WBS 1.3.4.8 Tevatron Alignment

Ray Stefanski

January 21, 2004

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Goals for the shutdown

There are four tasks in the Tevatron that involve magnet survey and alignment during this shutdown that the Alignment Task Force is involved in:

1. Installation of Real Time Motion Sensors (WBS 1.3.4.8.2)

a. BINP devices in B sector, (BINP, SLAC, Fermilab)
b. Tilt Monitors, (AD)
c. Homemade Devices; (PPD, AD)

2.Physical Alignment of the Tevatron (WBS 1.3.4.8.3)

a. Network Installation, and Measuring Horizontal and Vertical Magnet Positions, (PPD)
b. Roll Measurements, (CDF, DZero)
c. MTF tests (Impact of roll and position changes in warm and cold magnets) (TD)
d. Roll and Position Corrections; (PPD, AD)

Magnet Stand Replacement (associated with WBS - 1.3.4.8.3)

3. Smart Bolt Corrections (WBS 1.3.4.8.4)

a. MTF Tests (Impact of Shim Changes in Cold Tevatron Magnets.) (Beam Physics, TD)
b. Shim Corrections in 100 Tevatron Magnets; (AD, TD)

Reviewed by Garbincius Committee

Summary of WBS 1.3.4.8

Goals – Configuration Management; Keep Tev Magnets aligned; Keep correctors not saturated.

Status/Plans

- 10 tilt meters report on-line
- 26 HLS in B-sector in ’03, ring wide in 2004.
- Upgrade survey system to TevNet (Reviewed recommended.)
- Fixed Smart Bolts to limit coupling (Review recommended.)
- Much Progress on Unrolls and re-aligns.

Limited by Analysis Resources.
Linked to TeV Task Force.
Depends a great deal on PPD and TD for people and support.
Requires access to the Tevatron tunnel.

WBS 1.3.4.8 Magnet Alignment (In Review)	R. Stefanski	$280K through July 2005.	
WBS 1.3.4.8.1 Orbit/Aperture Optimization	G. Annala	$0	
WBS 1.3.4.8.2 TeV On-line Level System	J. Volk	$180K	Contingency = $100K
WBS 1.3.4.8.3 Magnet Alignment	R. Stefanski	$100K	Contingency = $60K
WBS 1.3.4.8.4 SC coil realignment/smart bolts	D. Harding	$0	

Additional Work done during this Period

- Vertical Alignment of LBQ at CDF
- Horizontal Alignment of LBQ at D0
- Alignment of Lambertson Magnets at F0
- Alignment of Kicker Magnet at A0

WBS 1.3.4.8.3 Magnet Alignment
$100K + contingency. (Done.)

To bring the network into tunnel, we need to:

1. Modify air vents top side.
2. Build towers over the air ducts/risers.

This also needs deep rod system installed on site.

Tower installtion for the TevNet Measurements

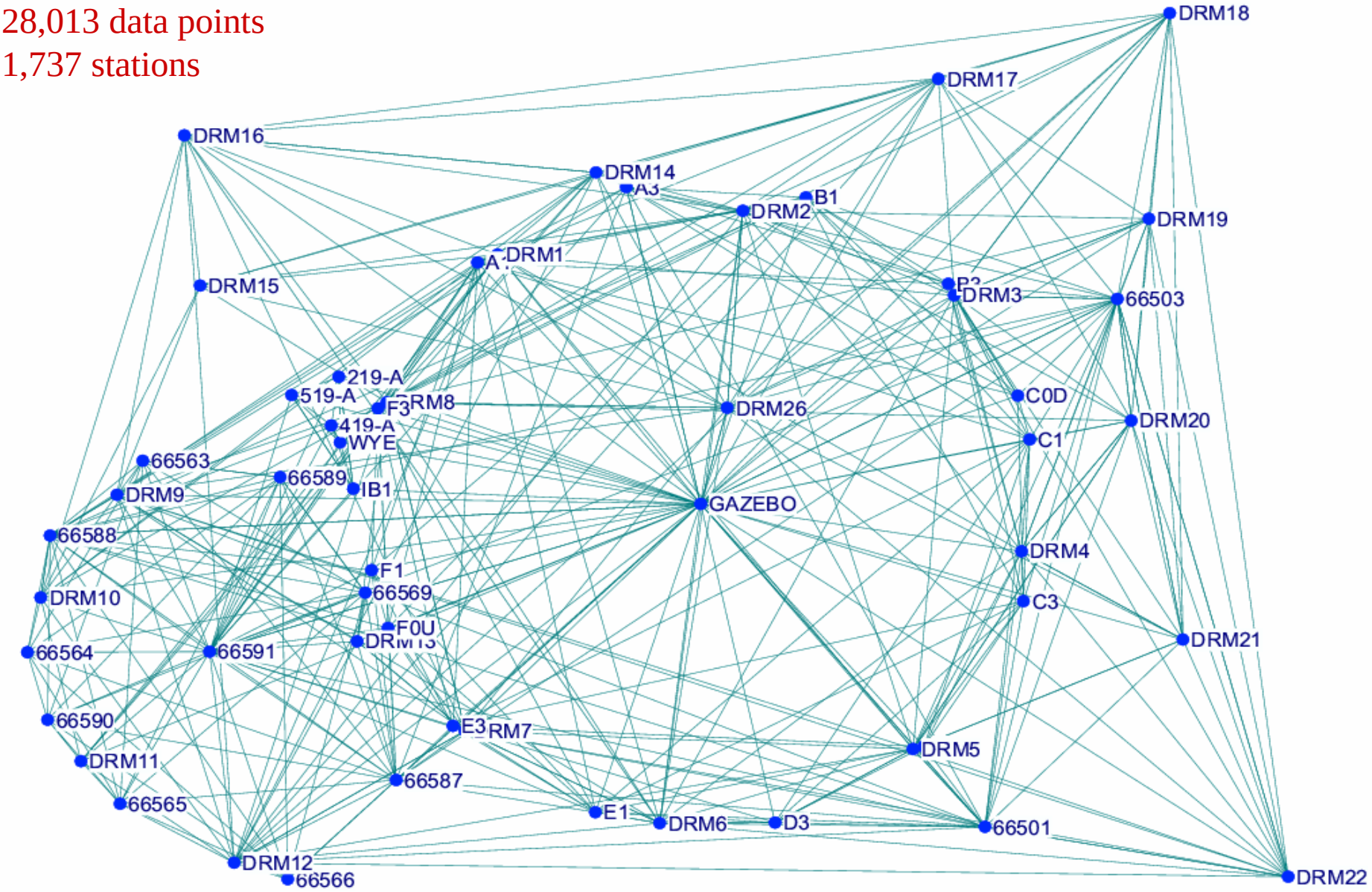
Tevatron Alignment
(1.3.4.8)

WBS 1.3.4.8.3 Magnet Alignment

$100K + contingency. TevNet

28,013 data points

1,737 stations



Where to from here?

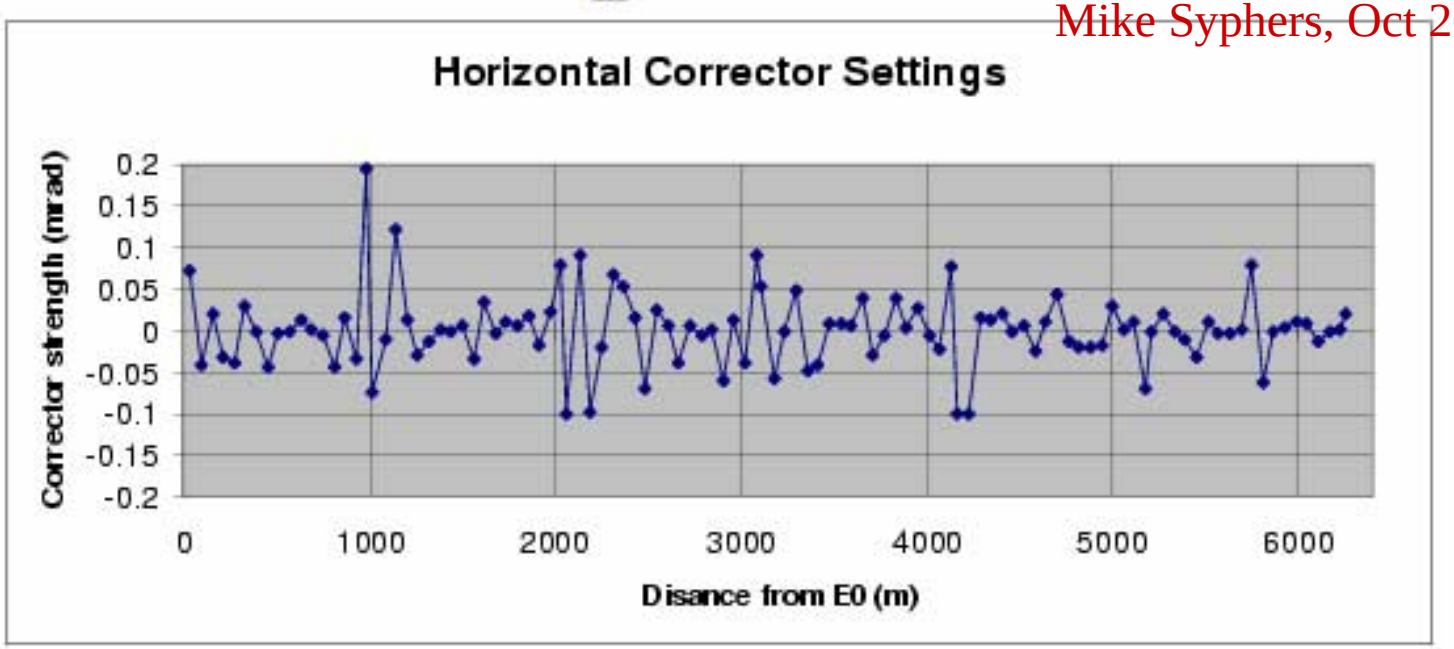
The original alignment spec was 10 mills for quads and 30 mills for dipoles with respect to the monument system. This was both horizontally and vertically.

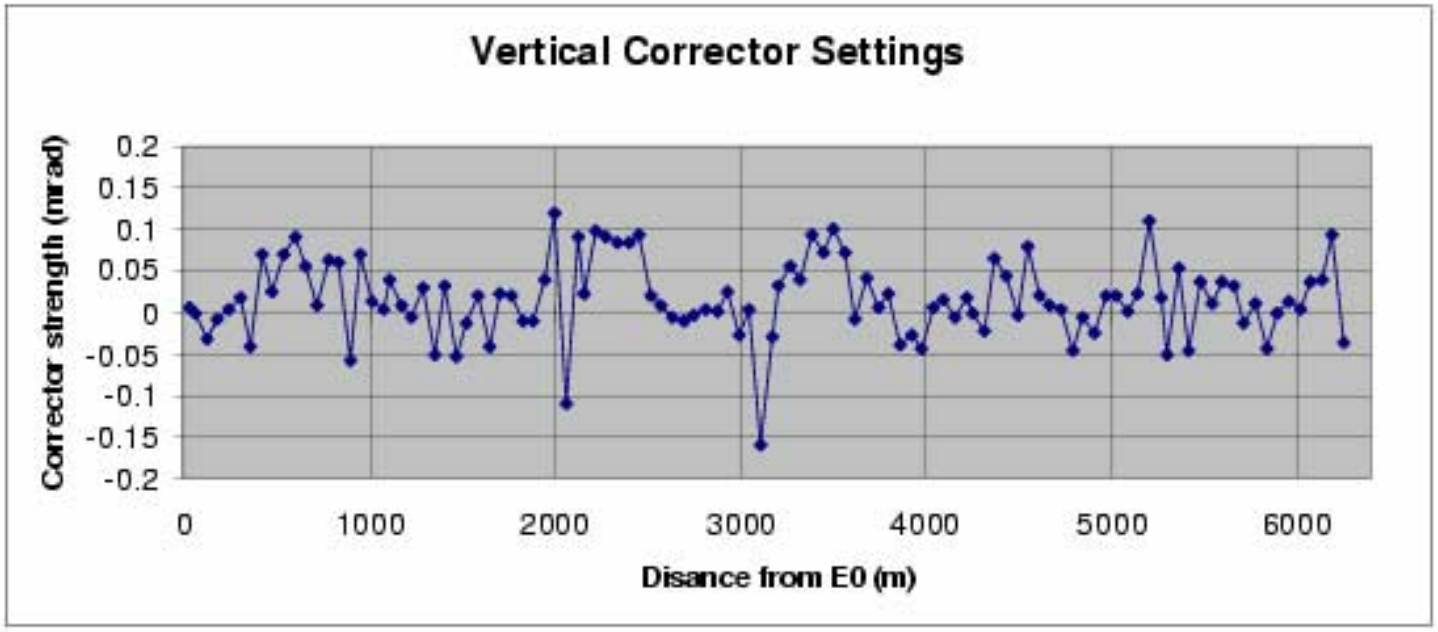
The total error budget also included measuring the magnetic center of the elements, setting the reference lugs on the outside wrt the magnetic center, and the error on analyzing and installing the monument system.

We will shoot for nothing less 20 years later, especially since TevNet is supposed to give us better information about the monument system.

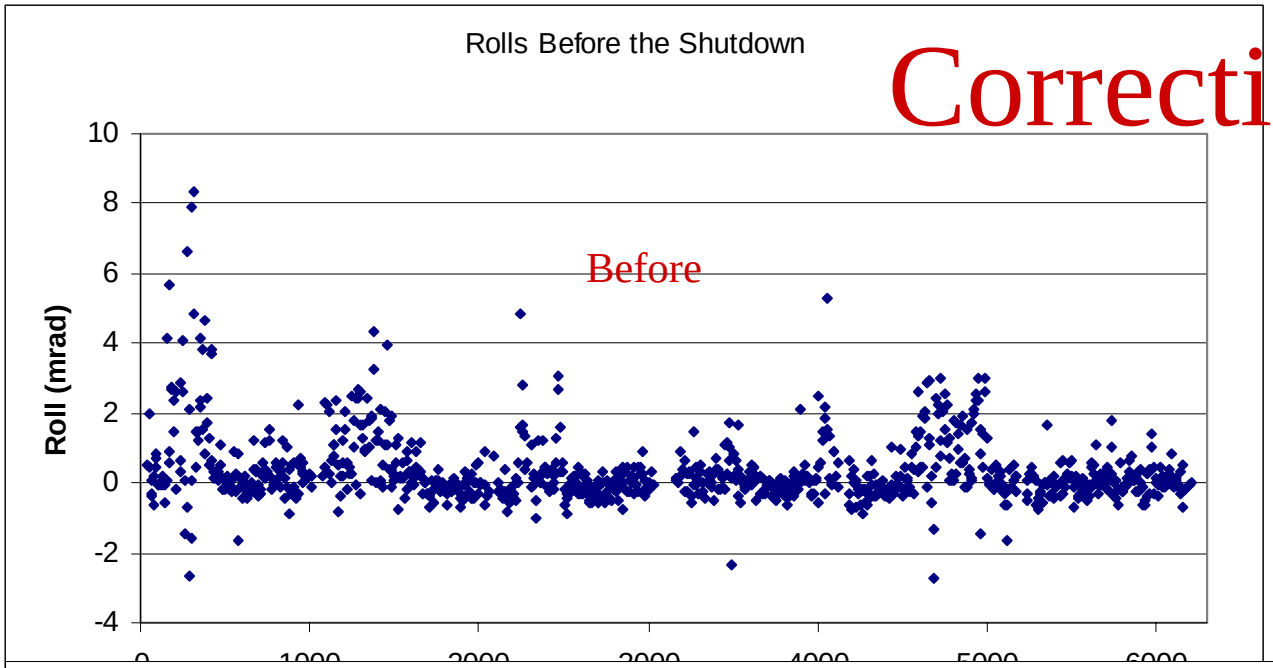
Craig Moore

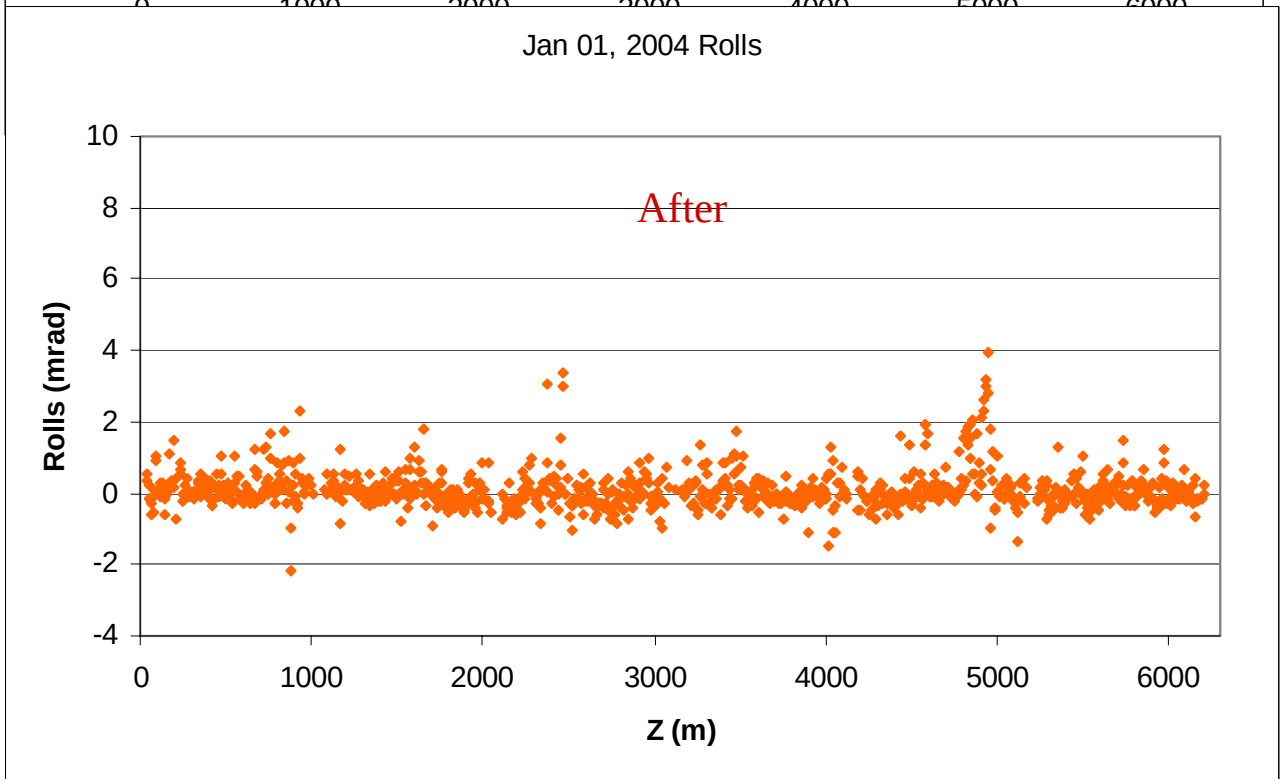
Mike Syphers, Oct 2002



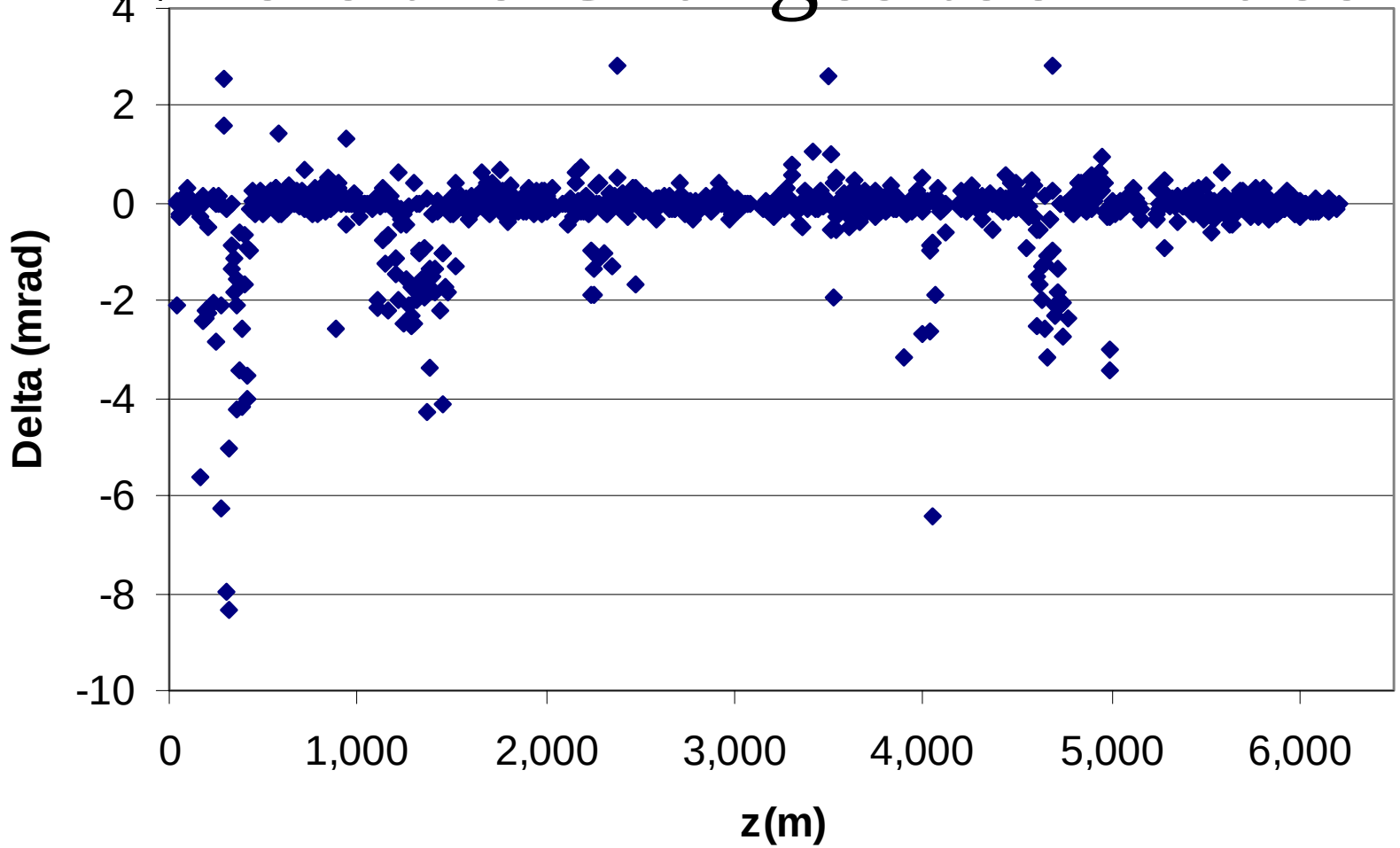


Correction in Rolls

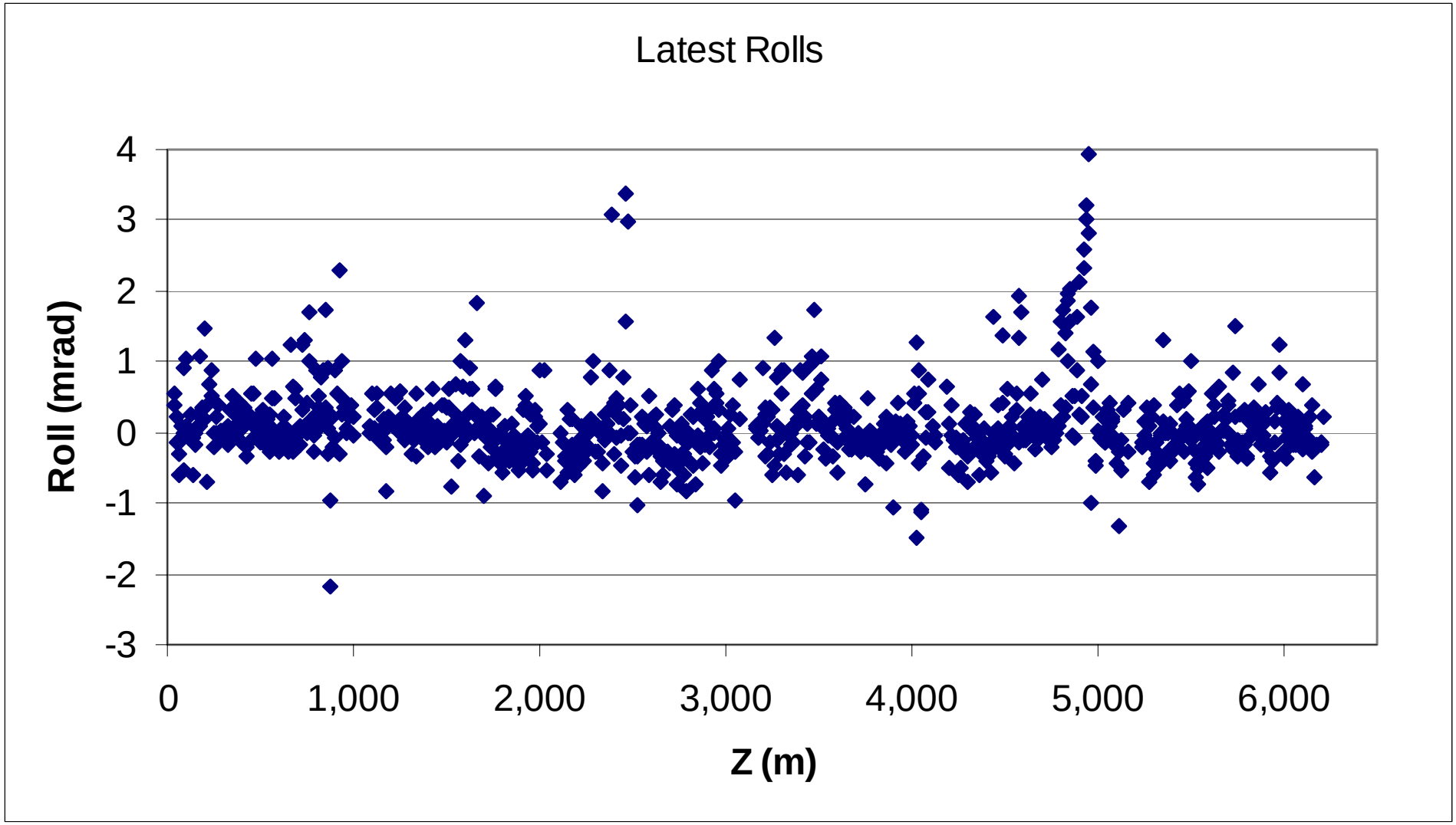


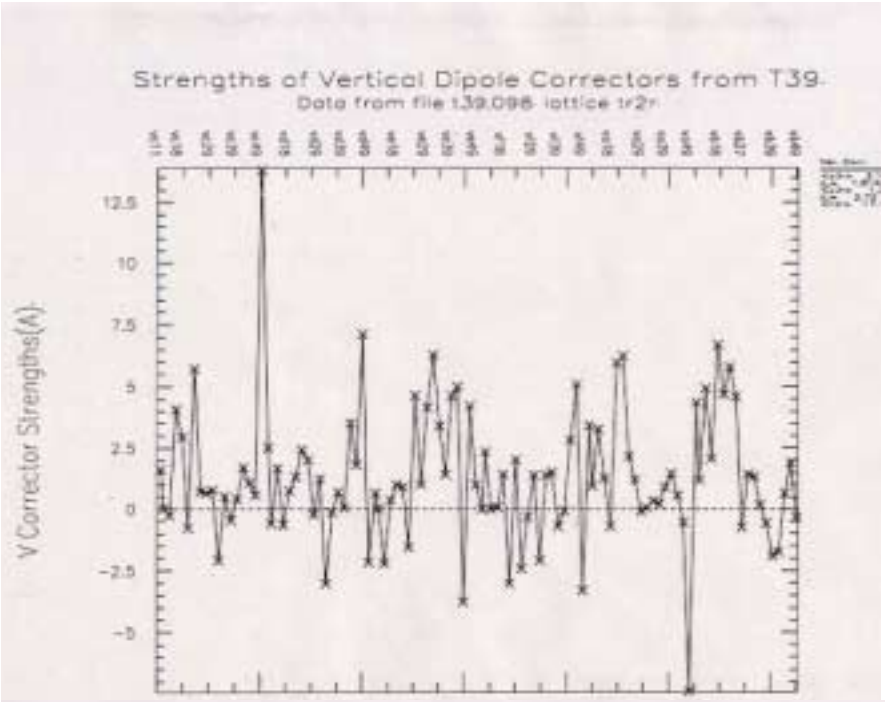


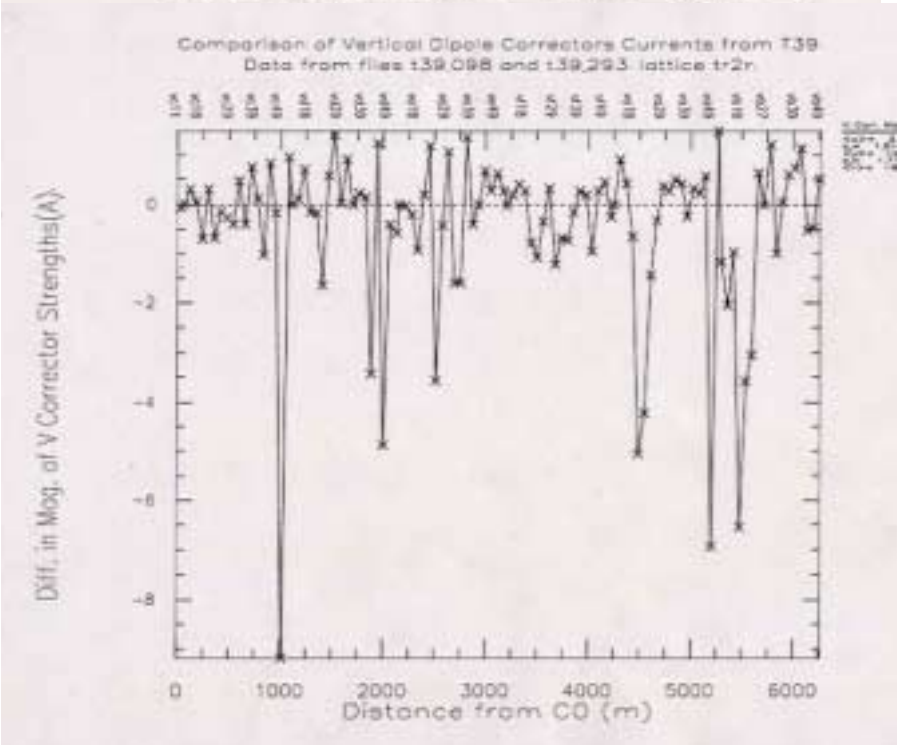
Where the Changes took Place

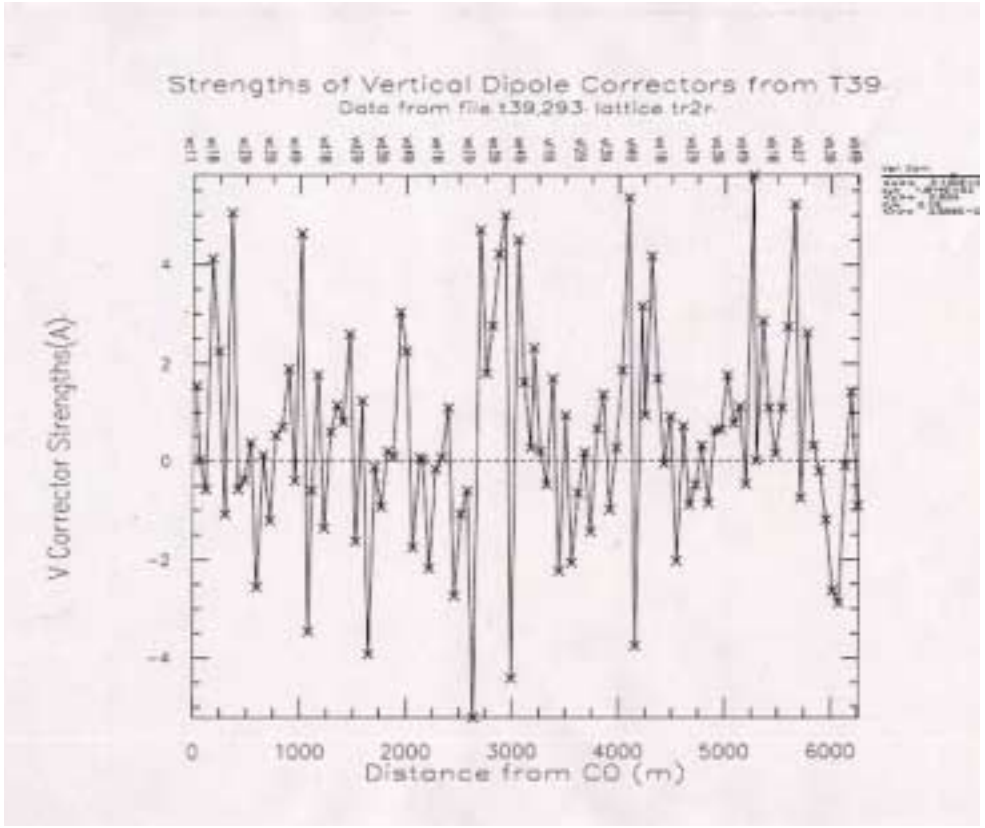


Latest Rolls

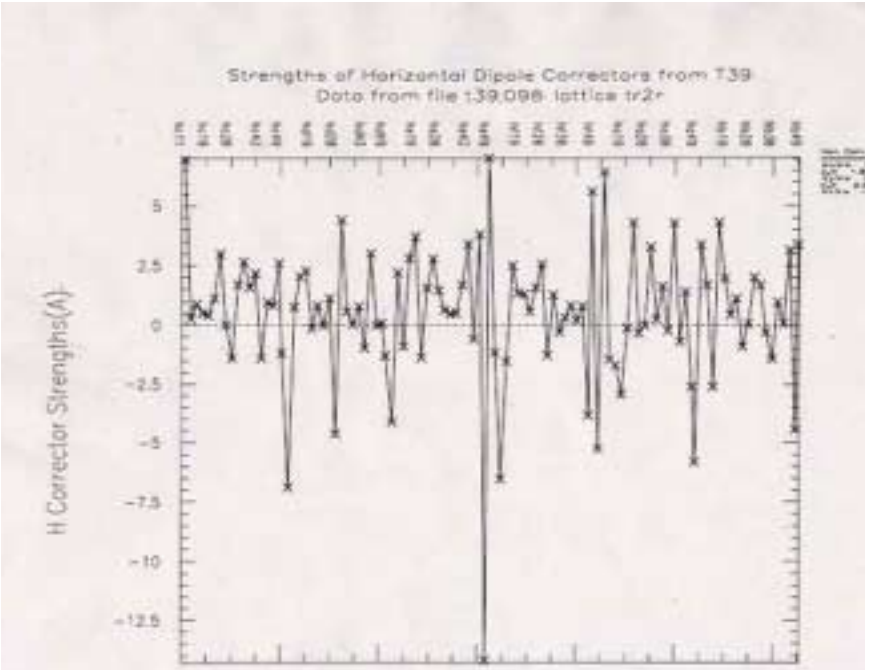


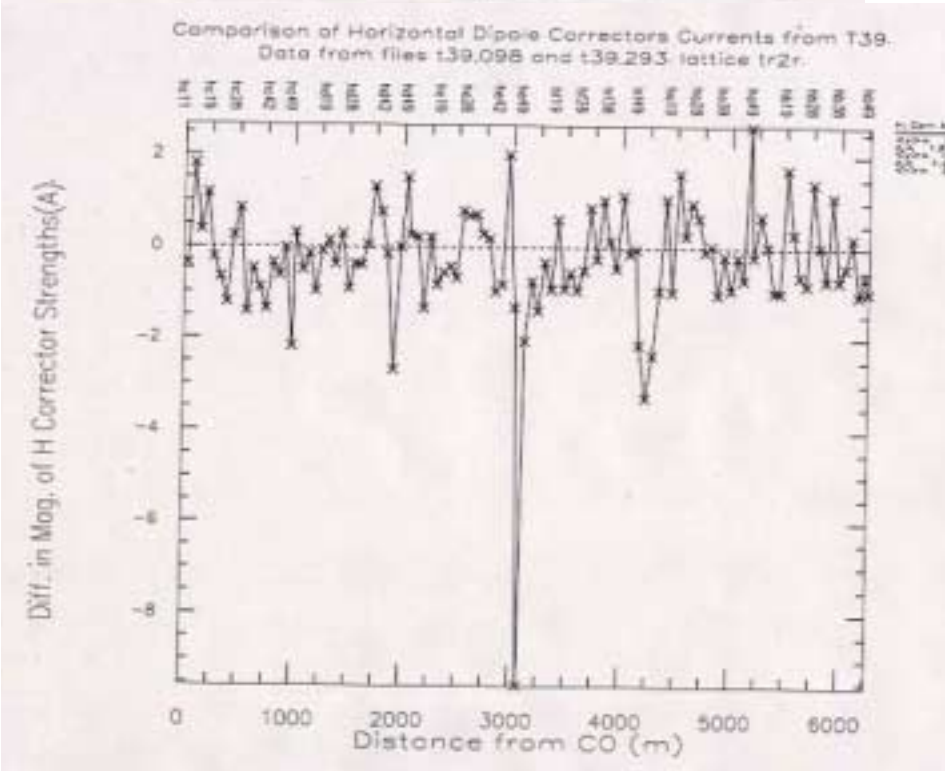


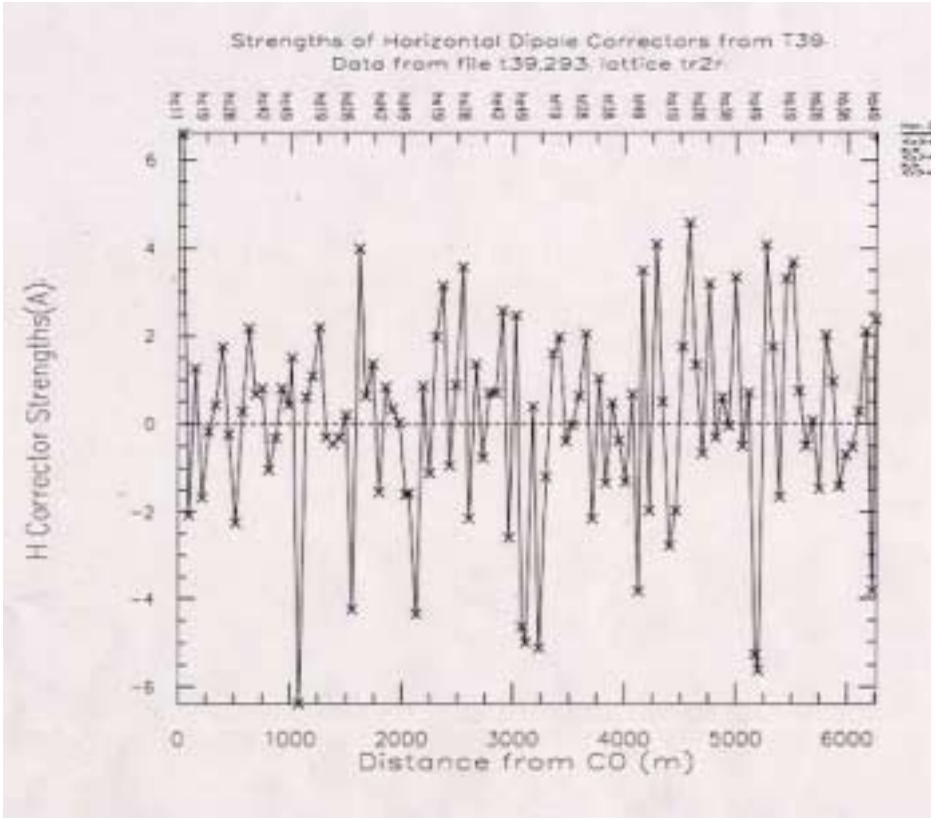




Vertical Corrector Settings







Horizontal Corrector Settings

WBS 1.3.4.8.3 Magnet Alignment Roll and Position Corrections

								% magnets	Number of
House	Roll Angle > N mrad							> 1 mrad	Magnets
								roll	Measured
	>1	>2	>3	>4	>5	>6	>7		in house.
A-1	1	1						0.66%	42
A-2	18	11	8	5	2	2	1	11.92%	45
A-3	5							3.31%	41
A-4	3	1						1.99%	35
B-1	20	10						13.25%	42
B-2	19	6	3	1				12.58%	43
B-3	2							1.32%	40
B-4								0.00%	36
C-1	10	2	1	1				6.62%	43
C-2	4	2	1					2.65%	45
C-3								0.00%	40
C-4								0.00%	26
D-1	1							0.66%	41
D-2	6	1						3.97%	44
D-3	1	1						0.66%	38
D-4	8	3	1	1	1			5.30%	33
E-1	1	0						0.66%	43
E-2	17	6						11.26%	44
E-3	23	10						15.23%	40
E-4	6	2						3.97%	36
F-1	1							0.66%	39
F-2	3							1.99%	45
F-3	2							1.32%	40
F-4								0.00%	32
Total > N	151	56	14	8	3	2	1	100.00%	953

The table gives the distribution of rolls among the 16 houses In the Tevatron before the shutdown.

These measurements were redone at the start of the Shutdown. CDF and D0 Experimenters did these measurements. We then Made corrections to as many Magnets as we could, given Other constraints on resources During the shutdown.

Many elevations and horizontal offsets were also be corrected, During the shutdown. However, data from the TevNet installation will not be available until the alalysis is done, perhaps before the Lehman review.

108 magnets had significant Realignment in this period.

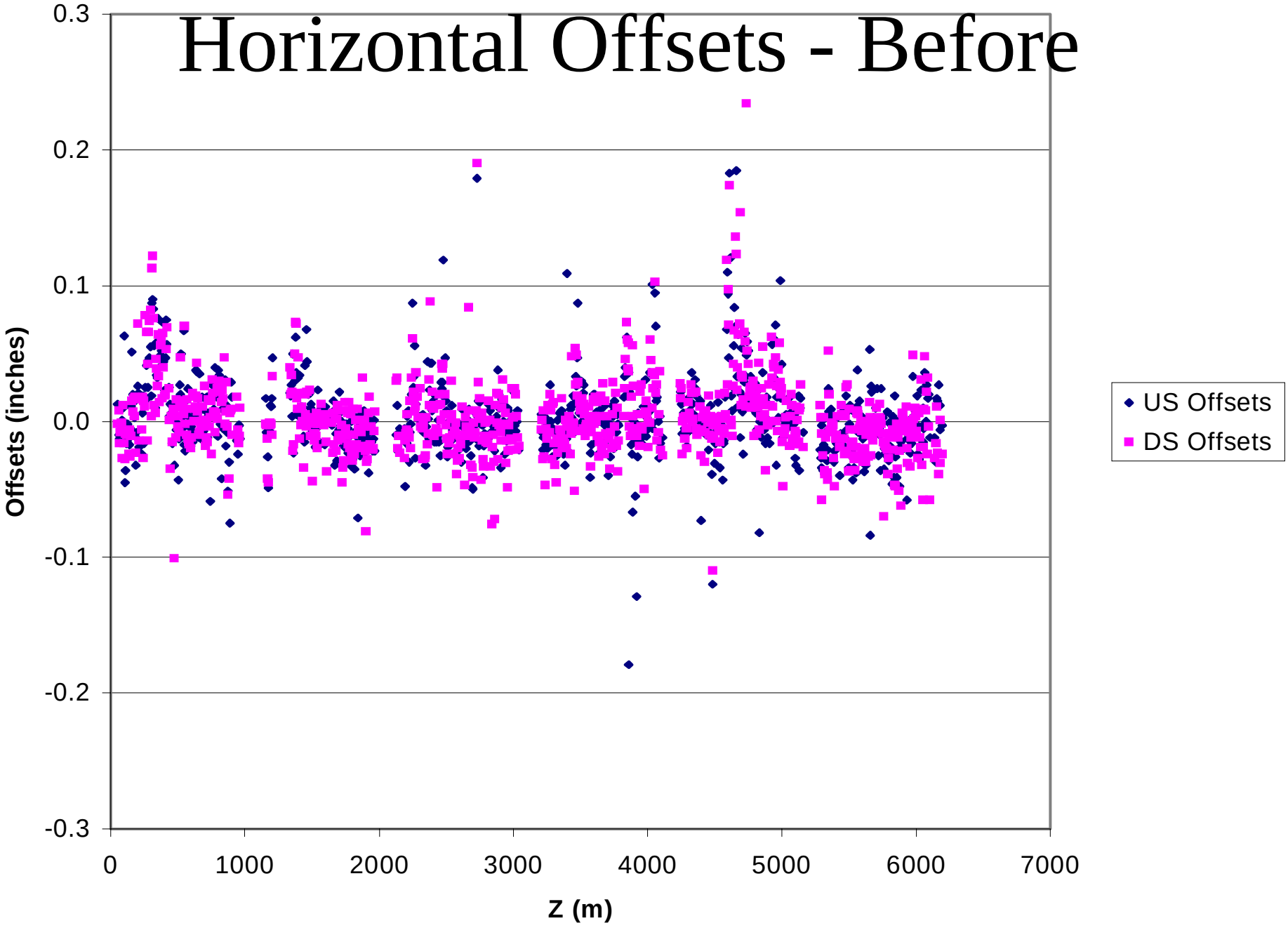
Latest Rolls

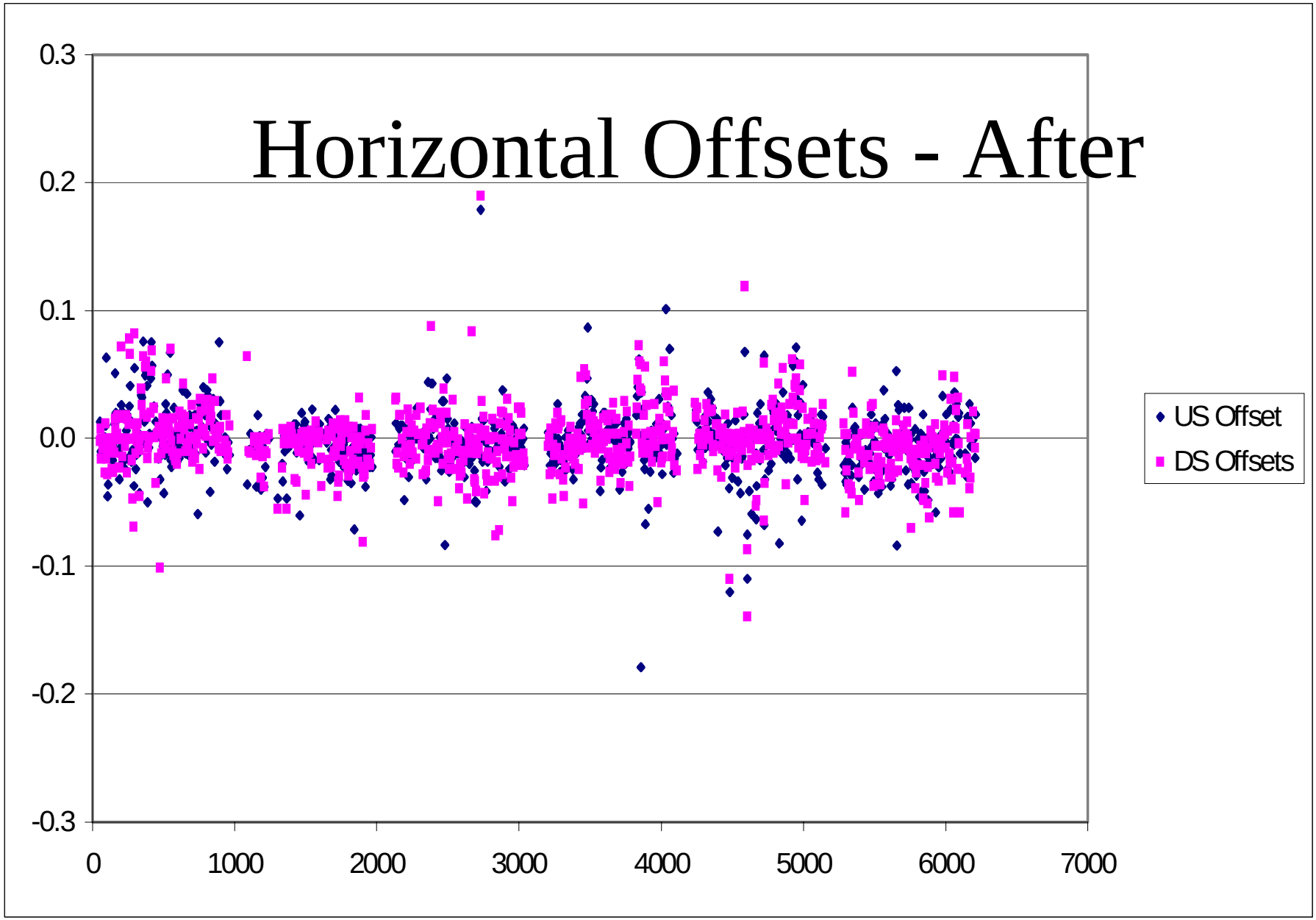
	>1	>2	>3
All	58	13	5
A Sector	12	2	0
B Sector	2	0	0
C Sector	5	3	2
D Sector	10	0	0
E Sector	25	8	3
F Sector	4	0	0

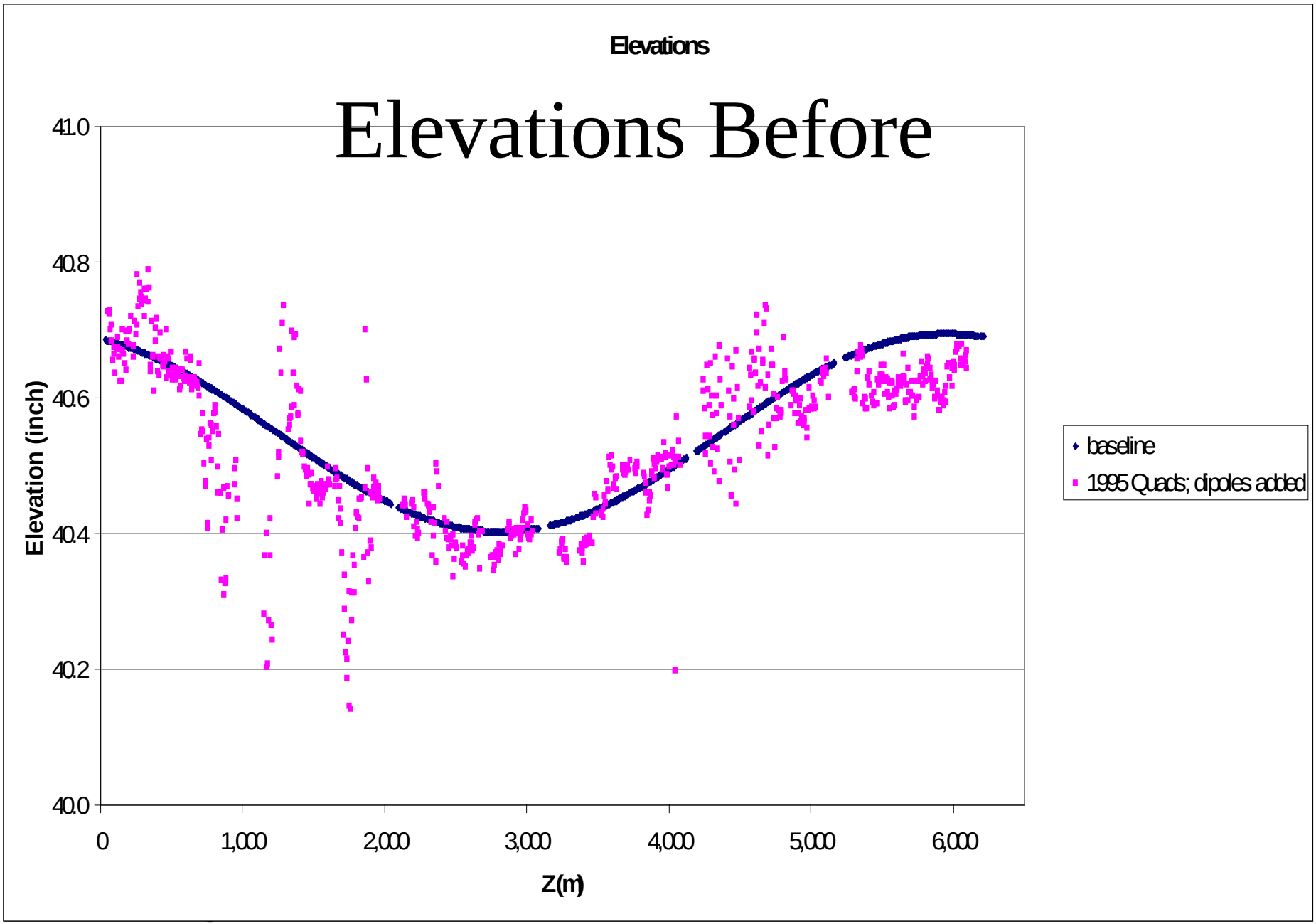
	>1	**>2**	**>3**
A-1	**3**	**0**	**0**
A-2	**2**	**0**	**0**
A-3	**4**	**0**	**0**
A-4	**3**	**2**	**0**
B-1	**0**	**0**	**0**
B-2	**0**	**0**	**0**
B-3	**2**	**0**	**0**
B-4	**0**	**0**	**0**
C-1	**0**	**0**	**0**
C-2	**5**	**3**	**2**
C-3	**0**	**0**	**0**
C-4	**0**	**0**	**0**

	>1	**>2**	**>3**
D-1	1	0	0
D-2	4	0	0
D-3	1	0	0
D-4	4	0	0
E-1	1	0	0
E-2	4	0	0
E-3	17	8	3
E-4	3	0	0
F-1	1	0	0
F-2	2	0	0
F-3	1	0	0
F-4	0	0	0
All	58	13	5

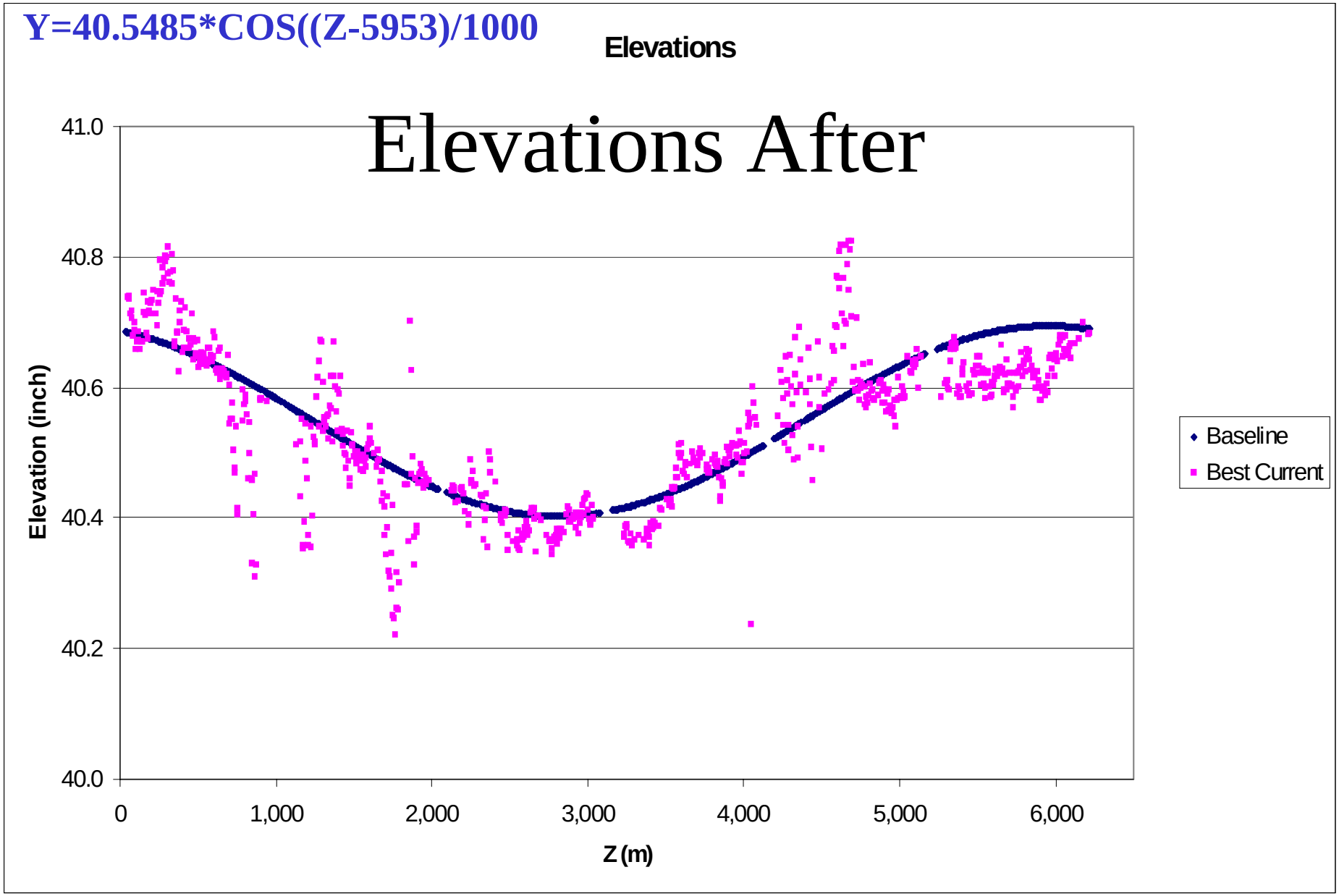
Horizontal Offsets - Before



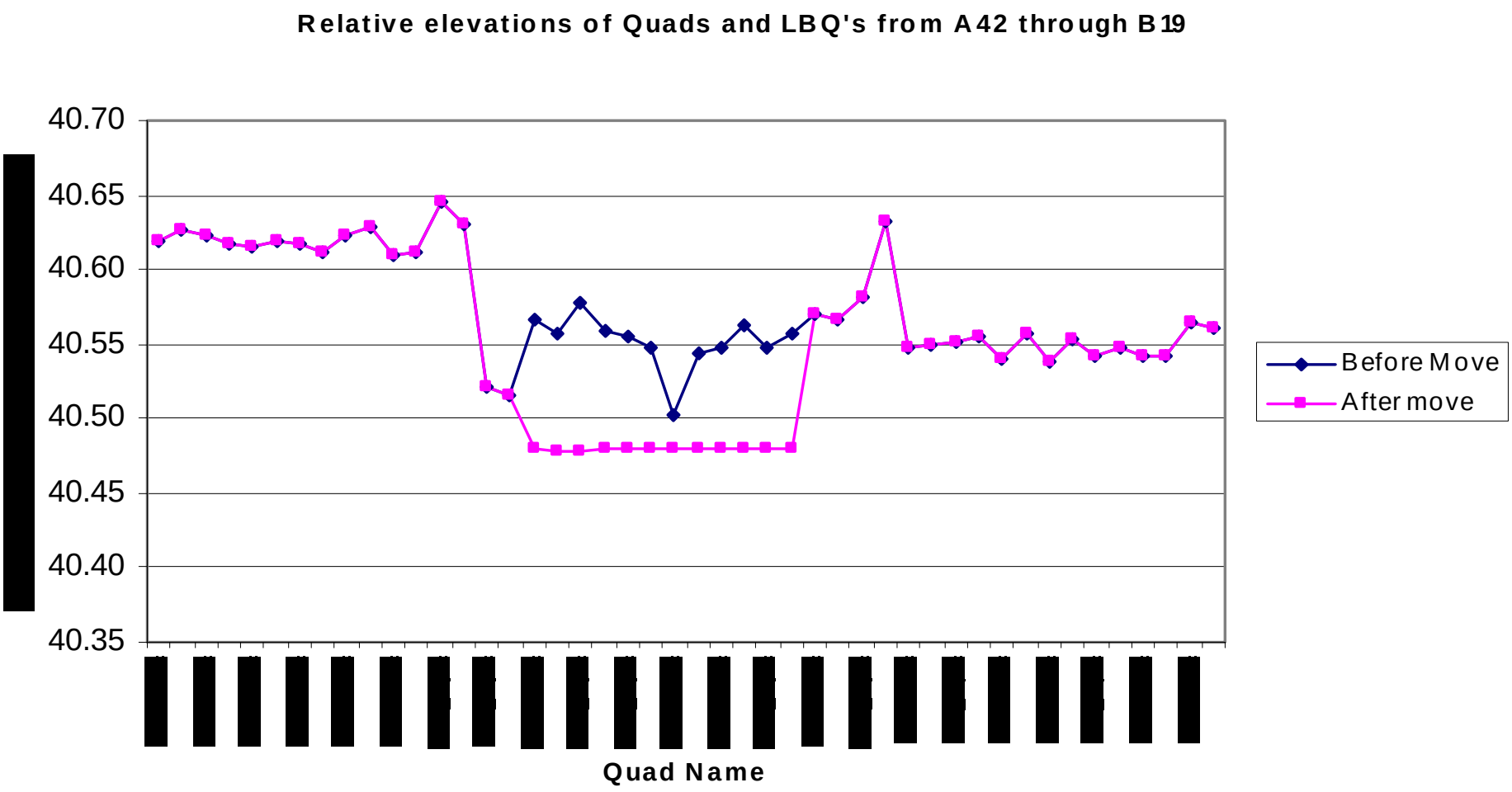

Horizontal Offsets - After
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0
1000
2000
3000
4000
5000
6000
7000
US Offset
DS Offsets


Elevations
Elevations Before
41.0
40.8
40.6
40.4
40.2
40.0
Elevation (inch)
0
1,000
2,000
3,000
4,000
5,000
6,000
Z(m)
baseline
1995 Quads; dipoles added

(1.3.4.8)


Y=40.5485*COS((Z-5953)/1000
Elevations
Elevations After
41.0
40.8
40.6
40.4
40.2
40.0
Elevation (inch)
0
1,000
2,000
3,000
4,000
5,000
6,000
Z (m)
Baseline
Best Current

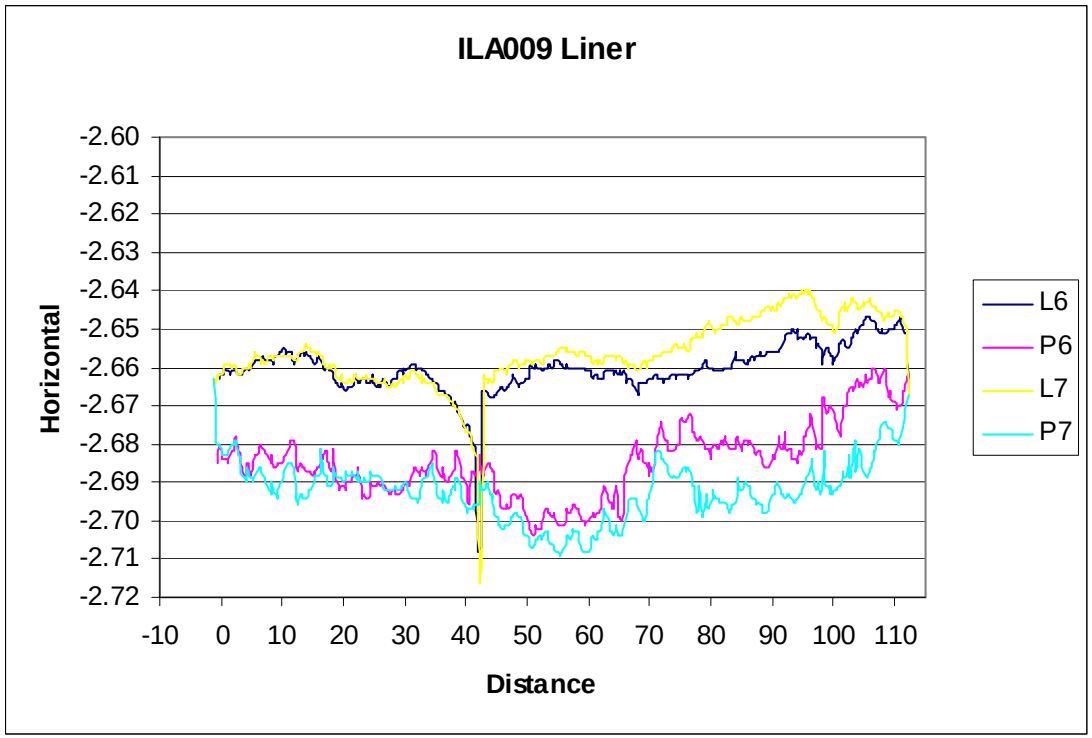
CDF LBQ corrections



D0 LBQ Corrections

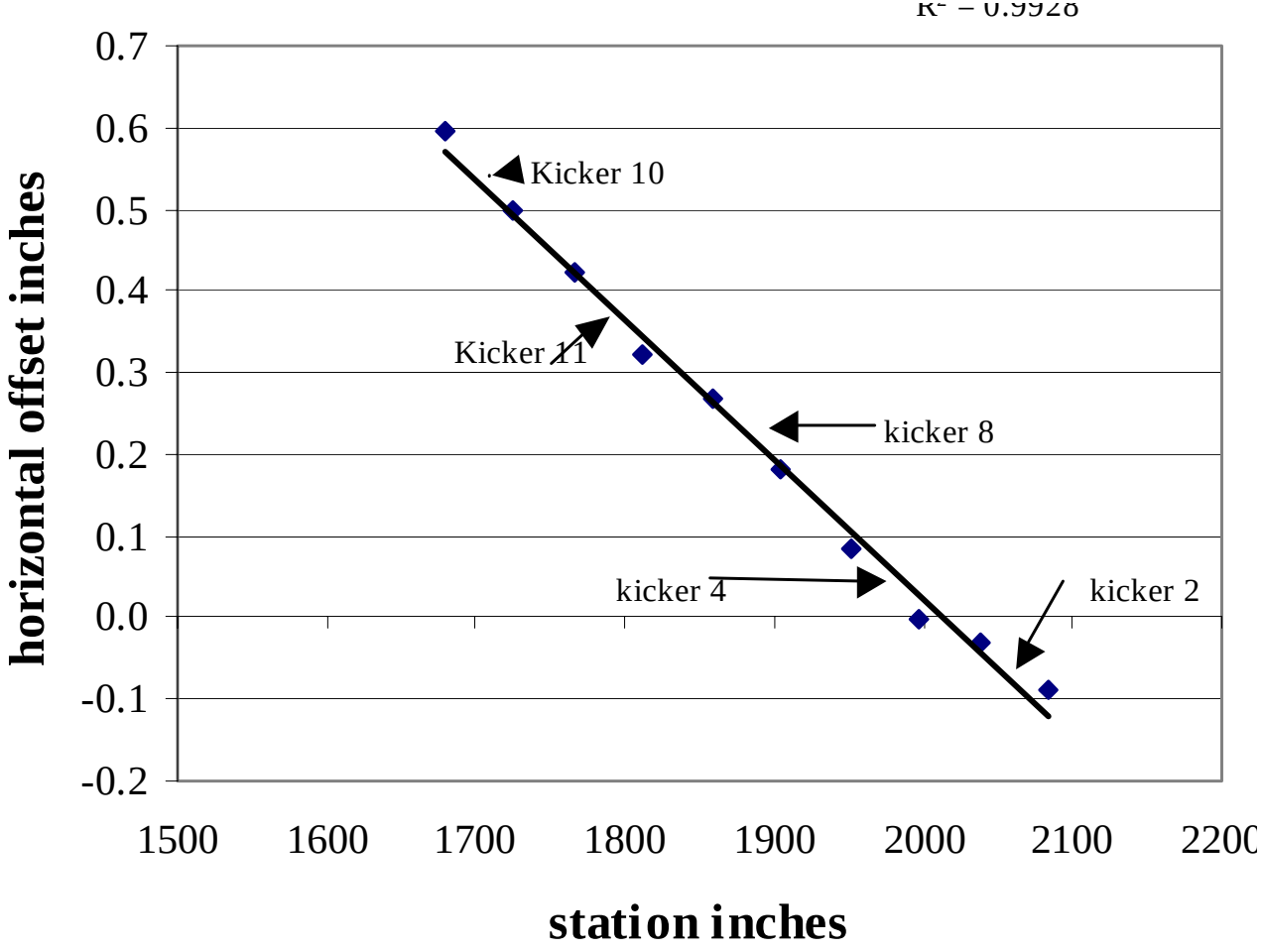
(1.3.4.8)

In the process of reassembly a mismatch or misalignment of about 6mm (0.25 inch) was discovered between the Tevatron and Main Injector. Given the size of the beam pipe, the aperture of the magnets and that the history of successful beam transport in this part of the Tevatron, no attempt was made to correct this misalignment during the summer shutdown. More work will be needed to understand the source of the misalignment, further beam studies will be done, with the goal of correcting this problem during the next shutdown.



Installation of F0 Lambertson Liner

All five kickers were mounted on a bedplate that was designed to move during the change from 800 GeV fixed target to colliding beam operations. Adjacent and to the radial inside were the bedplates for the fixed target extraction Lambertsons. Both systems were designed for easy movement during change over between these two running modes.



Pbar Kicker misalignment

It appears that sometime between March 2001 and October 2003 the bedplates for the Lambertsons were pushed into the bedplate for the kickers causing the offset.

Magnet Stand Replacement

A-1	2	D-1	0
A-2	15	D-2	0
A-3	0	D-3	0
A-4	0	D-4	2
A-Sector	17	D-Sector	2
B-1	15	E-1	0
B-2	5	E-2	12
B-3	0	E-3	5
B-4	0	E-4	1
B-Sector	20	E-Sector	18
C-1	1	F-1	0
C-2	1	F-2	0
C-3	2	F-3	0
C-4	0	F-4	0
C-Sector	4	F-Sector	0
		All	61

Hans Jostlein's measurements with tilt meters at D0, 1990

Readback from Two Tiltmeters on a Common Support Over a 38 Day Period.

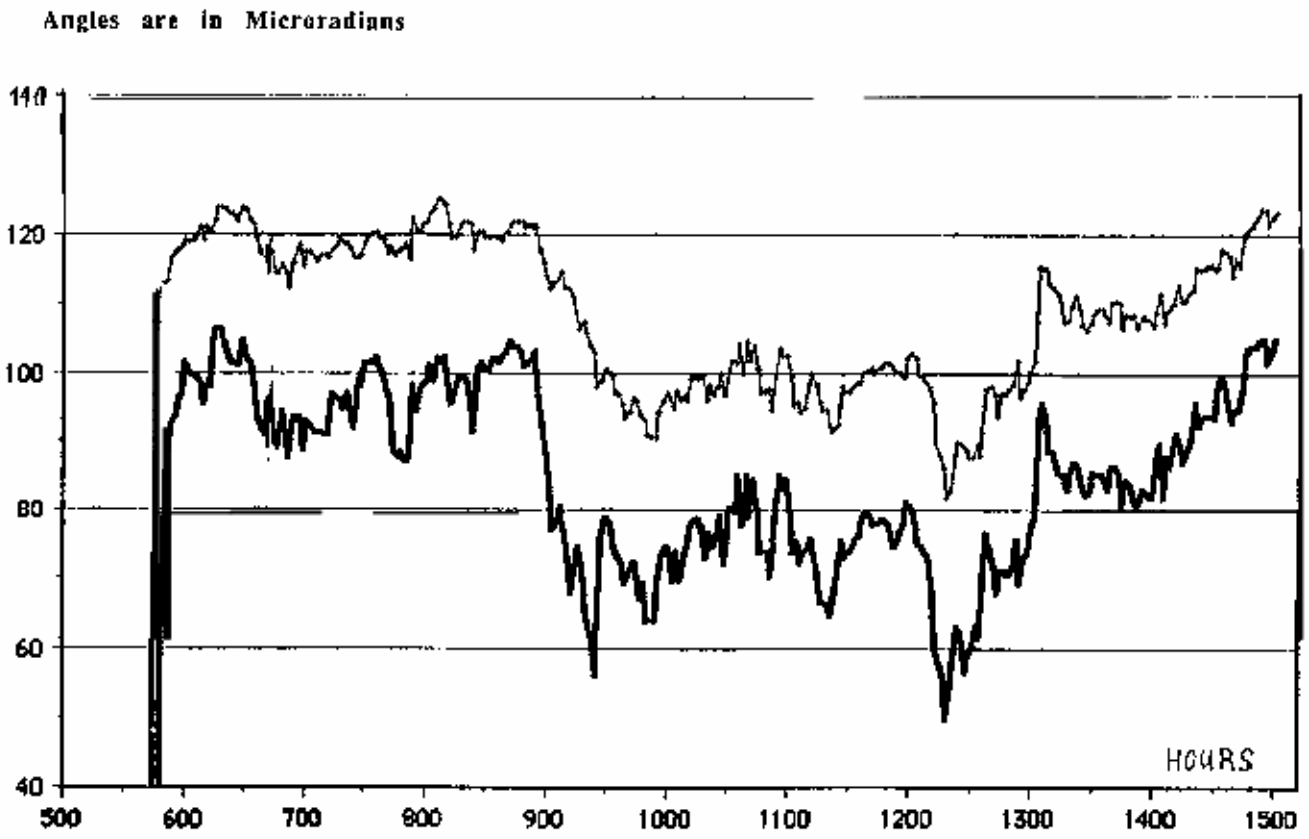
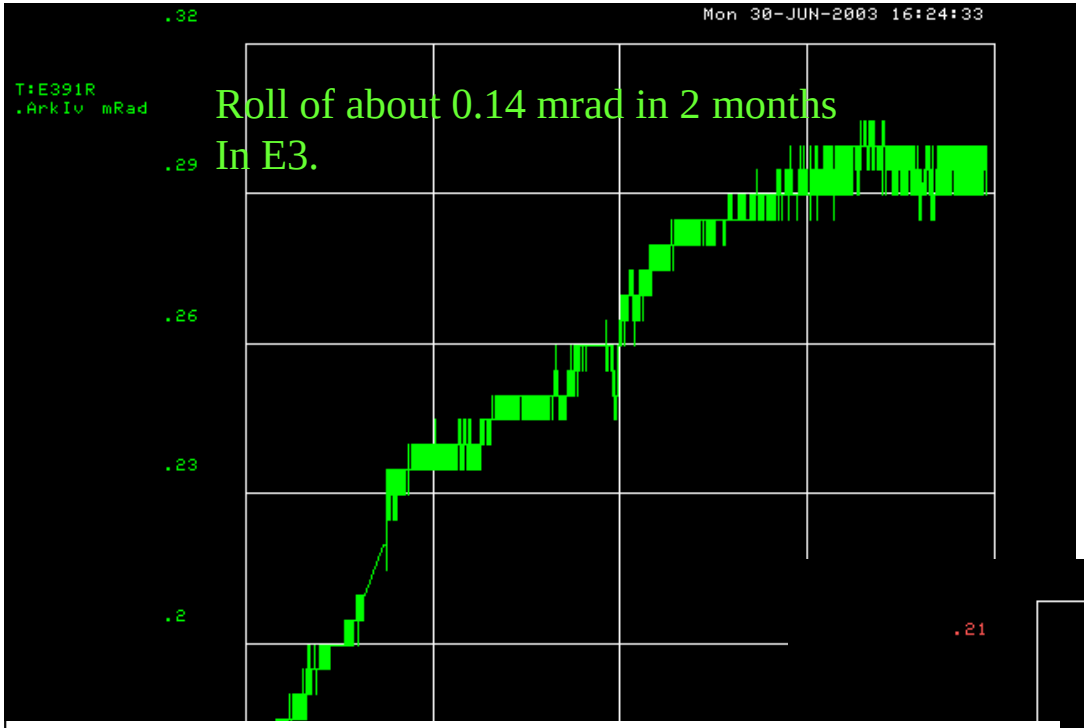
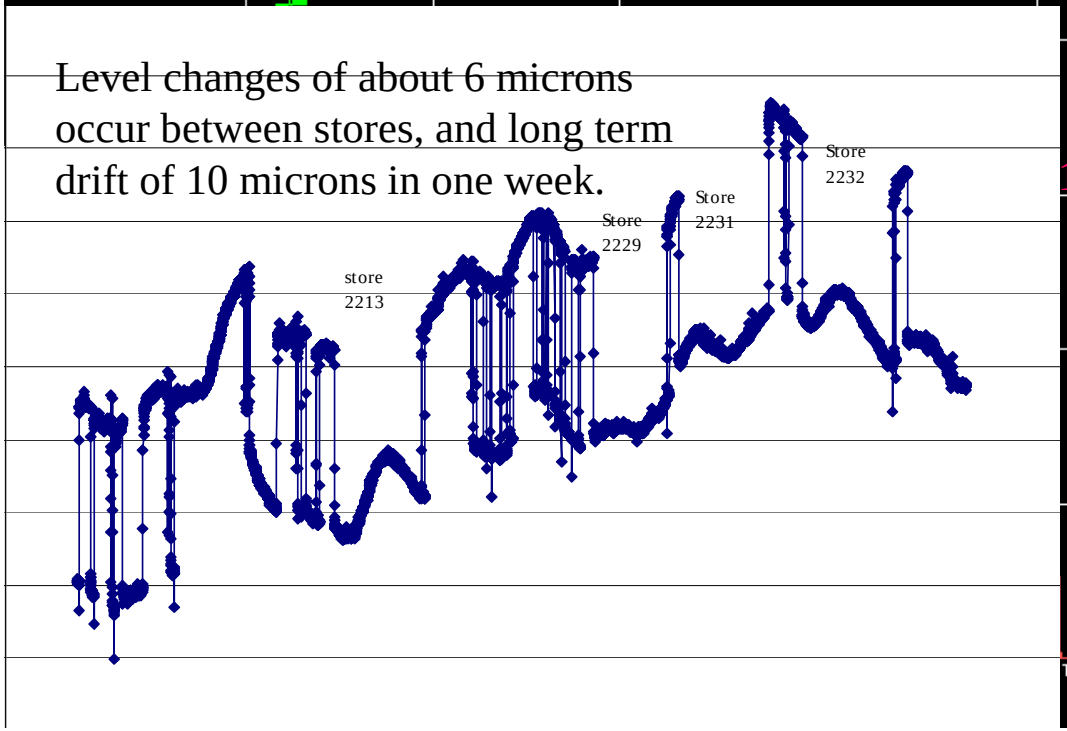
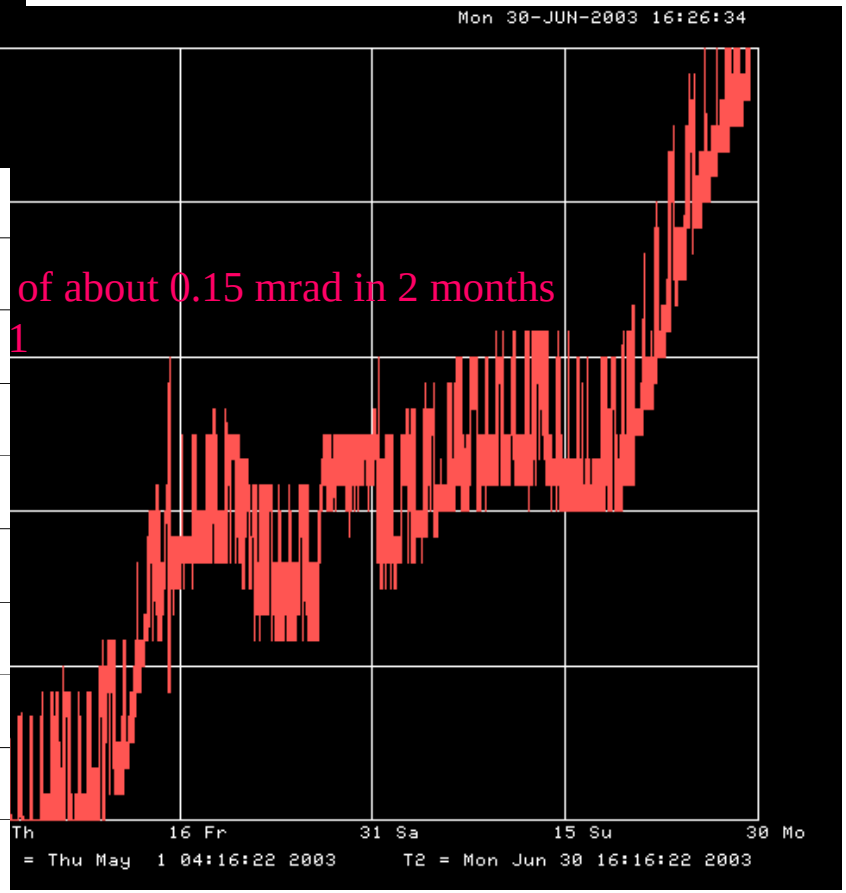


Fig. 10 Response of two Tiltmeters during a 38 Day Run



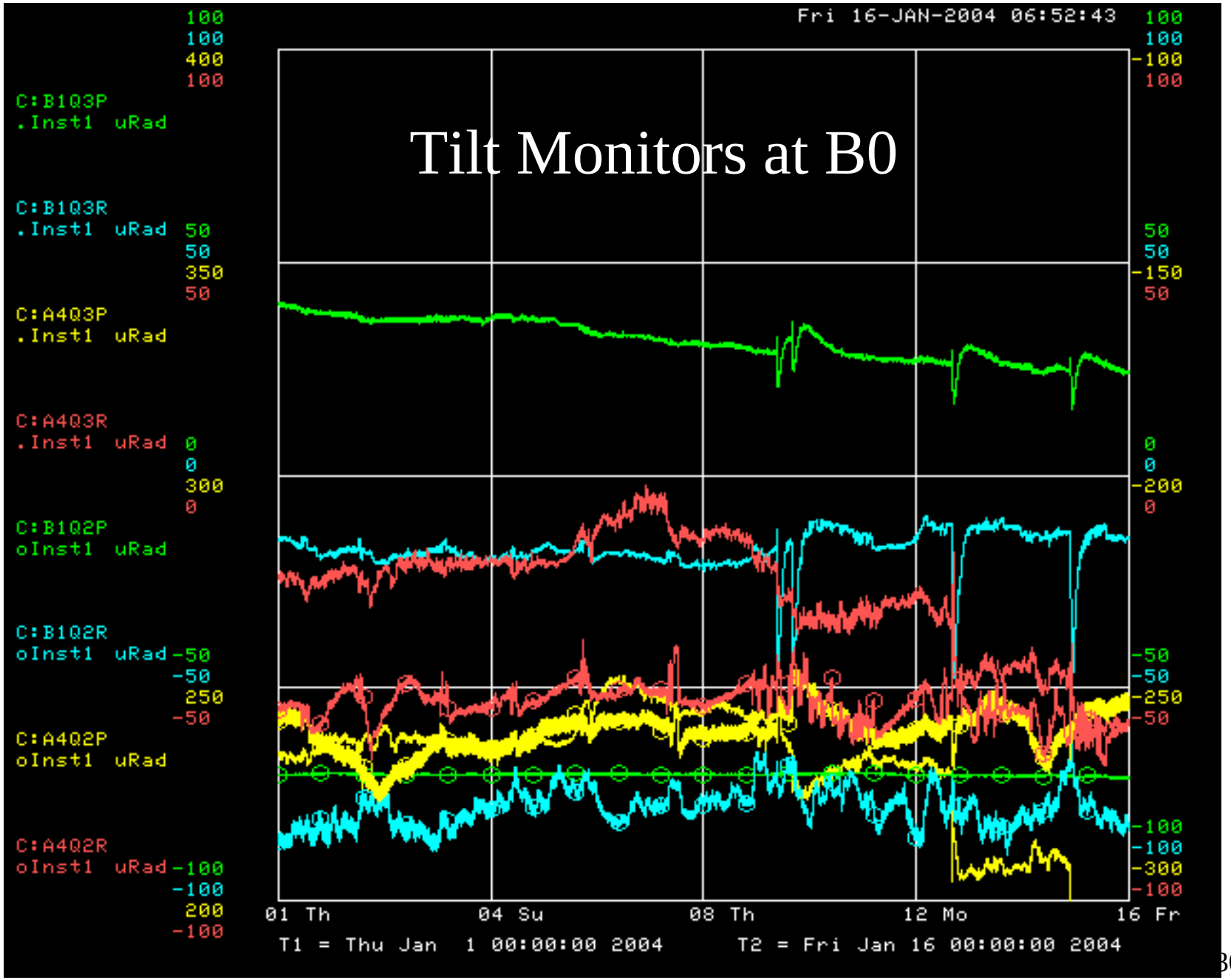
Tilt Monitors located in the Tev tunnel indicate that long term changes do occur. Discrete short term motion can also be seen.





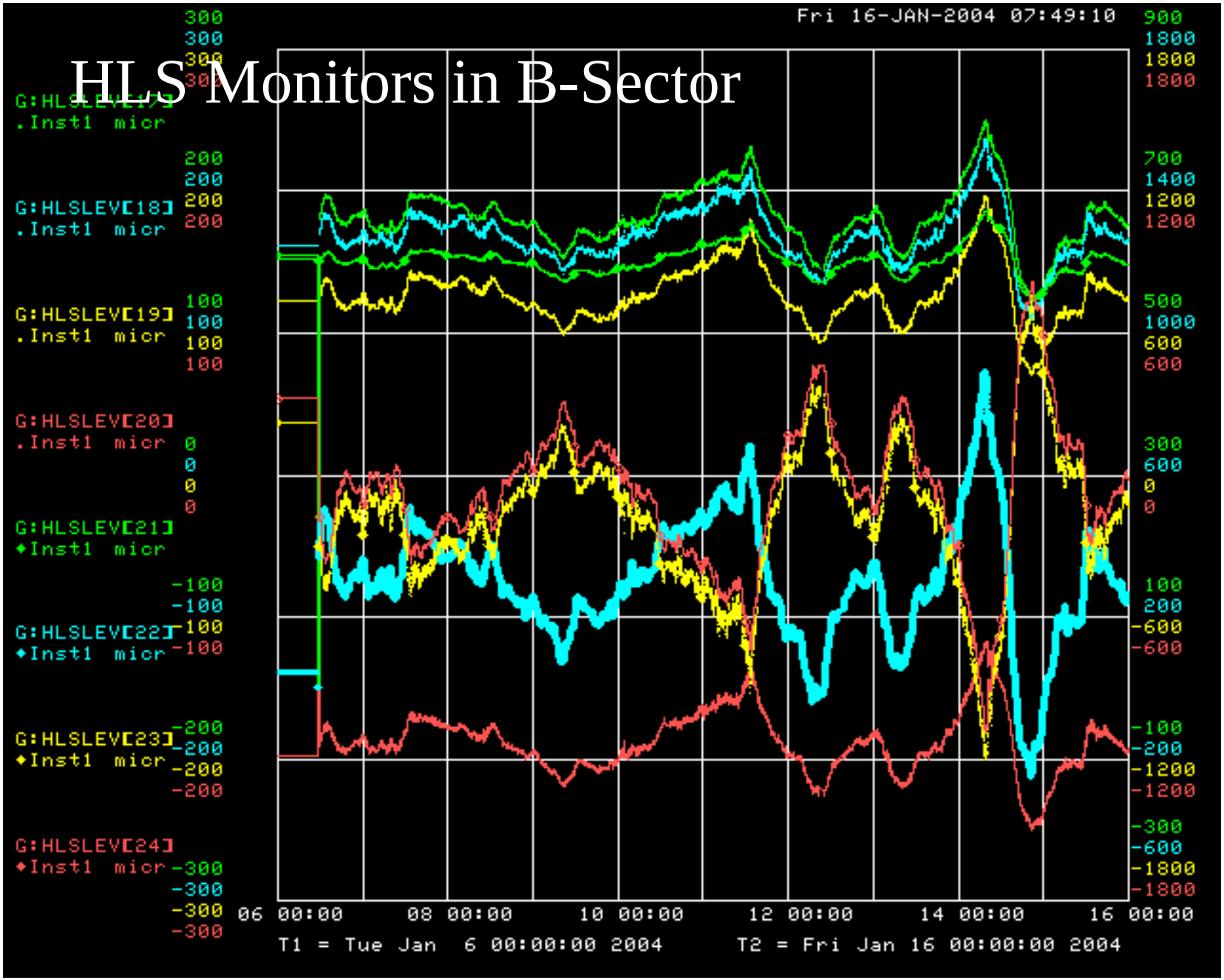
Tilt Monitor Data Detectors

Location	Average Roll/Time	Estimated Annual Roll
	μrad/day	μrad/year
A15-1 Quad	1.10	400
A16-3 Dipole	0.58	210
A21-1 Quad	0.21	77
B17-5 Dipole	1.52	555
B24-1 Quad	0.22	80
C24-1 Quad	1.30	474
E29-1 Quad	1.07	-390
E32-1 Quad	1.77	538
E39-1 Quad	1.18	430


Tilt Monitors at B0
Fri 16-JAN-2004 06:52:43
C:B1Q3P
.Inst1 uRad
C:B1Q3R
.Inst1 uRad
C:A4Q3P
.Inst1 uRad
C:A4Q3R
.Inst1 uRad
C:B1Q2P
oInst1 uRad
C:B1Q2R
oInst1 uRad
C:A4Q2P
oInst1 uRad
C:A4Q2R
oInst1 uRad
01 Th
04 Su
08 Th
12 Mo
16 Fr
T1 = Thu Jan 1 00:00:00 2004
T2 = Fri Jan 16 00:00:00 2004

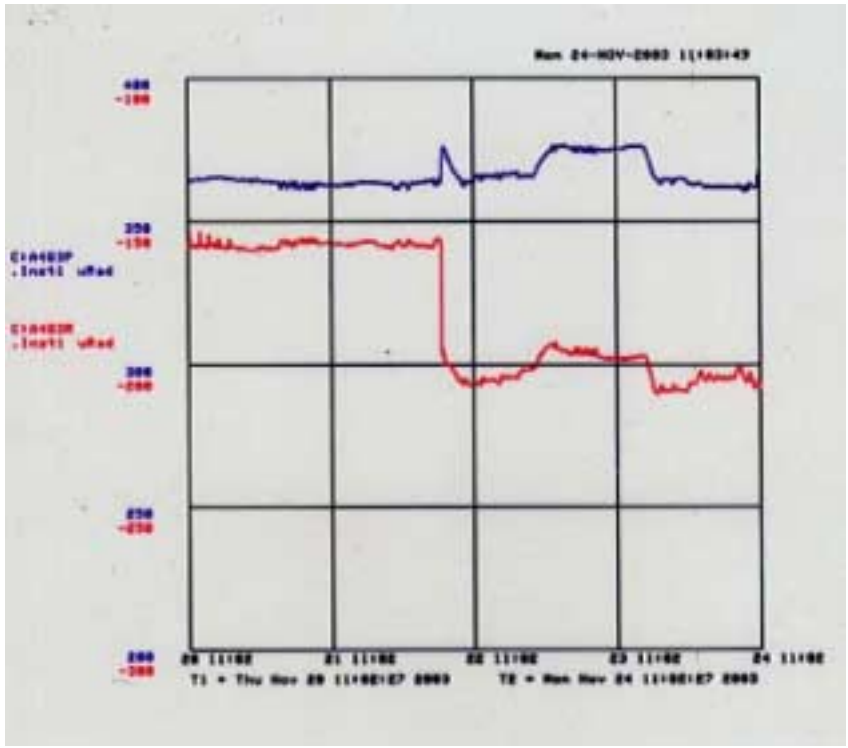
(1.3.4.8)

HLS Monitors in B-Sector

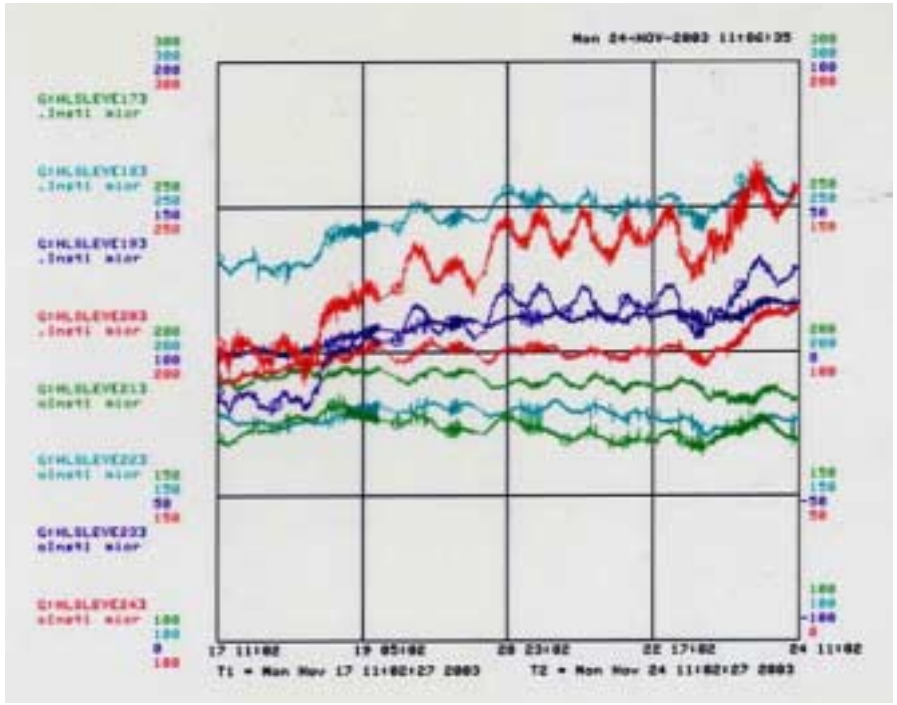


(1.3.4.8)

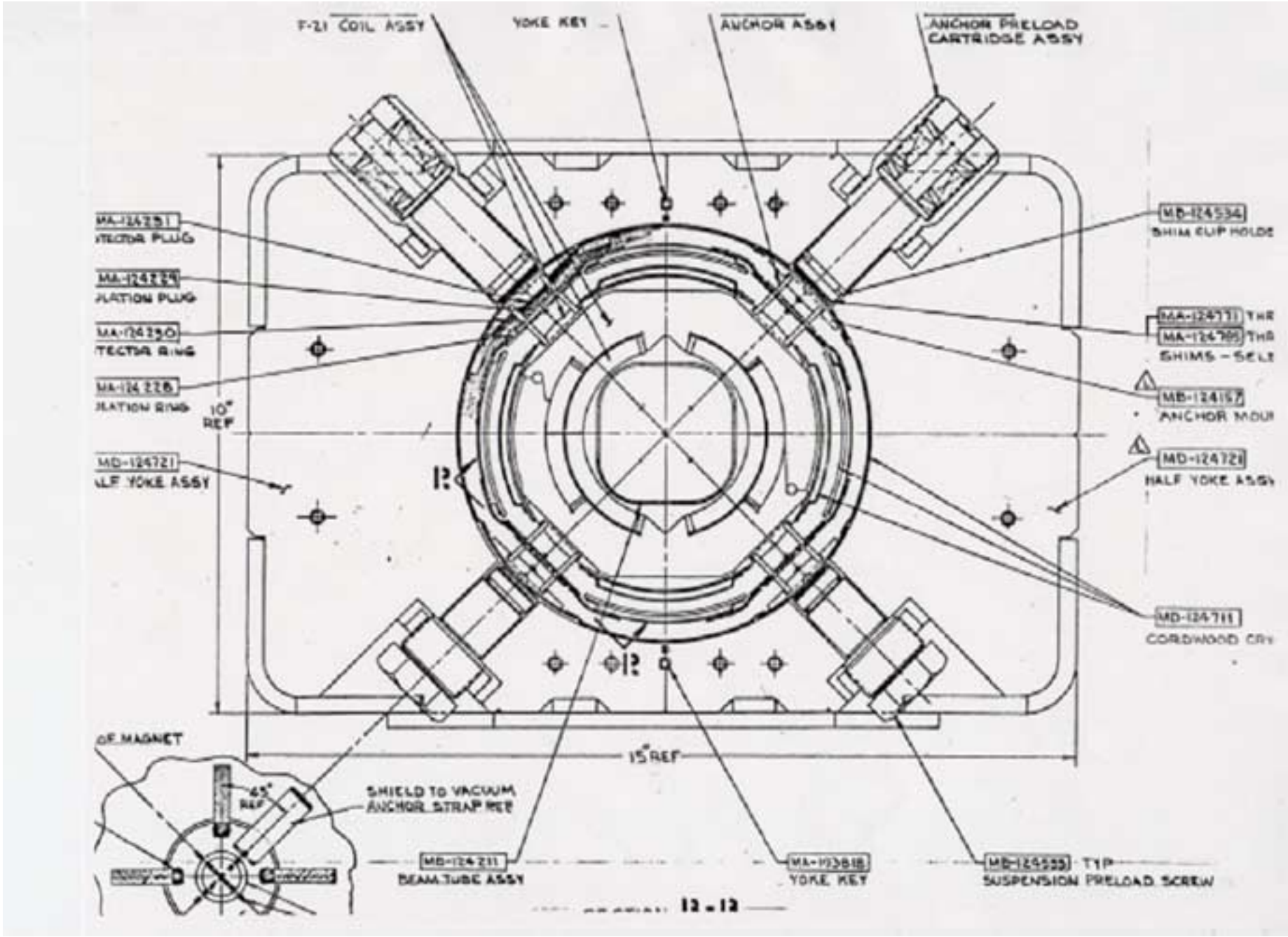
Example of a magnet quench



HLS response in B-Sector

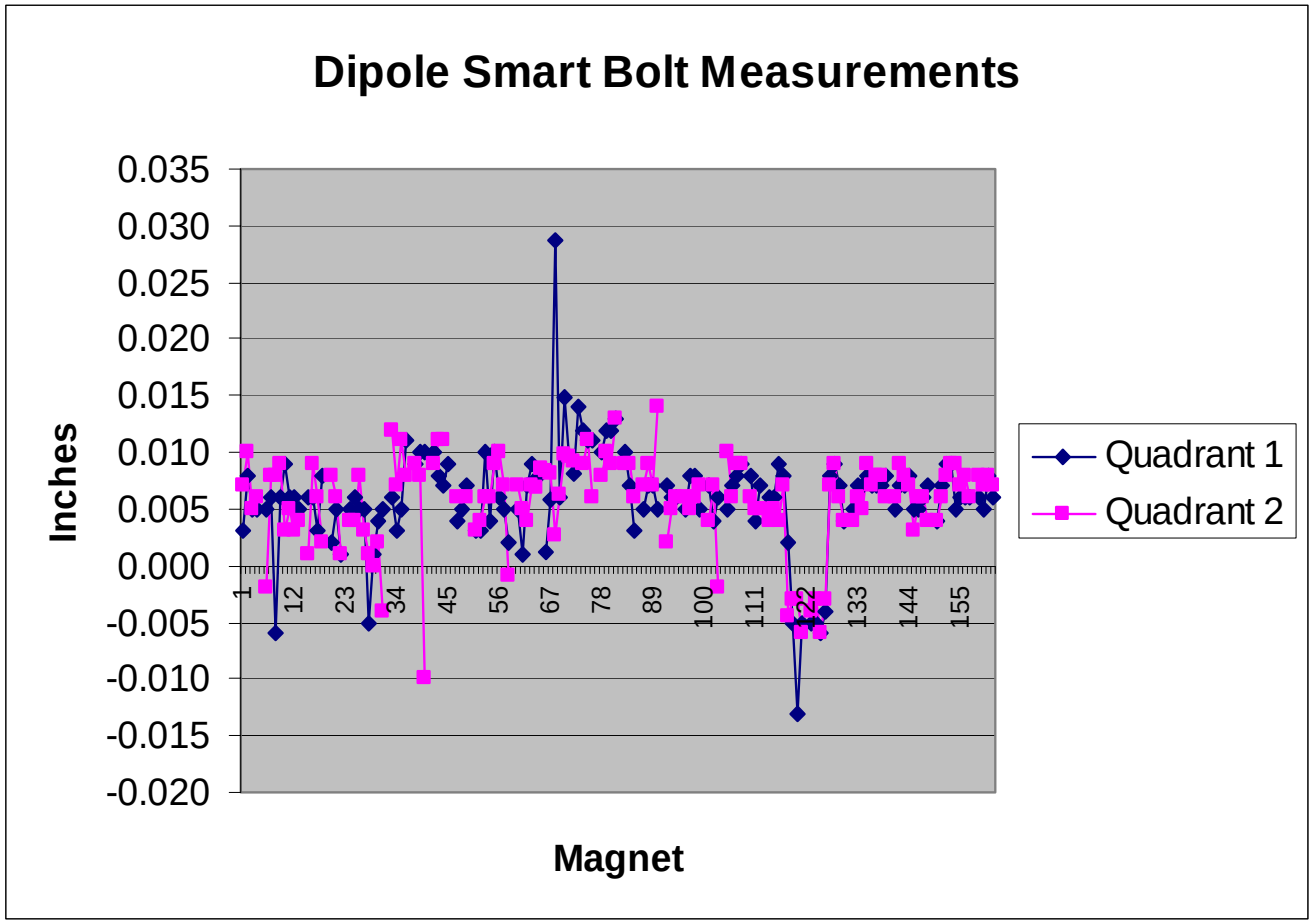


Tev Magnet cross section



106 dipole magnets near the low beta regions were modified for cryostat movement. By concentrating on the magnets that have no nearby skew-quad correctors, the coupling can be reduced by 75 %. Virtually all dipoles were measured in the Tevatron to establish a baseline: to detect future movement if it occurs. Some dipoles show unusual behavior, as if the anchor bolt is broken.

Suspicious magnets are being studied to develop an understanding of this phenomenon.



WBS 1.3.4.8.4 Smart Bolts

Tevatron Alignment (1.3.4.8)

Summary from Mike Syphers

The skew quadrupole circuits haven't been studied in depth since the shutdown due to lack of proper study time.
The circuits were generally brought up with the same currents used before the shutdown, and then adjusted empirically to be able to bring the two tunes together. We can probably do a better job at this With a little dedicated study time.
Thus, only a few general comments can be made:

1) The currents used in the skew quad circuits are lower than they were. The main circuit is lower by about the expected amount.
2) The auxiliary circuits, SQA0 in particular, have not been optimized in any systematic way
3) The vertical dispersion is slightly smaller, but this is present predominately due to the SQA0 quads
4) Study time is required to further optimize the system.

Database and Beam Sheets

Once the TevNet data is processed and the position of the machine and its components are documented, a statement of the current machine definition can be made - a beam-sheet, if you will. As the requests to move various components are submitted, a new 'beamsheet' evolves. Whether the request says "move this dipole 50 mils right and set the roll at 0.1 milliradians“ or it says "set the magnetic center at these coordinates with this roll, pitch, yaw set", doesn't change this at all.

The only correct way to put the position of a magnet into a database is to use absolute global coordinates. The reference trajectory changes often, so measurements relative to local coordinates would be difficult to maintain. (The reference orbit has changed five times since the summer shutdown.) However, beam diagnostic and design software operate in local coordinates. (Magnet roll plus vertical and horizontal offset relative to a reference orbit.) For survey measurements to be useful for machine studies, an absolute definition of a beam trajectory must be made.

Work Plan for 2004 Shutdown

- **Align the Tevatron**
  - **Eliminate rolls**
  - **Fix Murphy Line if Needed.**
  - **Identify and Implement Optimized Elevations**
- **Replace More Magnet Stands**
  - **Spool Stands, especially Bartelson Quads**
  - **Replace Quadrupole Stands**
  - **Replace more Dipole Stands**
- **Complete Installation of Motion Detectors**
  - **Verify that data is useful!**
  - **Choose HLS system, Complete the ring**
- **Implement Electronic Database**
- **Possible Work Needed for Dipoles with Broken Anchors**
- **Develop Better Understanding of Long Straights.**

Summary

We feel that much has been accomplished, but much more remains to be done.