# CDF Progress Report

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and
the CDF Collaboration

The first data run for CDF (the Collider Detector at Fermilab) took place during January-May 1987. The run served as an engineering run for the TEVATRON Collider and for the complete CDF detector. This progress report reviews the TEVATRON performance, the CDF detector performance, and some preliminary physics at 1.8 TeV.

Figure 1 shows the gain in peak luminosity during the run to a final value of about 1.5 x $10^{29}$ $cm^{-2}$ $sec^{-1}$. An integrated luminosity total of about 74 $nb^{-1}$ was delivered and 34 $nb^{-1}$ was written to tape (see Fig. 2). These luminosity values have an uncertainty of ±20%. More than 900 hours of pbar-p collisions took place (see Fig. 3), and we had access to the detector only eight times during this

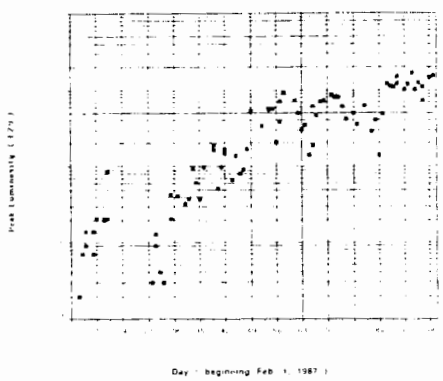

*Figure 1. TEVATRON peak luminosity ($10^{29}$ $cm^{-2}sec^{-1}$) for February 1 - May 11, 1987. Each point represents a separate pbar-p store.*

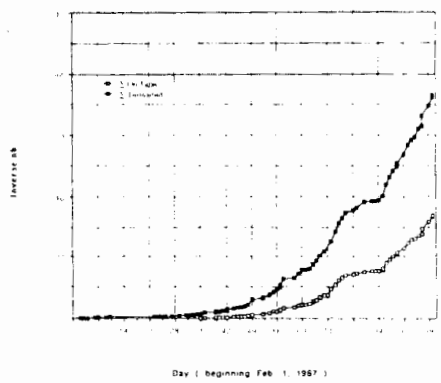

*Figure 2. The integrated luminosity ($nb^{-1}$) versus time for the 1987 run. The solid squares are delivered luminosity, and the open squares are the luminosity written to tape.*

# The CDF Collaboration

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## CDF Member Institutions

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[f] Harvard University- [g] University of Illinois- [h] KEK, Japan
[i] Lawrence Berkeley Laboratory- [j] University of Pennsylvania
[k] INFN, University and Scuola Normale Superiore of Pisa, Italy- [l] Purdue University
[m] Rockefeller University- [n] Rutgers University- [o] Texas A&M University
[p] University of Tsukuba, Japan- [q] University of Wisconsin

## Visitors

[1] Oxford University, England- [2] Saga University, Japan
[3] ICRR, Tokyo University, Japan- [4] CEN, Saclay, France-
[5] Haverford College, Haverford, PA.

period. By the end of the run the typical "day" consisted of a 4- to 8-hour set-up time for antiproton transfer, followed by a 12- to 20-hour Collider store with a luminosity lifetime of around 8 hours.

Figures 4, 5, and 6 show several views of the CDF detector. A 1.5 tesla superconducting solenoid surrounds two charged-particle tracking systems, a vertex TPC and a central drift chamber. Outside the coil, electromagnetic and hadronic sampling calorimeters point in tower geometry towards the nominal interaction point. In the central and endwall calorimeters the active medium is scintillator; the endplug and forward calorimeters use proportional tube chambers with cathode pad readout. The electromagnetic calorimeters use lead plates as the absorber and the hadronic calorimeters use steel. Muon drift chambers surround the central region calorimeters and solenoid, and a system of magnetized steel toroids and drift chambers detects forward muons.

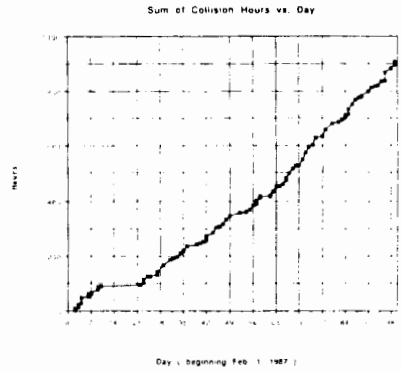


*Figure 3. Hours of Collider running during 1987.*

The detector was essentially complete for this run with the exception of: (1) half of the sampling planes in the forward hadron calorimeter, (2) a Level-2 trigger system for cluster triggers and track matching, and (3) a Level-3 trigger system of microprocessors and the associated full-rate data acquisition system. The data acquisition system and online software performed satisfactorily, reading out nearly 70,000 channels via FASTBUS. The front end electronics reliability was such that less than 1% of the channels were dead at any time. Routine procedures were established for monitoring, pedestals, and calibration. This included $Cs^{137}$ sources, a laser flasher, a Xenon flasher, and an LED flasher for the scintillator calorimeters, and a gas gain monitoring system of proportional tubes with $Fe^{55}$ sources for the gas calorimeters. The gas gain system ran continuously and the gain constants were downloaded every two hours (if necessary) into the trigger and readout electronics.

A standard trigger mix was established with a ~1 Hz rate @ 90% livetime. This "Level-1" trigger consisted of the following:

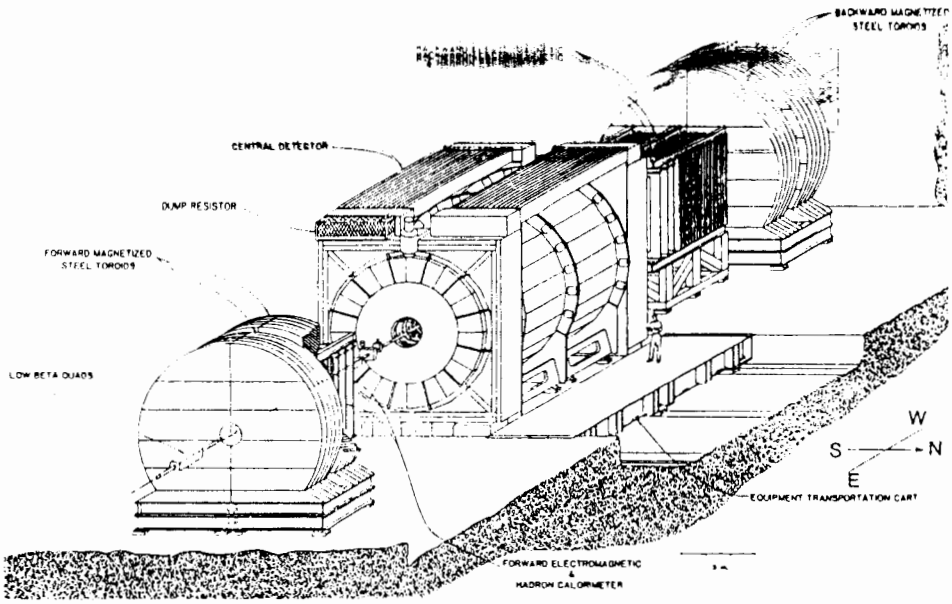


*Figure 4. Isometric drawing of CDF.*

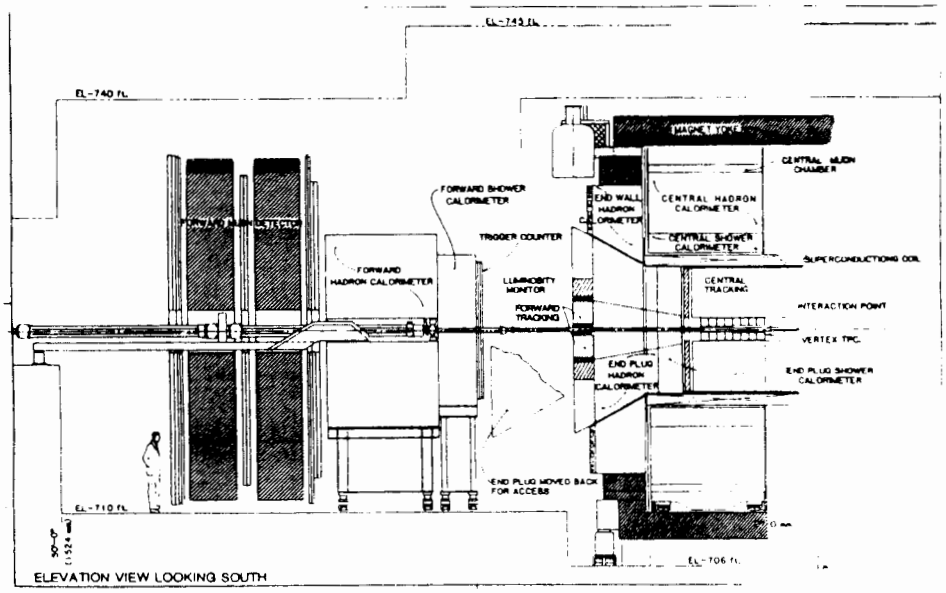


*Figure 5. A cut through one-half of CDF.*

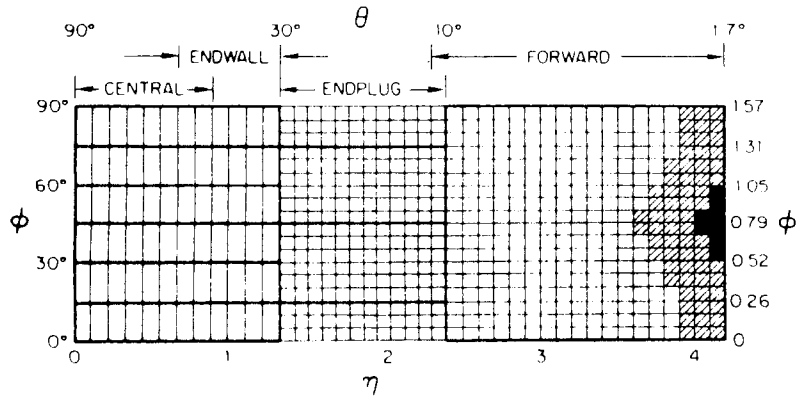


*Figure 6. One quadrant of hadron calorimeter towers. The heavy lines indicate module or chamber boundaries. The cross-hatched area has only partial hadron depth coverage due to space required for the low beta quadrupoles. The shaded area has no coverage. The electromagnetic calorimeters have complete ∅ coverage out to a pseudo-rapidity of 4.2.*

a) A total transverse energy ($E_t$) trigger made from the sum of the $E_t$ deposited in the calorimetry. The threshold was varied from 20 to 45 GeV depending on the luminosity.

b) An electron trigger formed using the sum of $E_t$ deposited in the electromagnetic calorimetry with an $E_t$ threshold of 15 GeV.

c) A high transverse momentum ($P_t$) muon trigger made from the coincidence of a central muon chamber track with a high $P_t$ track (>3 GeV) in the central drift chamber. The high $P_t$ track was found with a fast track processor.

d) A high $P_t$ muon trigger from the forward muon system. This trigger was rate limited in this run.

e) A rate limited "minimum bias" trigger made from a coincidence from the beam-beam counters (see Fig. 5) at the proper crossing time. This beam-beam coincidence was also required for triggers a) - d).

The performance of the detector can be illustrated by several *preliminary* physics distributions.

The minimum bias data sample for the single particle $P_t$ spectrum has ~12,000 tracks at $\sqrt{s}$=0.63 TeV and ~138,000 tracks at $\sqrt{s}$=1.8 TeV. Some data was taken at the higher energy triggering only on beam crossings, in order to study the effects of trigger bias. Intensive scanning of events in the VTPC and central drift chamber, and detailed detector simulation are being used to evaluate a number of sources of systematic errors and to improve the accuracy of the pattern recognition in the tracking programs. The present error of the momentum measurement is $\Delta p/p \approx 0.004\ p$, which is about twice the design value and is still being improved. The cell structure of the chamber is tipped to compensate for the E x B effect so that electron drift is along lines of constant radius. As a consequence, positive and negative tracks are not treated symmetrically by the track reconstruction programs. Figure 7 shows superimposed spectra for positive and negative tracks in the 1.8-TeV data sample. They demonstrate that the chamber construction does not lead to any appreciable sign-dependent bias. The preliminary data (sum of both signs) at 1.8 TeV is shown in Fig. 8 and a comparison between 0.63 TeV and 1.8 TeV will be forthcoming.

A typical two-jet event in the detector is shown in Fig. 9. The same two-jet event is shown in Fig. 10 in the tracking chamber view. The jets have raw cluster transverse energies of 83 GeV and 75 GeV. Cluster algorithms are still under study, and this one uses a nearest neighbor algorithm with an $E_t$ tower threshold of 0.1 GeV with cluster seed towers required to have more than 1.0 GeV. Clusters were merged if separated by less than the maximum merging distance R=0.7, where R is the square root of the sum of the squares of the phi and pseudo-rapidity deviations. The preliminary uncorrected energy scale is based

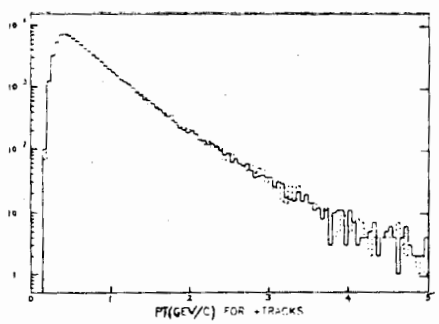


*Figure 7. Single particle $P_t$ spectrum for positive (solid line) and negative (dashed line) tracks as obtained from the central tracking chamber.*

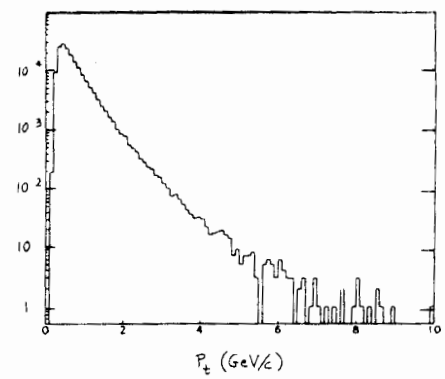


*Figure 8. Unnormalized single particle $P_t$ spectrum at $\sqrt{s}$ = 1.8 TeV.*

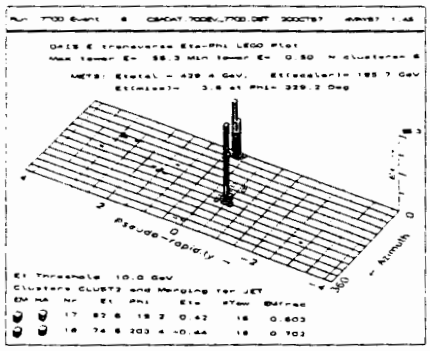

*Figure 9. Calorimeter "LEGO" plot of a typical two-jet event.*

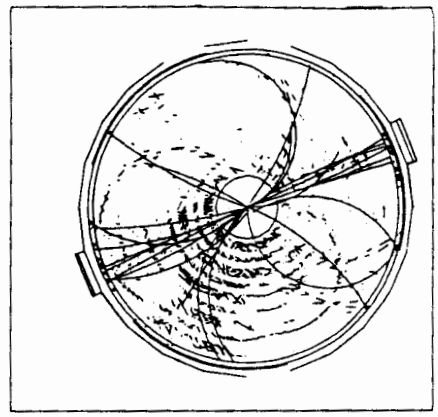

*Figure 10. Central tracking chamber view of the same two-jet event shown in Fig. 9. The TEVATRON beam pipe is perpendicular to the plane of the paper in this view.*

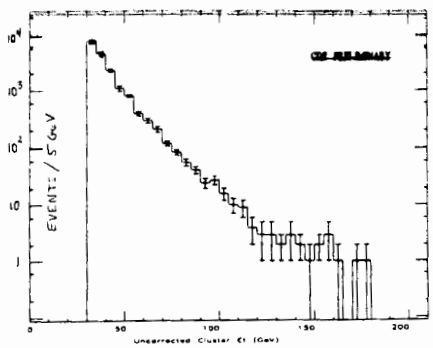


*Figure 11. Transverse energy distribution of clusters with pseudorapidity in the range -1.0 to +1.0. This sample is obtained by combining samples with various $E_t$ thresholds (all >30 GeV) weighted by the inverse of their relative integrated luminosities.*

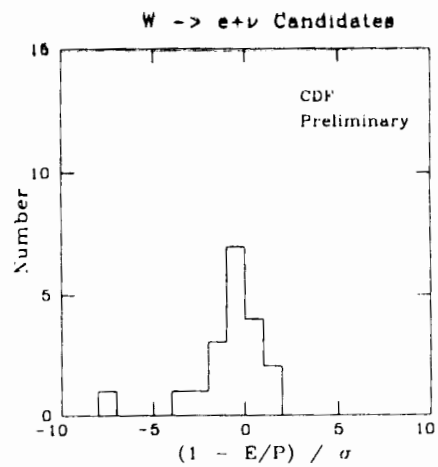


*Figure 12. The agreement between the central drift chamber measured transverse momentum (P) and the calorimeter measured transverse energy (E) for electrons in the CDF sample of W → (e+ neutrino) candidates.*

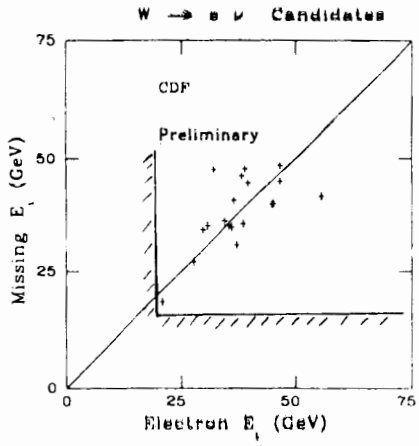


*Figure 13. Event missing transverse energy versus Electron transverse energy for the CDF sample of W→ (e+ neutrino) candidates. The shaded lines indicate cuts used in the analysis.*

on a simple sum of electromagnetic and hadronic energies in the clustered towers. The transverse energy distribution of jet clusters from the central calorimetry is shown in Fig. 11. Figure 11 is based on only about 1/3 of our total sample and it contains several events above 150 GeV. We are therefore already able to study the complete $E_t$ range accessible at the CERN SPS collider.

A complete analysis of the data for W and Z production is not yet available. We show here a selection $W \rightarrow e^+$ neutrino candidates which were produced with the following cuts on the electron cluster:

1. $-1.0 <$ pseudo=rapidity $< 1.0$,
2. $E_t \geq 20$ GeV,
3. Missing $E_t \geq 20$ GeV,
4. (Hadronic energy + Electromagnetic energy) $< 0.1$,
5. Only one track within a $\Delta\varnothing \times \Delta$ (pseudo-rapidity) cone of $15^o \times 0.3$,
6. $0.2 < E + p < 1.8$.

Figures 12 and 13 show distributions of events passing these cuts. These candidates are consistent with $W \rightarrow e^+$ neutrino production. We have about 20 such candidates. We also have six candidates compatible with $Z \rightarrow e^+e^-$.

The TEVATRON Collider experimental program is under way and CDF's goals for the 1987 run have been met. The detector checkout was satisfactory, and we have ~34 $nb^{-1}$ integrated luminosity on tape. The expected physics signals at 1.8 TeV are seen and they look reasonable.

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