nuclear anti-quark sea in P+N collisions $\rightarrow$ dimuons.	Uses E-605 detector. Ready for initial run in 1987.