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Beam Motion and Feedback

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Abstract

During Run 1B, a program of beam motion and feedback studies was undertaken. This program involved the collaboration with members of the Accelerator Division Main Accelerator and Controls Departments. In this note, the algorithm and implementation are described, sample data are presented, and results from preliminary control and feedback data are shown.

For Run 2, CDF (and possibly D0) will trigger on displaced tracks, presumably from B hadron decays, using the SVT processor [1]. As described below, a necessary feature of efficient triggering is a stable and well understood beam position. From initial investigations in the Run 1A dataset [2] and Run 1B dataset, it appeared that there was measurable motion during the course of a Tevatron store. An online monitor (BMON) was developed to measure the beam positions in real time and make them available to the accelerator controls system (ACNET).

In February 1996, a series of controlled experiments in beam motion was undertaken by members of the AD and CDF as a first step toward a motion control and feedback system. Results of these experiments have been presented publicly at several meetings but are documented for posterity in this note.

1 Why do we want beam control and feedback?

The SVT is designed to use tracks found in the outer tracking chamber (the COT) by the XFT trigger processor as seeds. It will reconstruct tracks in the $r - \phi$ dimensions only, not making use of the Z information from SVX II. Therefore, only the transverse impact parameter information will be available at trigger level 2. From studies of simulated $B \to \pi\pi$ decays and Run 1A minimum bias data, a cut at $\mid d \mid > 100$ microns presents a reasonable rate and efficiency [1].

These rates assume that the beam axis is parallel to the detector axis and well known. Motion of the beam centroid affects both the background rate and signal efficiency. In addition, an angle between the beam axis and detector axis will directly increase the trigger rate. Studies indicate that an angle of 100 microradians will increase the trigger rate by 25% and an angle of 500 microradians will increase the trigger rate by 900

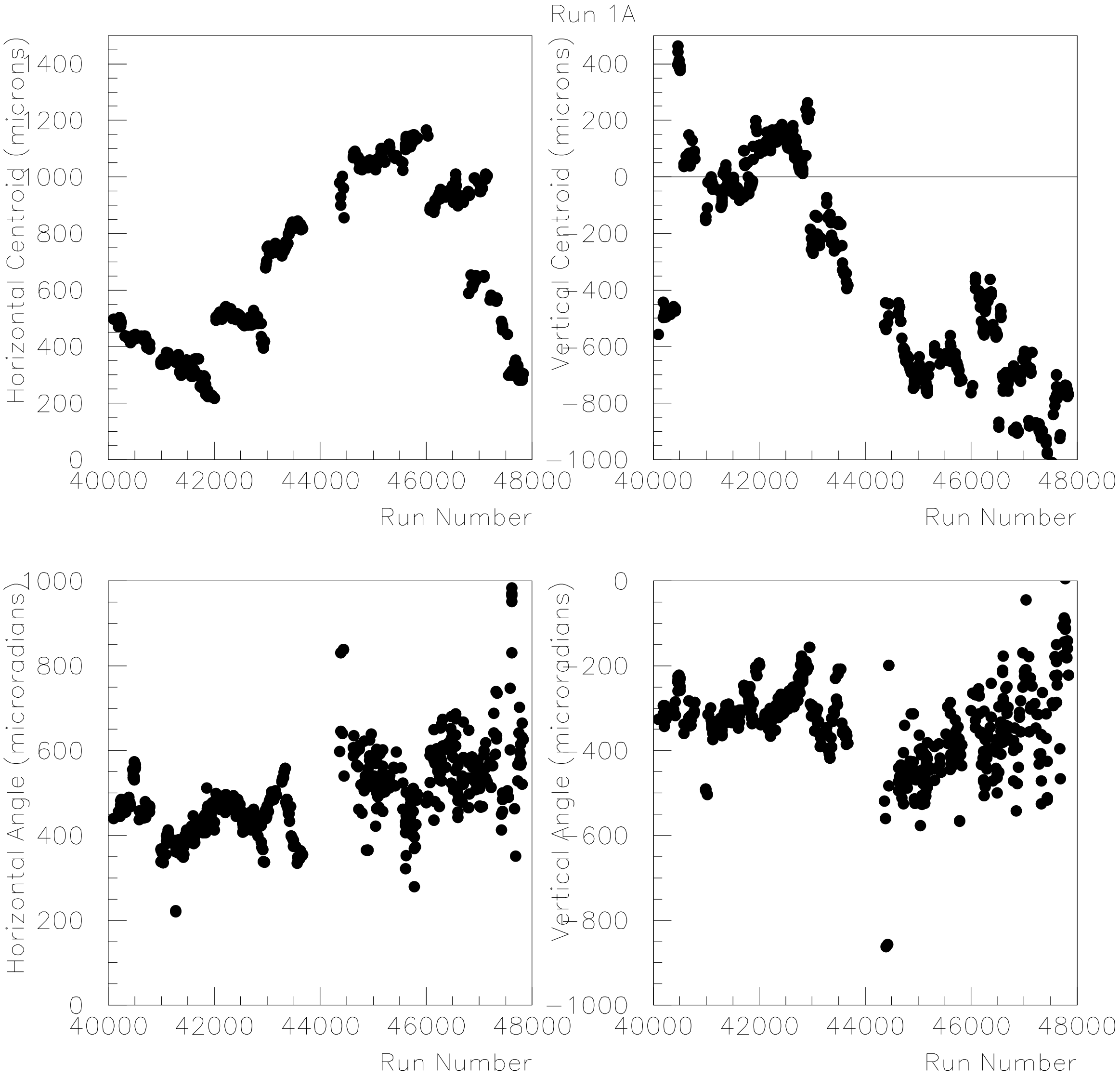

Figure 1: The horizontal and vertical centroids and angles for the Run 1A dataset. There is one entry for each data-taking run. The scale for the centroid plots covers 1500 microns and for the angle plots, 1000 microradians.

In figures 1 and 2, the centroid position and angle between the detector axis and beam axis for both the horizontal and vertical planes are shown. There is one measurement for each data run over the two long time periods. For both runs, we see significant changes in the centroid position. The long time scale can be seen in the drift as a function of run number, with discrete steps that occur before/after shutdown periods. The 2000 micron step in the Run 1B horizontal position data occurred when the B0 quadrupole roll was found and fixed. The SVT processor can account properly for offsets between the detector axis and the beam axis but not for changes in the axis without reloading the position information. Therefore, it is the relative changes in the position that are more important than the absolute position.

While the angles do not show the same long time scale drifts that the appear in the centroid data, they are still cause for worry. As noted above, the SVT processor cannot account for an angle. Not only are there angles on the order of 200-800 microradians present in both 1A and 1B data, but the angles varied on the level of a few hundred microradians throughout the runs. A part of this angle is initial alignment difficulty – the silicon vertex detectors are mounted inside the VTX and CTC, with the only freedom being motion of the entire central detector assembly. Even with a better initial alignment of the axes, it appears that the angle would still vary on the level of 200 microradians.

While the cause of the beam motion is not understood, an appropriate fix does appear possible. With real time measurements of the centroids and angles, adjustments to horizontal and vertical correction elements in the Tevatron lattice can be made to control the variation in these quantities.

2 Implementation of BMON

CDF tracking algorithms reconstruct the charged particle trajectory using 5 parameters - the curvature (related to transverse momentum), sin of the polar angle, the azimuthal direction at distance of closest approach, and the transverse and longitudinal distance of closest approach. By default, closest approach is defined with respect to the nominal detector center, which is not necessarily the interaction position. For many analyses, these parameters are measured with respect to either a reconstructed primary vertex position or the fit beam line position. For a hardware trigger, there are time and hardware constraints which make measurements with respect to a reconstructed primary vertex position difficult. Therefore, the SVT is designed to use a beam line position.

The BMON code reconstructs the beam line position in the CDF coordinate system by fitting the track impact parameter, azimuth, and z_0 to offsets and angles in the horizontal and vertical planes. The fitting algorithm is discussed in reference [2]. In the online environment, speed and efficiency are important. Therefore, the SVX track finding algorithms start from Level 3 CTC tracks (note that this confined the monitor to a subset of all events, since track finding was not done on all events in Level 3). Reconstructed tracks must have 4 hits in the same SVX barrel and a transverse momentum greater than 1 GeV/c. Once 500 such tracks are found, the beam line fitting algorithm is called.

Using a set of open access client Multinet routines [4] developed by the Accelerator Division Controls department, the relevant devices are set as ACNET devices. Table 1 contains a list of the ACNET device names and indices. From the users point of view, these devices are like most other ACNET devices. They can be logged in the Lumberjack dataloggers, plotted

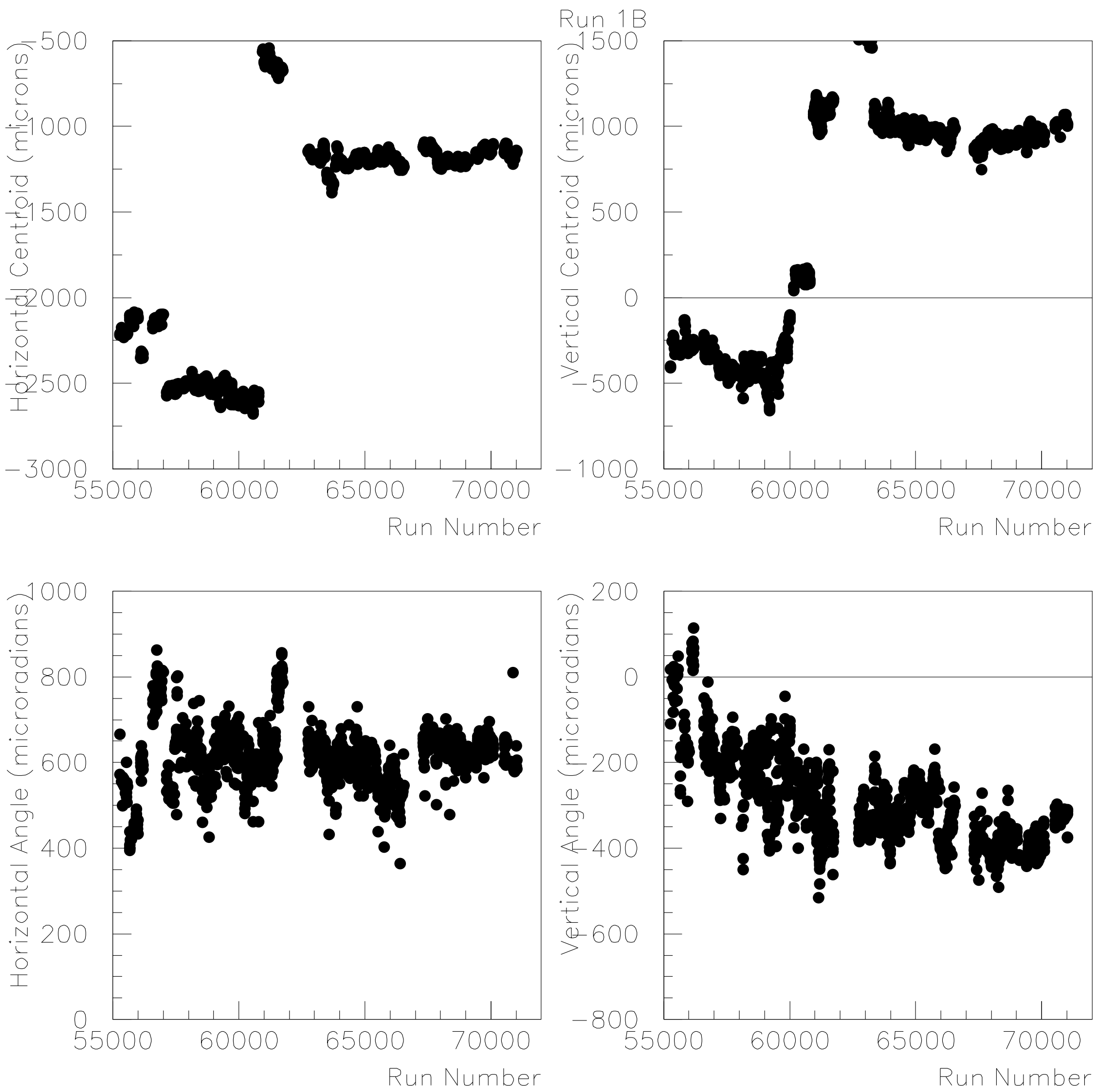

Figure 2: The horizontal and vertical centroids and angles for the Run 1B dataset. There is one entry for each data-taking run. The scale for the centroid plots covers 2500 microns and for the angle plots, 1000 microradians.

Device Name	Device Index	Description
C:B0XIP	90294	Horizontal Centroid (microns)
C:B0YIP	90297	Vertical Centroid (microns)
C:B0SIGX	90298	Horizontal Size (microns)
C:B0SIGY	90299	Vertical Size (microns)
C:B0DX	90302	Horizontal Angle (microradians)
C:B0DY	90303	Vertical Angle (microradians)
C:B0XTD	90314	H Centroid Time of Day stamp
C:B0YTD	90315	V Centroid Time of Day stamp
C:B0SXTD	90318	H Size Time of Day stamp
C:B0SYTD	90319	V Size Time of Day stamp
C:B0DXTD	90322	H Angle Time of Day stamp
C:B0DYTD	90323	V Angle Time of Day stamp
C:CDFRUN	92521	CDF Run Number

Table 1: Table of ACNET device names and indices.

on fast time plots, and displayed on parameter pages. For the particular application we have in mind, they are the control devices for a feedback application. Appendix A contains some sample C programs for the setting of these devices.

3 Sample information from BMON

Starting in May 1995 (near the end of Run 1B) and continuing through the Run 1C data taking, BMON was run on a regular basis. Depending upon the luminosity conditions, the dedicated Alpha station 200 4/233 processed events at 1-2 Hz [5], with an average of $\approx$2 selected tracks per events. At this rate, the centroids and angles were updated approximately every 3 minutes. Figure 3 shows the horizontal and vertical centroids and angles for a 12 hour run during April of 1995.

As discussed in the previous section, the program sets values for ACNET devices. Through the use of the Lumberjack datalogger, the time hisotry of positions and angles can be correlated with changes in accelerator operating conditions. In figure 4, the instantaneous luminosity (C:B0LUMS), the horizontal centroid (C:B0XIP, circles), the vertical centroid (C:BOYIP, squares), the CDF Run number (C:CDFRUN, triangles) and the Tevatron Store number (T:STORE) are shown for a typical store in January 1996. The centroids are in units of microns, with an average uncertainty (not plotted) of ± 5 μm per point. The steps in the horizontal and vertical centroids (both about 25 microns) at the beginning of the store shows the change from the last measured position in the previous store. A drift on the order of 2 μm per hour is visible in the vertical centroid.

During the month of Feb 1996, a broken wire in the CDF Central Tracking Chamber caused only half of the chamber to be operational. The effect on the beam position fits was investigated by comparing fit results with the full azimuthal acceptance to fit results with only half azimuthal acceptance (done with data taken before the broken wire affected

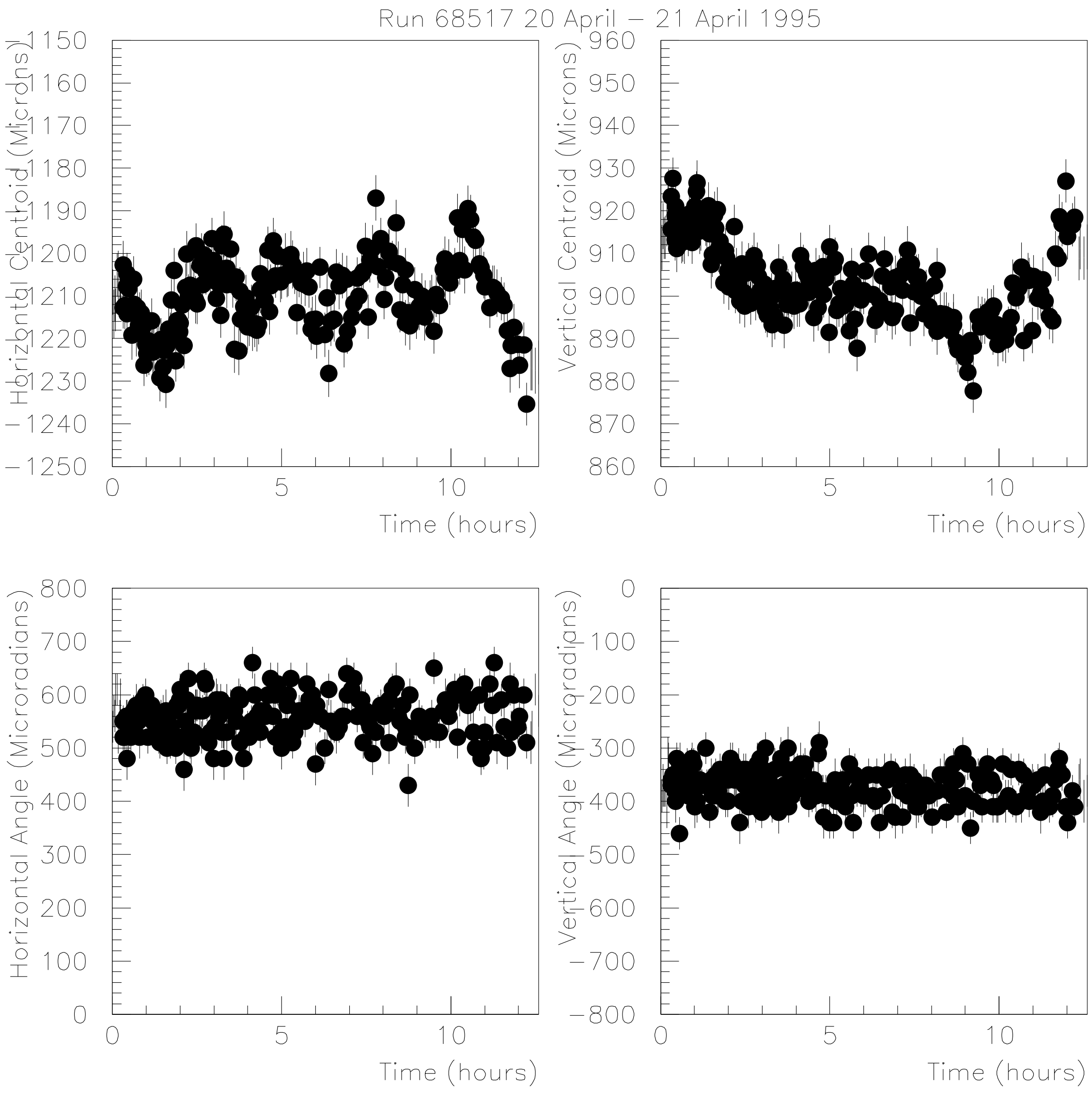

Figure 3: The horizontal and vertical centroids and angles for run 68517, as a function of time during the run. The error bars are the uncertainties for each fit.

chamber operation). No systematic changes in either the centroids or the angles was seen.

4 Implementation of Beam Control

An ACNET application has been developed for control of the position and angle in both the horizontal and vertical planes. The application can control the positions at both the B0 and D0 interaction regions independently through use of Tevatron dipole correction elements. For control at the B0 interaction region, combinations of the dipole correctors between A46 and B14 are used. Similar sets in the C4 and D1 sectors are used for control at the D0 interaction region. The position and angle bumps at each region are designed to be local in origin, so that the closed orbit outside of the interaction regions is not changed. All of the correction elements used for position control are run off of 50 A supplies and are used in the orbit closure program for the Tevatron.

5 Test of Position Control

On Feb 14, 1996, a test of the position control application was done. The beam was moved in both the vertical and horizontal planes at the B0 interaction region. During this test, beam losses at both B0 and D0 were monitored and no change was seen. Closed orbit measurements verified that the bumps were local to the B0 interaction region.

Over a period of 30 minutes, 5 10 micron steps were made in the vertical position. Unfortunately, just as the test began the CDF Central Tracking Chamber tripped off, so no position data was available over the course of the half hour. When the chamber had recovered and CDF data taking again underway, a net change of 56 microns in the vertical position was seen (from 789 microns to 845 microns). A horizontal position change, done in two 40 micron steps separated by about 5 minutes, was then done. The steps here were seen, as the CDF DAQ stayed alive during this move. The measured position change was 68 mircrons (from -1518 microns to -1450 microns). Figure 5 shows the vertical (C:B0YIP, triangles) and horizontal (C:B0XIP, circles) centroids during the test period. As angle and position changes can be related directly, we did not attempt an angle change.

6 Limitations

The correction elements run at an administrative maximum of 50 amps. This maximum limits the total range of possible corrections. With the nominal closed orbit (correction elements running at 0 amps) and 1 TeV beams, the angle corrections are limited to ± 100 microradians. Since the beam will probably not be on the nominal orbit, it is probable that this range will be restricted even more. Exactly how much is not known at this time. During the early part of Run II, it may be necessary to make some low β quadrupole moves to improve the positioning. CDF note 4059 [6] details a proposal to make measurements of the beam position in the CDF collision before the installation of the detector.

One operating scenario is that the desired changes to centroid and angle are outside the range of correction (settling in the collision hall or in the accelerator tunnel). At that point

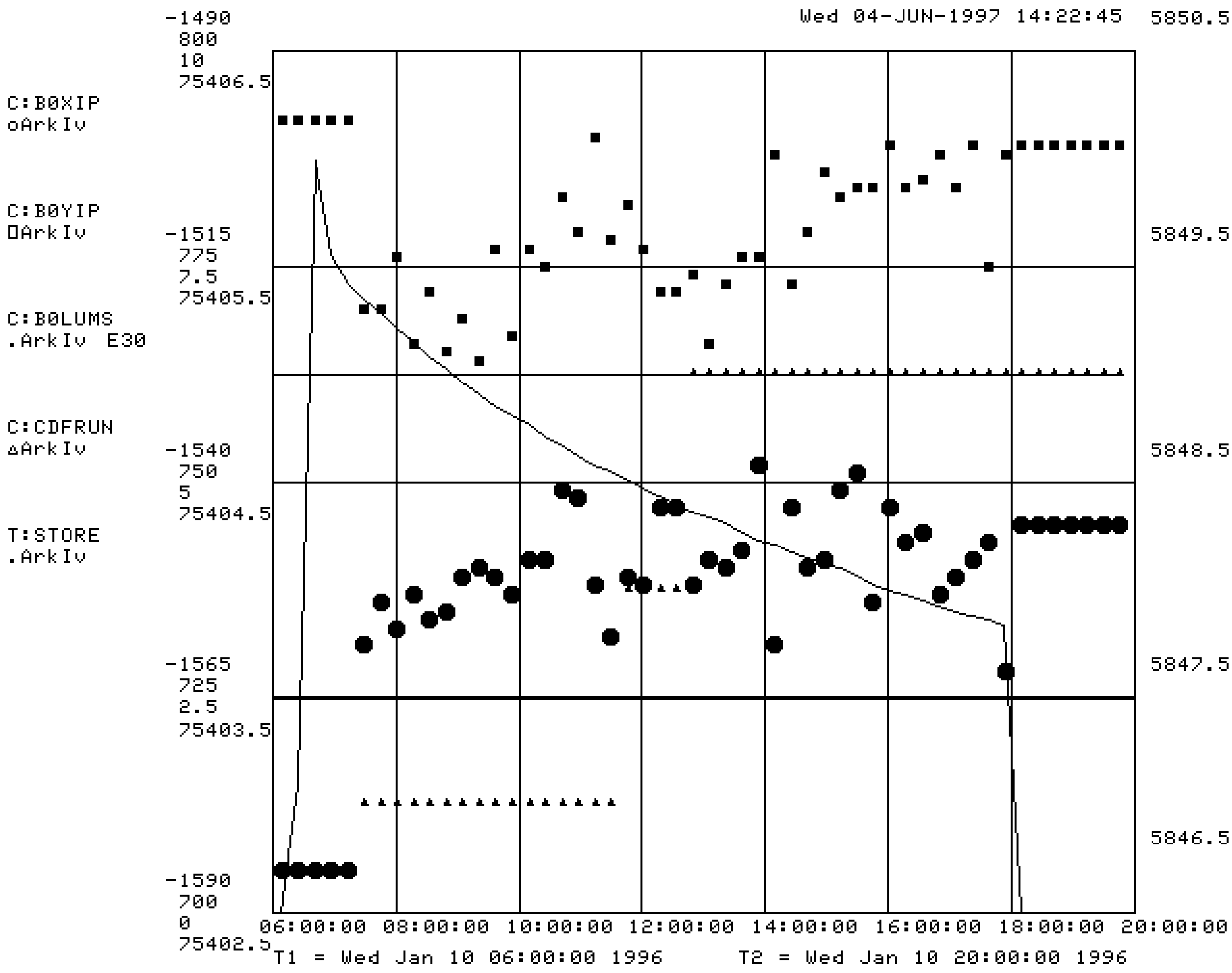

Figure 4: Sample data from a store in January 1996, showing horizontal and vertical centroids, instantaneous luminosity at B0, and the CDF Run and Tevatron Store numbers.

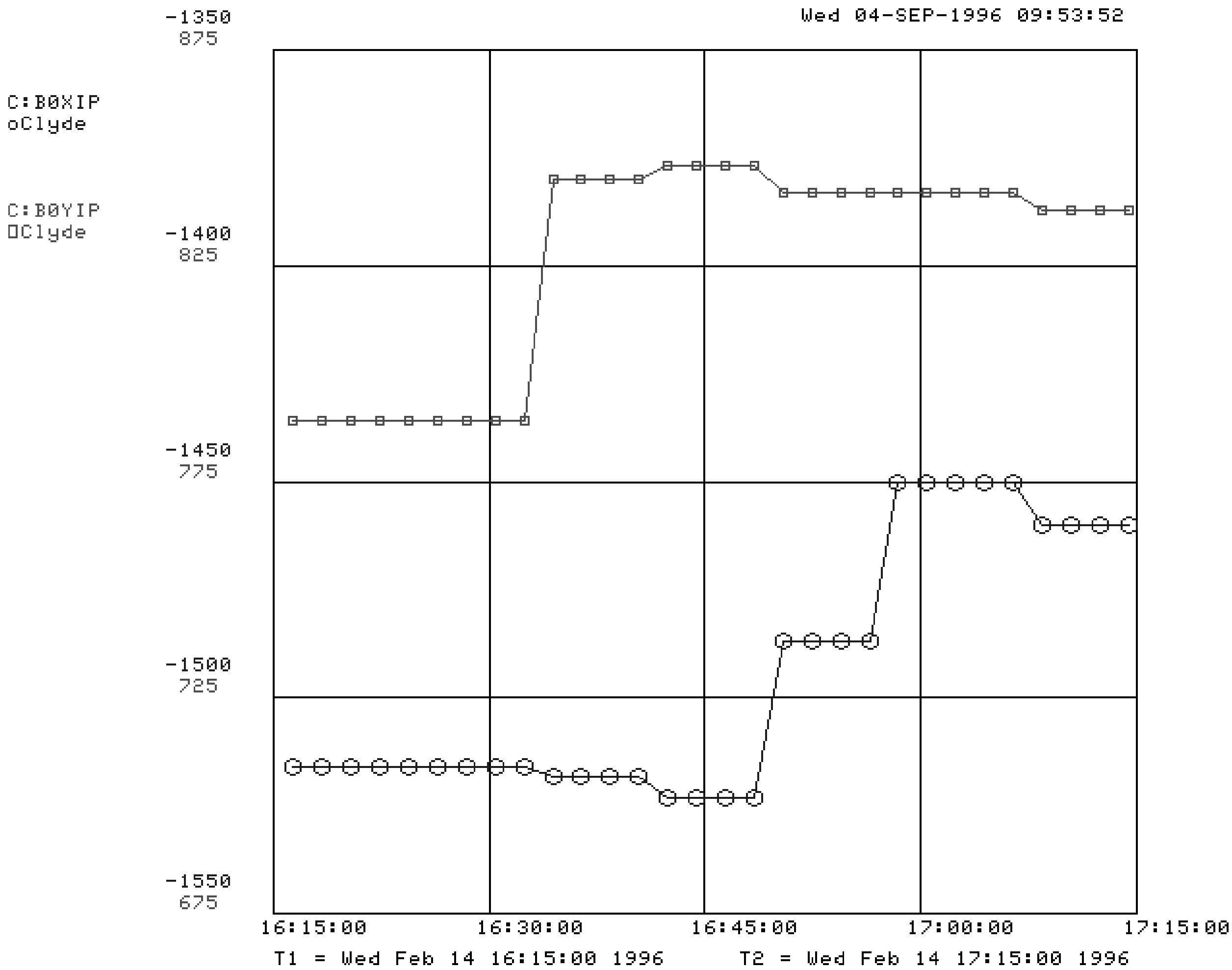

Figure 5: Data from the position control tests in February 1996. A 50 micron vertical position change was followed by 2 40 micron horizontal position changes, well tracked by the measurements.

in time it may be necessary to move the SVXII detector rather than the beam.

7 Conclusions

A system to measure and correct the interaction region beam position has been described. The ability to control both centroid and angle has been tested and shown to work, so in principle the stability of the beam position with respect to SVXII has been demonstrated. In practice, there are still problems to solve in implementation and operating procedure. The full implementation of control will involve effort from both the experiment and the Beams Division.

A Example Routines

```
/*
**++
**  FACILITY:  setup_send.c
**
**      set things up to send the information to ACNET
**
**        21 Dec 93  P Derwent        copied from R Joshel example
**--
**/
/*******************************************************************************/
#include <time.h>
#include <stdio.h>
#include <string.h>
#include "clib$include:cnsparam.h"              /* CLIB defs & functions... */
#include "clib$include:cbslib.h"
#include "ul$oac:remote_send.h"



setup_send()
{

/* call this in the global init entrypoint of the module */

        remote_server(HOST_REMSET,IP_REMSET);

}

/*
**++
**  FACILITY:  send_info.c
**
**      set things up to send the information to ACNET
**
**        21 Dec 93  P Derwent        copied from R Joshel example
**        23 Mar 95  P Derwent        change dis from constant
**--
**/
/*******************************************************************************/
#include <time.h>
#include <stdio.h>
#include <string.h>
#include "clib$include:cnsparam.h"              /* CLIB defs & functions... */
#include "clib$include:cbslib.h"
```

```
#include "ul$oac:remote_send.h"

#define NUM_DEV          13                /* # of devices to set */
#define NUM_TIME         6                 /* # of time stamps */


send_info(float setval[13])
{
        int         i;               /* looper */
        int         jj;              /* type code for remote_send? */
        int         status;          /* status return code from remote_ routines */
        double     time_now;         /* current time */
        static int dis[NUM_DEV] =         /* device indices */
        {90294,90297,90298,90299,90302,90303,
         90314,90315,90318,90319,90322,90323,92521};
/*  these are listed in the order:
        C:B0XIP        X position (microns)
        C:B0YIP        Y position (microns)
        C:B0SIGX       X size (microns)
        C:B0SIGY       Y size (microns)
        C:B0DX         X slope (microns/meter)
        C:B0DY         Y slope (microns/meter)
        C:B0XTD        X position time of date stamp
        C:B0YTD        Y position time of date stamp
        C:B0SXTD       X size time of date stamp
        C:B0SYTD       Y size time of date stamp
        C:B0DXTD       X slope time of date stamp
        C:B0DYTD       Y slope time of date stamp
        C:CDFRUN       CDF Run Number
 */



        time_now = time((time_t *)0);        /* get current time */

        for(i=6; i < NUM_DEV-1; i++) setval[i] = time_now;

        jj = 0;                          /* should ask Bob about type code */
        status = remote_send(jj,NUM_DEV,dis,setval);
/* do the update */

        if (status) printf("\nTESTER: remote_send failed %d",status);
/* check status return */
}
```

References

[1] SVT Technical Design Report, **CDF3108**

[2] H. Wenzel, **CDF1924**, *Fitting the beam position with the SVX*

[3] G. Punzi, private communication.

[4] See http://www-bd.fnal.gov/www/controls/user_libraries/ul_oac/ul_oac.html for documentation on these routines.

[5] The monitor program was not CPU limited at luminosities of 2e31 but I/O limited. We could conceivably gain a factor of two before hitting the processing limitation.

[6] Paul Derwent and Brenna Flaugher, **CDF4059**, *Interaction Region Measurements during Run II Startup*