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Commissioning of the Tune Drift Compensations System in the Tevatron

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Introduction

The Tevatron tune drift compensation system[1] was commissioned and implemented during Tevatron studies on 9/23/02 and has been used successfully in Collider operations. After adjustments to the parameters in the compensation algorithm, the measured tune drift was less than 0.001 over forty minutes at 150 GeV and the measured minimum tune split was below 0.003 units during this time. These magnitudes should be compared to measured tune drifts of about 0.01 and minimum tune split drifts of 0.02 if the drifts are left uncompensated. Figure 1 shows a summary plot of the measured tune drifts before and after the compensation system was implemented.

[1] Details of the hardware and software algorithms for the tune drift system can be found in the note "Chromaticity, Tune, and Coupling Drift and Snapback Correction Algorithms in the Tevatron", Mike Martens, Jerry Annala, Beams-doc-467, http://beamdocs.fnal.gov/cgi-bin/public/DocDB/ShowDocument?docid=467

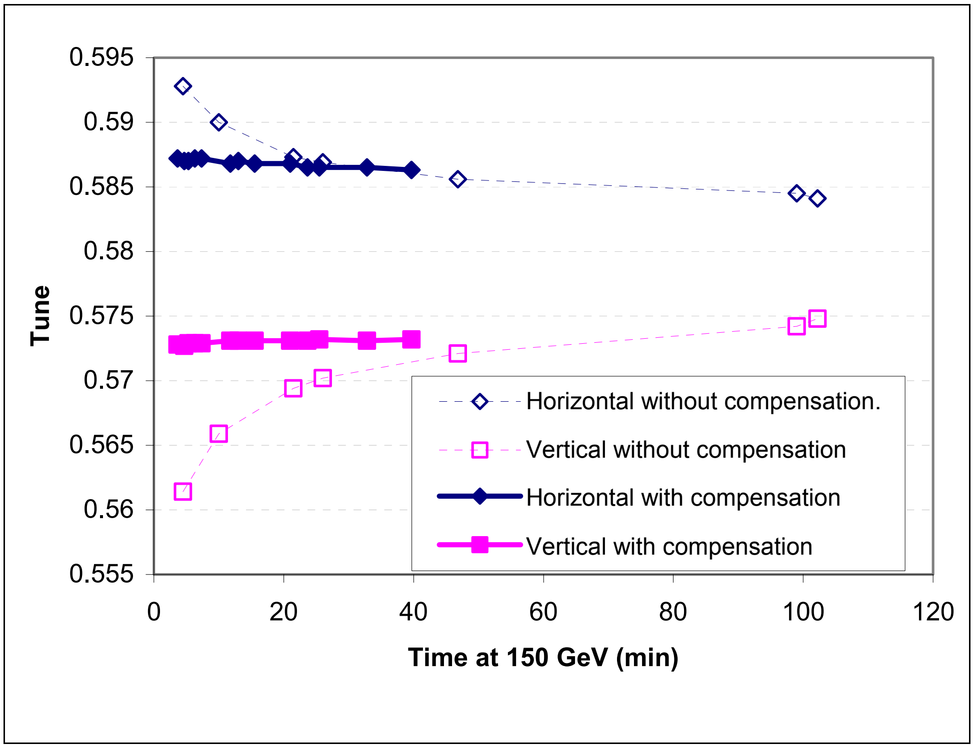


Figure 1 Comparison of the tune drift at 150 GeV with and without the tune drift compensation. The measured tunes are plotted from data collected on 5/15/02 with no tune drift compensation, and data collected on 9/23/02 with the tune drift compensation active.

The tunes at the start of the ramp were also measured to investigate the "unwind" algorithm during the snapback at the start of the Tevatron ramp. Limitations on the accuracy of the tune measurements make it difficult to quantify how well the snapback algorithm works, but the preliminary data suggests the resulting tune drift at the start of the ramp is not a problem with the snapback correction in place. For future reference the beam position and the settings of the dipole correctors during these measurements were recorded and documented.

The rest of this memo presents the data collected during the commissioning of the tune drift system.

Summary of Measurements

The data presented in this memo is summarized as follows:

- **Measurement #1**. Checked that the hardware and software were operating as expected. Made rough adjustments to the tunes and coupling and verified that the system was working.
- **Measurement #2**. Made precise measurements of the tune and coupling drift as a function of time on the 150 GeV front porch. During this store the tunes drifted by about 0.002 units over 130 minutes and the minimum tune split remained below 0.003 tune units.
- **Calibrated the tune circuits.** The tune circuits used for the tune drift compensation, T:QDD1 and T:QFA4, were calibrated by measuring the tune as a function of current in the trim quadrupole circuits.
- **Adjusted drift algorithm.** Used the results of the tune circuit calibration to modify the parameters in the drift compensation algorithm.
- **Measurement #3.** Made precise measurements of the tune and coupling drift with the update parameters. During this store the tunes drifted by only 0.001 units over 40 minutes and the minimum tune split remained below 0.003 tune units.
- **Measurement #3 snapback.** Measured the tunes on the Tevatron ramp to verify that the correction for the tune drift snapback worked correctly.

In addition to these measurements, the BPM orbits in the Tevatron and the DFG settings at 150 GeV were collected and the data is listed in Appendix A.

Data from Measurement #2

The horizontal and vertical tunes were measured as a function of time at 150 GeV and the data are plotted in Figure 2. As evident from the plots, the tunes drifted by about 0.002 units over the two hours they were measured. During this front porch the coupling was measured at 5.5, 11.2, 18.2, 32.7, and 82 minutes and the minimum tune split was below 0.0027 units at all of these times. Thus the first attempt at correcting the tune drift reduced the amount of tune drift considerably, but left room for improvement.

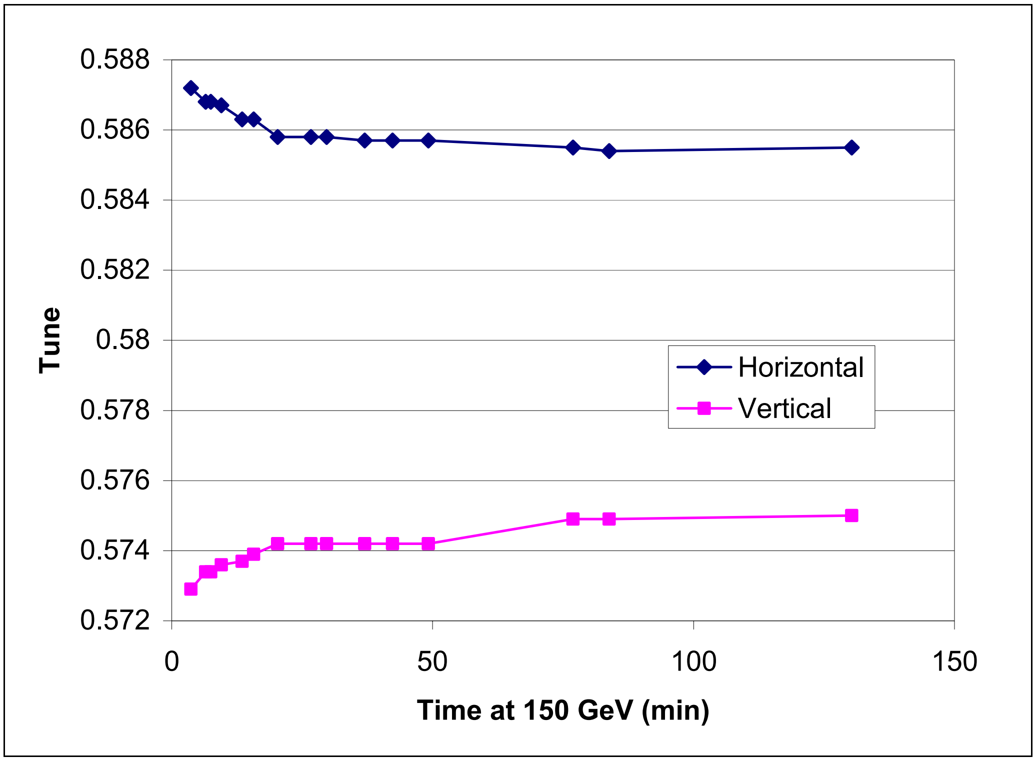


Figure 2 Measured tune as a function of time on the 150 GeV front porch during measurement #2.

The ramp history of the Tevatron magnets is important since it may affect the tune and coupling drift. For these studies the Tevatron was ramped to a 980 GeV flattop (and to low beta) with a flattop time of 2446 seconds (40.7 minutes) and a back porch time of 83 seconds. For a Collider shot setup the ramp history is typically a dry squeeze with a 980 GeV flattop time of 15-20 minutes and a back porch time of 60-90 seconds. Thus the ramp history for this measurement is representative of the conditions during a Collider shot setup.

The tune drift compensation algorithm was determined from previous measurements of the tune and coupling drift at 150 GeV. The drift compensation used during this measurement is given in Equations 1-3

$<\Delta\nu_x> = -0.00778 + 0.0019 * \ln(t)$ **Equation 1**

$<\Delta\nu_y> = 0.0127 - 0.0031 * \ln(t)$ **Equation 2**

$<\Delta\kappa_{SQ}> = 0.0250 - 0.0061 * \ln(t)$ **Equation 3**

where t is the time (in seconds) from the start of the front porch. The currents in the trim quadrupole circuits are then determined from Equations 4-6 which relate currents in the trim quadrupoles to the change in tunes

I_{QFB2} (in Amps) = $(10.1)* <\Delta\nu_x> +(3.15) <\Delta\nu_y>$ **Equation 4**

I_{QDB2} (in Amps) = $(-3.00)* <\Delta\nu_x> +(-9.74) <\Delta\nu_y>$ **Equation 5**

I_{SQB2} (in Amps) = $(9.47)* <\Delta\kappa_{SQ}>$. **Equation 6**

The actual currents used for this measurement are plotted in Figure 3. For this measurement no current was used in the C:SQ0B2 (=T:SQA0) circuit.

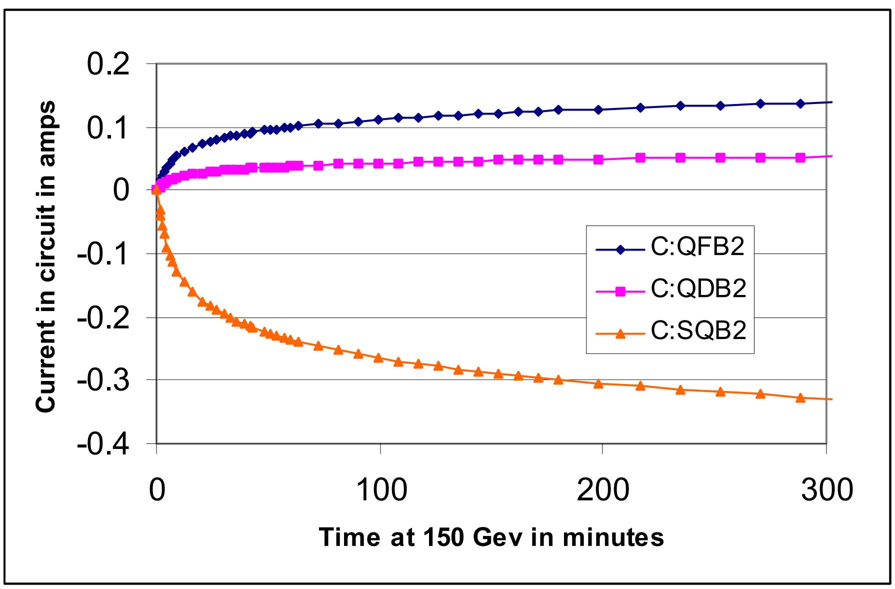


Figure 3 Plot of currents in tune drift circuits as a function of time at 150 GeV.

The BPM orbits at 150 GeV and the dipole corrector (DFG) settings were recorded during these measurements and the data are listed in Appendix A.

Calibration of tune circuits

After it was discovered that the tune drift algorithm did not completely compensate for the tune drifts, the trim quad circuits T:QDD1 and T:QDF4 were calibrated. A measurement of the tune shifts versus the current in the trim quads was performed and the results are plotted in Figure 4 and Figure 5. From linear fits to the data we find the matrix relationship between tune changes and current changes in the tune quad circuits,

$$\begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix} = \begin{pmatrix} 0.100 & 0.0272 \\ -0.0267 & -0.1045 \end{pmatrix} \begin{pmatrix} \Delta I_{QFA4} \\ \Delta I_{QDD1} \end{pmatrix} \qquad \text{(Measured tune response)}$$

and inversely,

$$\begin{pmatrix} \Delta I_{QFA4} \\ \Delta I_{QDD1} \end{pmatrix} = \begin{pmatrix} 10.75 & 2.80 \\ -2.75 & -10.28 \end{pmatrix} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix}.$$

Based on this calibration, the coefficients in Equations 4 and 5 of the tune drift algorithm were updated and used for the next set of measurements of the tune drift at 150 GeV.

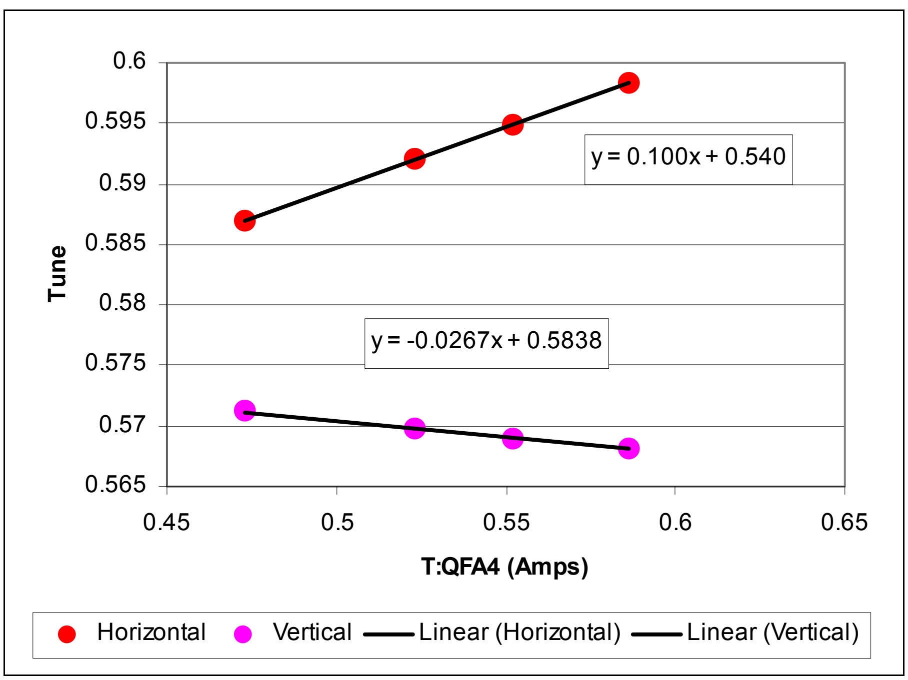


Figure 4 Plot of tune versus current in T:QFA4 at 150 GeV and the results of a linear fit to the data.

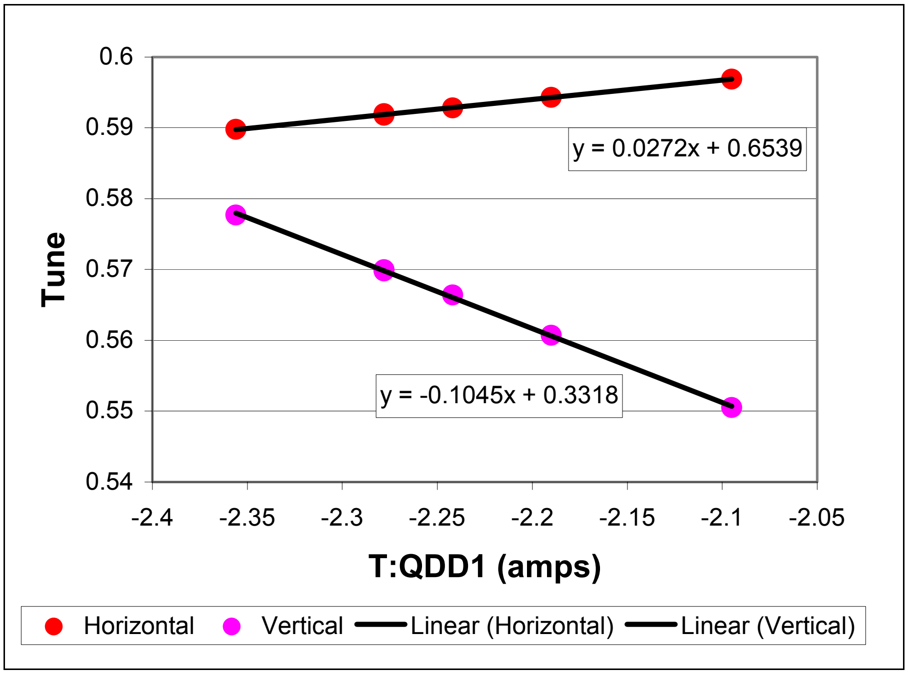


Figure 5 Plot of tune versus current in T:QDD1 at 150 GeV and the results of a linear fit to the data.

For comparison, we give the matrix relationship derived from a MAD file of the design lattice and the design strengths of the trim quadrupole magnets

$$\begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix} = \begin{pmatrix} 0.110 & 0.0352 \\ -0.0337 & -0.114 \end{pmatrix} \begin{pmatrix} \Delta I_{QFA4} \\ \Delta I_{QDD1} \end{pmatrix} \qquad \text{(Calculated tune response)}$$

and inversely

$$\begin{pmatrix} \Delta I_{QFA4} \\ \Delta I_{QDD1} \end{pmatrix} = \begin{pmatrix} 10.1 & 3.15 \\ -3.00 & -9.74 \end{pmatrix} \begin{pmatrix} \Delta\nu_x \\ \Delta\nu_y \end{pmatrix}.$$

This shows that the trim quads are stronger than expected by about 10-30%.

Data from Measurement #3

The horizontal and vertical tunes were measured as a function of time at 150 GeV with the updated tune drift algorithm based on the trim quad calibration data of the previous section. The data are plotted in Figure 6 and show that the tune drifted by less than 0.001 over the 40 minutes at 150 GeV. During this front porch the coupling was measured at 9.17, 22, and 34.83 minutes and was below 0.0031 units at all of these times.

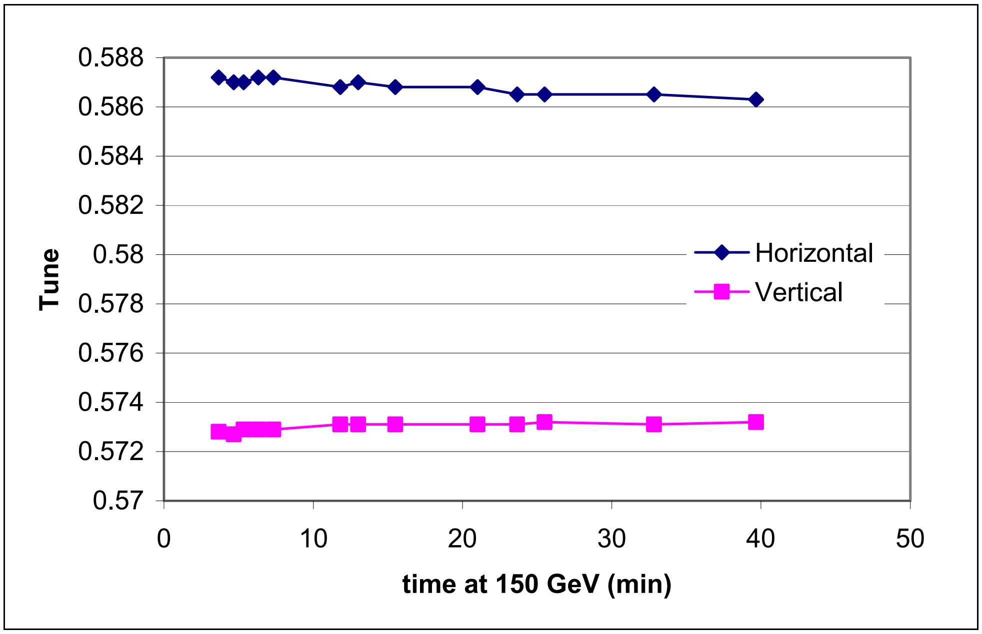


Figure 6 Measured tune drift as a function of time at 150 GeV for measurement #3.

The Tevatron ramp cycle before this measurement had flattop time of 2399 seconds (40 minutes) and a back porch time of 79 seconds. This is similar to the ramp history in measurement #2 and for a typical shot setup. The orbits and DFGs for this measurement were similar to those for measurement #2 and are listed in Appendix A.

For comparison we plot the tune drift with the compensation system active on the same plot as measurements made on 5/15/02 with no tune drift compensation.

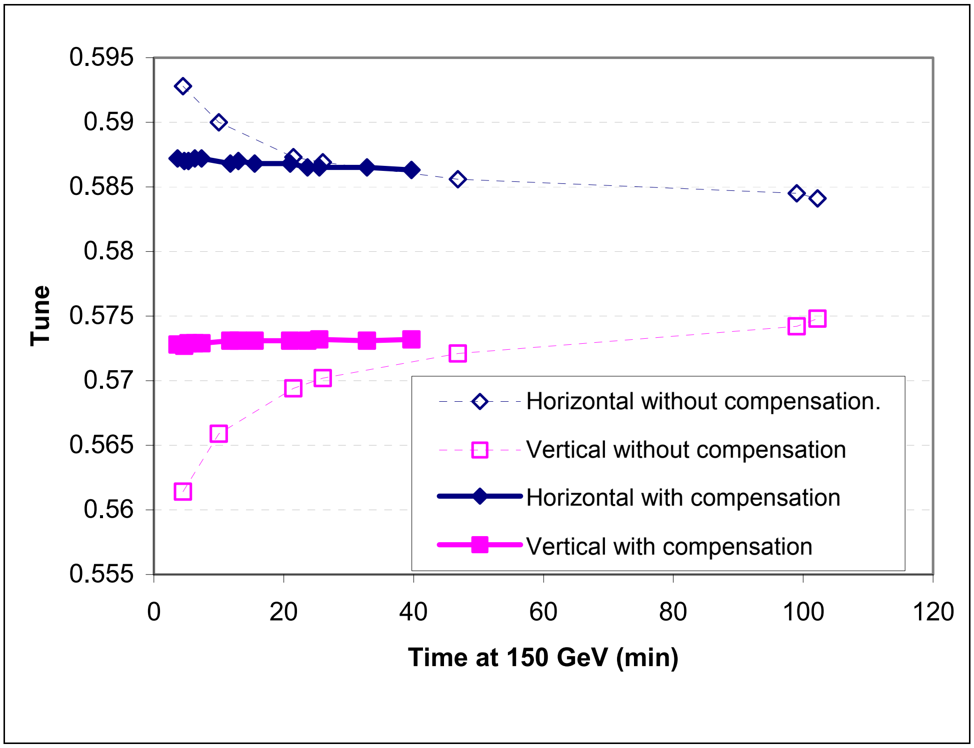


Figure 7 Comparison of horizontal and vertical tune drift with and without the compensation system active. The measurements without the compensation system were taken on 5/15/02.

Data from Measurement #3 snapback

The circuits used to correct the tune and coupling drift at 150 GeV are also used to compensate for the snapback of the tune and coupling drift at the start of the ramp. Since we don't know the source of the tune drift at 150 GeV we somewhat arbitrarily decided to use a 6 second unwind of the drift compensation at the start of the ramp. This is the same amount of time used to unwind the chromaticity correction circuits to compensate for the drifting b_2 in the Tevatron dipoles. The amount of current accumulated in the tune and coupling compensation circuits is ramped down to zero current in 6 seconds using a quartic function given in Equation 7

$$I(t) = I_0[1 - 2 (t/T)^2 + (t/T)^4] \qquad \textbf{Equation 7}$$

where t is the time in seconds, and T is the time of the unwind curve.

The measured tunes during the snapback portion of the ramp are shown in Figure 8. Plotted are the measured tunes during the first 6 seconds of the Tevatron ramp. During this first 6 second of the ramp, the Tevatron energy increases parabolically with time from 150 GeV to about 153 GeV. In addition to the unwind of the correction circuits, the horizontal tune settings (on C49) remain constant at a value of Qh = 0.607, while the vertical tune setting changes from a value of Qv = 0.576 at 150 GeV to 0.570 units at 153.09 GeV.

The measured tunes during the snapback suggest that the snapback portion of the tune drift is adjusted adequately. However, the imprecision of the measurements means that the tunes can easily be in error by as much as tune 0.002 units. A more precise measurement of the tunes at the start of ramp is needed before it can be determined just how well the snapback is corrected.

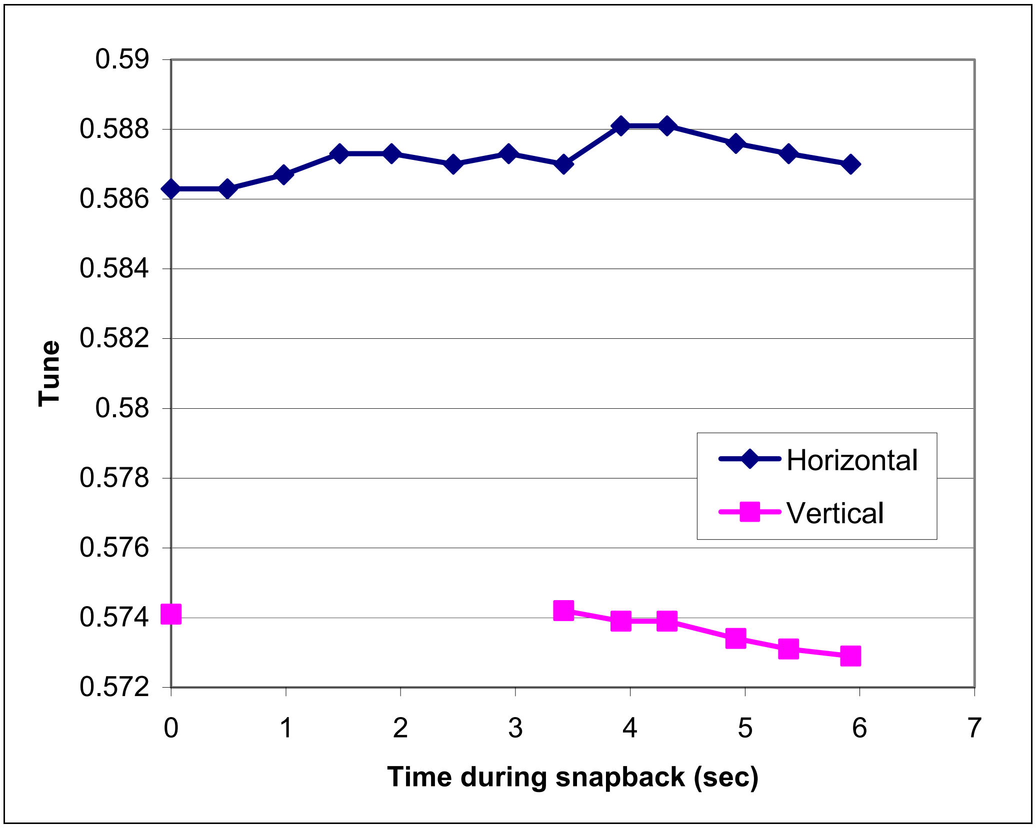


Figure 8 Plot of measured horizontal and vertical tunes during the 6 seconds of snapback at the start of the Tevatron ramp. These measurements can easily be in error by as much as tune 0.002 units. During the time the Tevatron ramps from 150 GeV to about 153 GeV. In addition to the unwind of the snapback correction, the horizontal tune settings (on C49) remain constant at Qh = 0.607, while the vertical tune setting changes from Qv = 0.576 at 150 GeV to 0.570 units at 153.09 GeV.

The measured tunes and tune settings at the breakpoints on the Tevatron ramp were recorded in hopes that this would help determine how well the snapback was tuned up. These are plotted in Figure 9. As is evident from the plot, the tunes and tune settings jump around by about 0.005 units at breakpoints near the start of the ramp. This makes it difficult to tell exactly how well the snapback correction works. It is also uncertain how well the coupling has been corrected for this particular ramp. For future reference the settings of the coupling circuit T:SQ are shown in Figure 11.

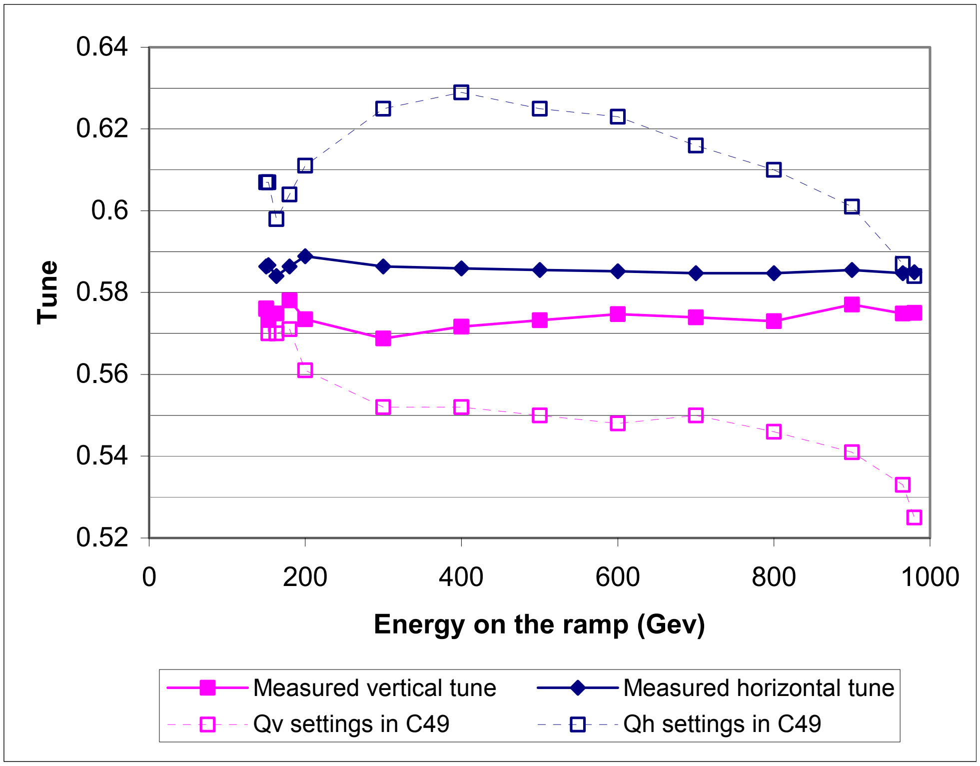


Figure 9 Measured tunes on the ramp at the C49 breakpoints and the C49 tune setting values (Qh and Qv) at the breakpoints on the ramp. With the variations in the tune measurements and the tune settings it is difficult to estimate how well the snapback portion of the tune compensation system is adjusted.

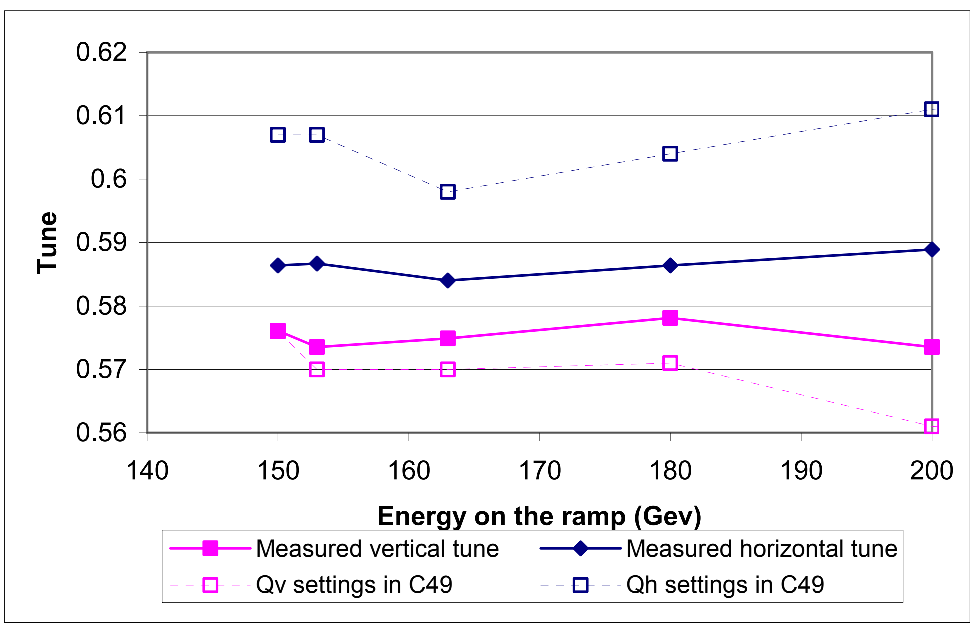


Figure 10 Same data as in Figure 9 but only showing the data at the breakpoints near the beginning of the Tevatron ramp.

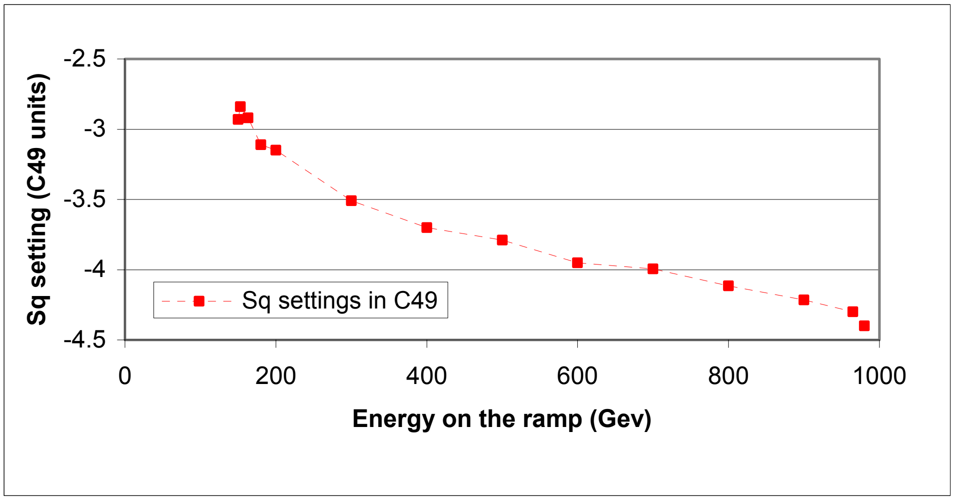


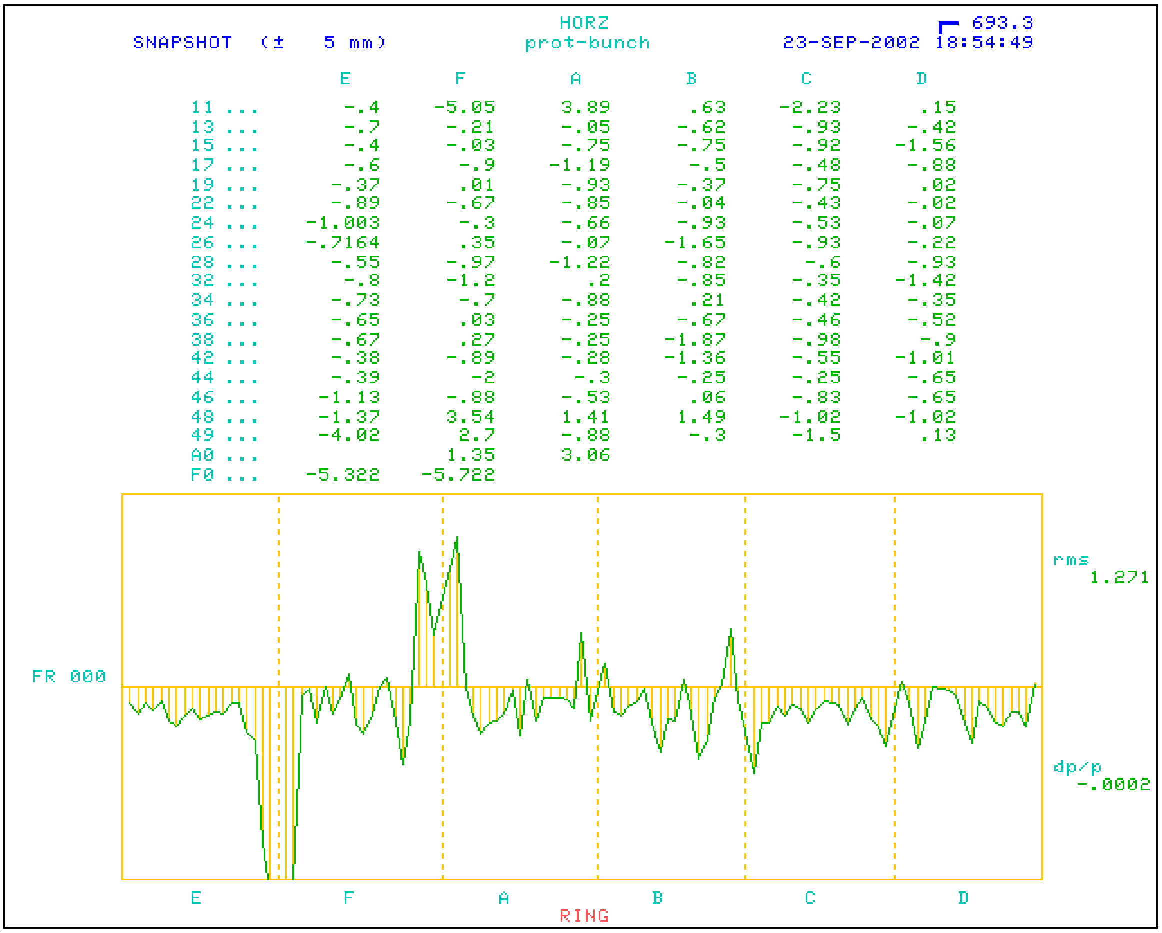
Figure 11 Settings of the Sq skew family (in C49 units) at the energy breakpoints on the ramp.

Conclusions

The tune drift compensation scheme was tuned up and implemented successfully. With the system active the tunes drift by less than 0.001 units over the period of 40 minutes and the minimum tune split remains below 0.003 units.

Appendix A: BPM and DFG data collected during tune drift studies.

Figure 12 and Figure 13 show the orbits in the Tevatron taken while sitting at 150 GeV with the separators off and with uncoalesced beam circulating in the Tevatron. Below these figures the BPM readings and the settings of the dipole correctors (DFGs) are listed.



	E	F	A	B	C	D
11 ...	-.4	-5.05	3.89	.63	-2.23	.15
13 ...	-.7	-.21	-.05	-.62	-.93	-.42
15 ...	-.4	-.03	-.75	-.75	-.92	-1.56
17 ...	-.6	-.9	-1.19	-.5	-.48	-.88
19 ...	-.37	.01	-.93	-.37	-.75	.02
22 ...	-.89	-.67	-.85	-.04	-.43	-.02
24 ...	-1.003	-.3	-.66	-.93	-.53	-.07
26 ...	-.7164	.35	-.07	-1.65	-.93	-.22
28 ...	-.55	-.97	-1.22	-.82	-.6	-.93
32 ...	-.8	-1.2	.2	-.85	-.35	-1.42
34 ...	-.73	-.7	-.88	.21	-.42	-.35
36 ...	-.65	.03	-.25	-.67	-.46	-.52
38 ...	-.67	.27	-.25	-1.87	-.98	-.9
42 ...	-.38	-.89	-.28	-1.36	-.55	-1.01
44 ...	-.39	-2	-.3	-.25	-.25	-.65
46 ...	-1.13	-.88	-.53	.06	-.83	-.65
48 ...	-1.37	3.54	1.41	1.49	-1.02	-1.02
49 ...	-4.02	2.7	-.88	-.3	-1.5	.13
A0 ...		1.35	3.06			
F0 ...	-5.322	-5.722				

Figure 12 BPM snapshot of the horizontal orbit while on the 150 GeV front porch. This is the central orbit (with helix off) and with uncoalesced beam.

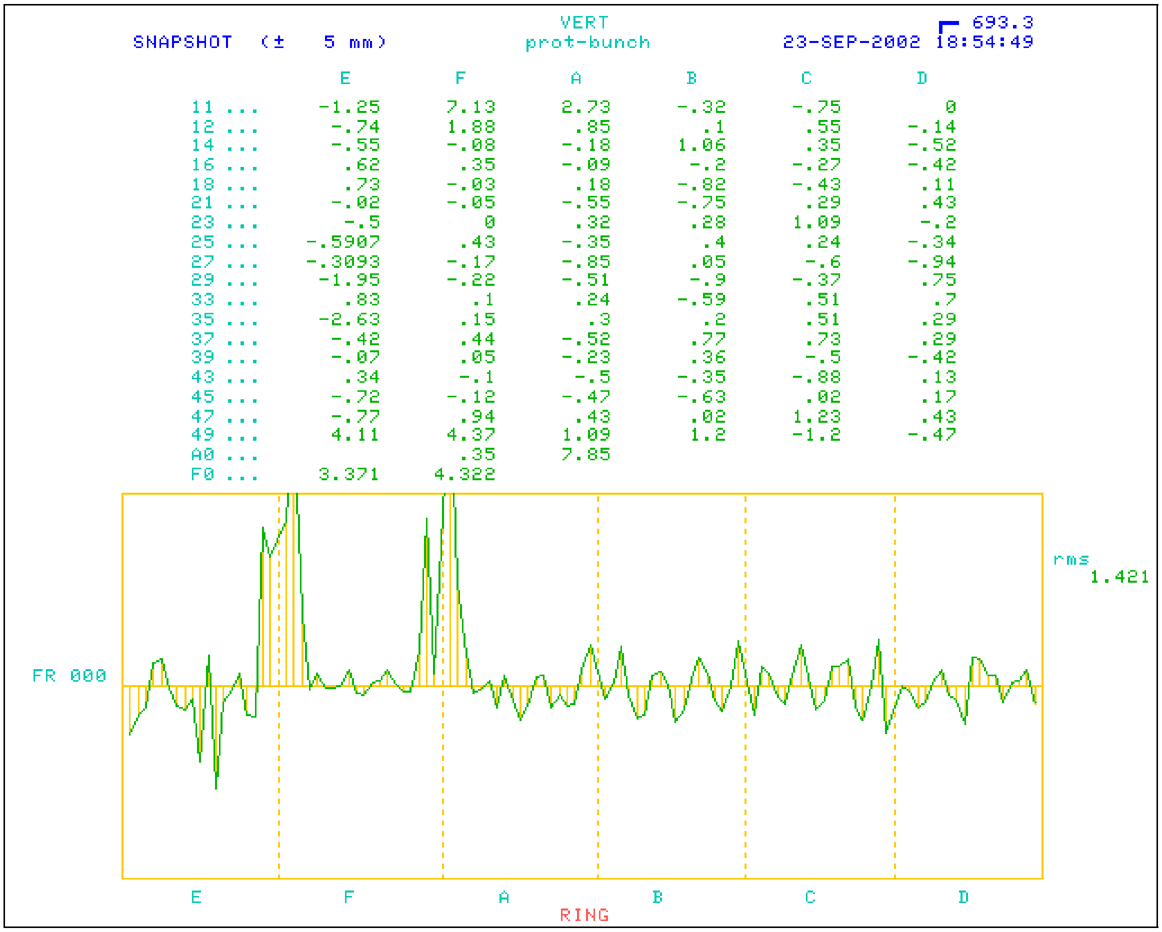


Figure 13 BPM snapshot of the vertical orbit while on the 150 GeV front porch. This is the central orbit (with helix off) and with uncoalesced beam.

Listing of BPM data from Figure 12 and Figure 13.

T39 file: 202
Date: 09/23/02 2223
Title: 150 GeV b4 ramp 1784

s(meters) from E0	BPM name	position (mm)	s(meters) from E0	BPM name	position (mm)
32.74000	T:HPE11	-0.4000	35.45200	T:VPE11	-1.2500
91.28000	T:HPE13	-0.7000	62.40100	T:VPE12	-0.5800
150.76601	T:HPE15	-0.4000	121.02300	T:VPE14	-0.4000
210.25301	T:HPE17	-0.7500	180.50999	T:VPE16	0.6200
269.73999	T:HPE19	-0.5200	239.99699	T:VPE18	0.5800
329.22699	T:HPE22	-0.7400	299.48300	T:VPE21	-0.0200
388.71399	T:HPE24	-1.0029	358.97000	T:VPE23	-0.5000
448.20001	T:HPE26	-0.8057	418.45700	T:VPE25	-0.5014
507.68701	T:HPE28	-0.5500	477.94400	T:VPE27	-0.3093
567.17401	T:HPE32	-0.8000	537.43103	T:VPE29	-1.9500
626.66101	T:HPE34	-0.5800	596.91699	T:VPE33	0.9800
686.14801	T:HPE36	-0.6500	656.40399	T:VPE35	-2.6300
745.63397	T:HPE38	-0.8300	715.89099	T:VPE37	-0.2700
805.12097	T:HPE42	-0.2300	775.37799	T:VPE39	-0.2200
864.60797	T:HPE44	-0.3900	834.86499	T:VPE43	0.3400
924.09497	T:HPE46	-1.1300	894.35101	T:VPE45	-0.7200
983.58197	T:HPE48	-1.3700	953.83801	T:VPE47	-0.7700
1011.95502	T:HPE49	-4.0200	1016.80499	T:VPE49	4.1100
1052.32300	T:HPF0LU	-5.7468	1052.13196	T:VPF0LU	3.3715
1068.01697	T:HPF0LD	-5.7223	1068.20801	T:VPF0LD	3.8978
1079.93799	T:HPF11	-5.0500	1082.64905	T:VPF11	7.1300
1138.47705	T:HPF13	-0.2100	1109.59802	T:VPF12	1.8800
1197.96399	T:HPF15	-0.0300	1168.21997	T:VPF14	-0.0800
1257.45105	T:HPF17	-0.9000	1227.70703	T:VPF16	0.2000
1316.93701	T:HPF19	0.0100	1287.19397	T:VPF18	0.1200
1376.42395	T:HPF22	-0.5200	1346.68103	T:VPF21	-0.2000
1435.91101	T:HPF24	-0.4500	1406.16797	T:VPF23	0.0000
1495.39795	T:HPF26	0.5000	1465.65405	T:VPF25	0.2800
1554.88501	T:HPF28	-0.8200	1525.14099	T:VPF27	-0.1700
1614.37097	T:HPF32	-1.2000	1584.62805	T:VPF29	-0.2200
1673.85803	T:HPF34	-0.7000	1644.11499	T:VPF33	0.1000
1733.34497	T:HPF36	0.0300	1703.60205	T:VPF35	0.1500
1792.83203	T:HPF38	0.2700	1763.08801	T:VPF37	0.4400
1852.31897	T:HPF42	-0.8900	1822.57495	T:VPF39	0.0500
1911.80505	T:HPF44	-2.1500	1882.06201	T:VPF43	0.0500
1971.29199	T:HPF46	-1.0300	1941.54895	T:VPF45	0.0300
2030.77905	T:HPF48	3.5400	2001.03601	T:VPF47	0.9400
2058.92993	T:HPF49	2.7000	2064.00293	T:VPF49	4.3700
2088.51489	T:HPA0U	1.3500	2088.70508	T:VPA0U	0.2000
2100.13403	T:HPA0D	3.0600	2099.89502	T:VPA0D	7.8500
2127.16992	T:HPA11	3.7300	2130.01611	T:VPA11	2.5700
2185.67700	T:HPA13	-0.0500	2156.96411	T:VPA12	0.8500
2245.16309	T:HPA15	-0.6000	2215.41992	T:VPA14	-0.1800
2304.64990	T:HPA17	-1.1900	2274.90698	T:VPA16	-0.0900
2364.13696	T:HPA19	-1.0800	2334.39404	T:VPA18	0.1800
2423.62402	T:HPA22	-0.8500	2393.87988	T:VPA21	-0.5500
2483.11108	T:HPA24	-0.6600	2453.36694	T:VPA23	0.3200
2542.59692	T:HPA26	0.0800	2512.85400	T:VPA25	-0.2000
2602.08398	T:HPA28	-0.9200	2572.34106	T:VPA27	-0.4000
2661.57104	T:HPA32	0.2000	2631.82788	T:VPA29	-0.3600
2721.05811	T:HPA34	-1.0300	2691.31396	T:VPA33	0.0900
2780.54492	T:HPA36	-0.4000	2750.80103	T:VPA35	0.1500
2840.03101	T:HPA38	-0.2500	2810.28809	T:VPA37	-0.5200
2899.51807	T:HPA42	-0.2800	2869.77490	T:VPA39	-0.0800
2959.00488	T:HPA44	-0.1500	2929.26196	T:VPA43	-0.3500
3018.49194	T:HPA46	-0.5300	2988.74805	T:VPA45	-1.0700
3080.61011	T:HPA48	1.4100	3048.23511	T:VPA47	0.4300
3108.98291	T:HPA49	-0.8800	3080.83789	T:VPA48	1.7400

3134.11108	T:HPB0U	-0.5500	3109.21191	T:VPA49	1.2400
3149.07788	T:HPB0D	1.5500	3134.23096	T:VPB0U	-1.4300
3174.20508	T:HPB11	0.6300	3148.95703	T:VPB0D	0.1400
3206.62598	T:HPB12	-0.2800	3173.97607	T:VPB11	-0.4700
3232.87402	T:HPB13	-0.4700	3206.85498	T:VPB12	-0.0500
3292.36108	T:HPB15	-0.7500	3262.61792	T:VPB14	1.0600
3351.84790	T:HPB17	-0.5000	3322.10400	T:VPB16	-0.2000
3411.33496	T:HPB19	-0.2200	3381.59106	T:VPB18	-0.6700
3470.82104	T:HPB22	-0.0400	3441.07788	T:VPB21	-0.7500
3530.30811	T:HPB24	-0.9300	3500.56494	T:VPB23	0.1300
3589.79492	T:HPB26	-1.3400	3560.05200	T:VPB25	0.2500
3649.28198	T:HPB28	-0.8200	3619.53809	T:VPB27	0.0500
3708.76904	T:HPB32	-0.8500	3679.02490	T:VPB29	-0.7500
3768.25488	T:HPB34	0.2100	3738.51196	T:VPB33	-0.4400
3827.74194	T:HPB36	-0.5200	3797.99902	T:VPB35	0.2000
3887.22900	T:HPB38	-1.8700	3857.48608	T:VPB37	0.7700
3946.71606	T:HPB42	-1.3600	3916.97192	T:VPB39	0.3600
4006.20288	T:HPB44	-0.2500	3976.45898	T:VPB43	-0.2000
4065.68896	T:HPB46	0.0600	4035.94604	T:VPB45	-0.4700
4125.17578	T:HPB48	1.6500	4095.43311	T:VPB47	0.0200
4153.54980	T:HPB49	-0.1500	4158.39990	T:VPB49	0.9000
4221.53320	T:HPC11	-2.2300	4224.24414	T:VPC11	-0.7500
4280.07178	T:HPC13	-0.9300	4251.19287	T:VPC12	0.5500
4339.55908	T:HPC15	-1.0700	4309.81494	T:VPC14	0.3500
4399.04492	T:HPC17	-0.6300	4369.30176	T:VPC16	-0.2700
4458.53223	T:HPC19	-0.9000	4428.78906	T:VPC18	-0.4300
4518.01904	T:HPC22	-0.4300	4488.27588	T:VPC21	0.2900
4577.50586	T:HPC24	-0.5300	4547.76221	T:VPC23	0.9400
4636.99316	T:HPC26	-1.0800	4607.24902	T:VPC25	0.3900
4696.47900	T:HPC28	-0.7500	4666.73584	T:VPC27	-0.4500
4755.96582	T:HPC32	-0.3500	4726.22314	T:VPC29	-0.3700
4815.45313	T:HPC34	-0.4200	4785.70996	T:VPC33	0.3600
4874.93994	T:HPC36	-0.3100	4845.19580	T:VPC35	0.3600
4934.42676	T:HPC38	-0.8300	4904.68311	T:VPC37	0.7300
4993.91309	T:HPC42	-0.7000	4964.16992	T:VPC39	-0.3500
5053.39990	T:HPC44	-0.1000	5023.65723	T:VPC43	-0.7300
5112.88721	T:HPC46	-0.9800	5083.14404	T:VPC45	-0.1300
5175.00488	T:HPC48	-1.0200	5142.62988	T:VPC47	0.7800
5202.26807	T:HPC49	-1.5000	5175.23291	T:VPC48	-0.3500
5228.50586	T:HPD0U	1.9900	5201.03320	T:VPC49	-1.2000
5243.47314	T:HPD0D	2.6500	5228.62598	T:VPD0U	1.4600
5269.70996	T:HPD11	0.1500	5243.35205	T:VPD0D	-0.1000
5301.02100	T:HPD12	0.1800	5270.94580	T:VPD11	-0.1500
5327.26904	T:HPD13	-0.2700	5301.25000	T:VPD12	-0.1400
5386.75586	T:HPD15	-1.4000	5357.01318	T:VPD14	-0.0700
5446.24316	T:HPD17	-1.0300	5416.50000	T:VPD16	-0.4200
5505.72998	T:HPD19	-0.2800	5475.98584	T:VPD18	0.1100
5565.21680	T:HPD22	0.1300	5535.47314	T:VPD21	0.4300
5624.70313	T:HPD24	0.0800	5594.95996	T:VPD23	-0.2000
5684.18994	T:HPD26	-0.0700	5654.44678	T:VPD25	-0.1900
5743.67676	T:HPD28	-1.0800	5713.93408	T:VPD27	-0.7900
5803.16406	T:HPD32	-1.7200	5773.41992	T:VPD29	0.7500
5862.65088	T:HPD34	-0.5000	5832.90723	T:VPD33	0.5500
5922.13721	T:HPD36	-0.5200	5892.39404	T:VPD35	0.1400
5981.62402	T:HPD38	-0.7500	5951.88086	T:VPD37	0.1400
6041.11084	T:HPD42	-1.0100	6011.36816	T:VPD39	-0.5700
6100.59814	T:HPD44	-0.8000	6070.85400	T:VPD43	-0.0200
6160.08496	T:HPD46	-0.6500	6130.34082	T:VPD45	0.0200
6219.57080	T:HPD48	-1.1800	6189.82813	T:VPD47	0.4300
6247.94482	T:HPD49	0.1300	6252.79492	T:VPD49	-0.4700

Listing of dipole corrector (DFG) settings

These are DFG settings (in mrad) for the 150 and 200 GeV energy slots.

DFG Name	150 GeV	200 GeV	DFG Name	150 GeV	200 GeV
T:HE11	.073	.069	T:VE11	.0052	.0056
T:HE13	-.0406	-.0403	T:VE12	0	0
T:HE15	.0205	.0136	T:VE14	-.0324	-.0384
T:HE17	-.033	-.0344	T:VE16	-.0082	-.0055
T:HE19	-.0383	-.0396	T:VE18	.0028	.0012
T:HE22	.0296	.0292	T:VE21	.0181	.0178
T:HE24	-.0008	.0035	T:VE23	-.042	-.0463
T:HE26	-.0428	-.0455	T:VE25	.0691	.0738
T:HE28	-.003	.0013	T:VE27	.0251	.0225
T:HE32	-.0017	.003	T:VE29	.0703	.0744
T:HE34	.0121	.0067	T:VE33	.0917	.0869
T:HE36	.0016	.0029	T:VE35	.0563	.068
T:HE38	-.0065	-.0135	T:VE37	.0094	.0028
T:HE42	-.0437	-.051	T:VE39	.0628	.0686
T:HE44	.0165	.0223	T:VE43	.0601	.0645
T:HE46	-.0336	-.0429	T:VE45	-.0582	-.0649
T:HE48	.1955	.1923	T:VE47	.0701	.0791
T:HE49	-.0736	-.06	T:VE49	.0126	.0081
T:HF11	-.0101	-.0171	T:VF11	.003	.0078
T:HF13	.1221	.1202	T:VF12	.0401	.0401
T:HF15	.0121	.0114	T:VF14	.0082	.004
T:HF17	-.0305	-.0322	T:VF16	-.0048	-.005
T:HF19	-.0128	-.0197	T:VF18	.0301	.0334
T:HF22	.0002	.0051	T:VF21	-.0516	-.0607
T:HF24	0	.003	T:VF23	.0322	.0379
T:HF26	.0052	-.0027	T:VF25	-.0542	-.0537
T:HF28	-.0331	-.0243	T:VF27	-.014	-.0161
T:HF32	.0342	.0317	T:VF29	.0193	.0186
T:HF34	-.0028	-.0001	T:VF33	-.0406	-.0399
T:HF36	.0104	.0119	T:VF35	.022	.0157
T:HF38	.0067	.0026	T:VF37	.0193	.024
T:HF42	.0169	.017	T:VF39	-.0097	-.0129
T:HF44	-.0174	-.0158	T:VF43	-.011	-.0108
T:HF46	.022	.0115	T:VF45	.0389	.0381
T:HF48	.0785	.0688	T:VF47	.1188	.1435
T:HF49	-.1001	-.0975	T:VF49	-.1107	-.1377
T:HA11	.0901	.0716	T:VA11	.0904	.1129
T:HA13	-.099	-.102	T:VA12	.0221	.0221
T:HA15	-.0191	-.0252	T:VA14	.0978	.1045
T:HA17	.0673	.0734	T:VA16	.0906	.0902
T:HA19	.0529	.0468	T:VA18	.0845	.0906
T:HA22	.016	.0184	T:VA21	.0834	.0794
T:HA24	-.069	-.07	T:VA23	.0943	.1044
T:HA26	.0257	.0223	T:VA25	.0207	.0263
T:HA28	.0054	.0087	T:VA27	.0087	.0069
T:HA32	-.0386	-.0445	T:VA29	-.0049	.005
T:HA34	.0065	.0101	T:VA33	-.0106	-.0054
T:HA36	-.0057	-.0077	T:VA35	-.0033	-.0011
T:HA38	.0017	.0032	T:VA37	.004	.0058
T:HA42	-.0611	-.0554	T:VA39	.0013	.0059
T:HA44	.0124	.0101	T:VA43	.0244	.0221
T:HA46	-.0391	-.0341	T:VA45	-.0271	-.0248
C:HA48	0	0	T:VA47	.0038	.0035
T:HA48	.0912	.0927	C:VA48	0	0
T:HA49	.0529	.0571	T:VA49	-.1594	-.1528
T:HB11	-.0574	-.0634	T:VB11	-.03	-.03
C:HB12	0	0	T:VB12	.033	.033
T:HB13	-.0006	-.0016	T:VB14	.0559	.0595
T:HB15	.0477	.0448	T:VB16	.0393	.0368
T:HB17	-.0486	-.0578	T:VB18	.0943	.0961
T:HB19	-.041	-.0332	T:VB21	.0716	.0779
T:HB22	.0094	.0017	T:VB23	.0996	.0996

T:HB24	.0075	.0101
T:HB26	.0059	.0087
T:HB28	.0398	.0397
T:HB32	-.0301	-.0263
T:HB34	-.0068	-.0079
T:HB36	.0402	.041
T:HB38	.0035	.0024
T:HB42	.0284	.0288
T:HB44	-.0062	-.0068
T:HB46	-.0232	-.0264
T:HB48	.076	.0938
T:HB49	-.1008	-.1001
T:HC11	-.0998	-.0663
T:HC13	.0157	.0144
T:HC15	.0123	.0115
T:HC17	.0192	.015
T:HC19	-.0021	.0034
T:HC22	.0069	.0013
T:HC24	-.0254	-.0253
T:HC26	.0104	.0111
T:HC28	.0442	.0459
T:HC32	-.0139	-.0182
T:HC34	-.0203	-.0175
T:HC36	-.0206	-.0259
T:HC38	-.0168	-.0126
T:HC42	.0291	.036
T:HC44	.0009	-.0097
T:HC46	.0112	.0204
C:HC48	0	0
T:HC48	-.07	-.07
T:HC49	-.0007	-.016
T:HD11	.0198	-.0104
C:HD12	0	0
T:HD13	0	.0059
T:HD15	-.0116	-.012
T:HD17	-.0322	-.031
T:HD19	.0117	.0106
T:HD22	-.0033	-.0047
T:HD24	-.0025	-.0001
T:HD26	.0011	.0001
T:HD28	.0804	.0826
T:HD32	-.0629	-.0626
T:HD34	-.0004	-.0012
T:HD36	.0032	.0066
T:HD38	.0116	.0104
T:HD42	.0093	.0088
T:HD44	-.0127	-.0155
T:HD46	-.0016	-.003
T:HD48	.0018	-.0003
T:HD49	.021	.0187

T:VB25	.0712	.0749
T:VB27	-.009	-.0084
T:VB29	.0424	.0424
T:VB33	.0049	.0076
T:VB35	.0218	.0197
T:VB37	-.0389	-.0381
T:VB39	-.0261	-.0299
T:VB43	-.044	-.0431
T:VB45	.0057	.0018
T:VB47	.0145	.0228
T:VB49	-.0051	-.0049
T:VC11	.018	.021
T:VC12	0	0
T:VC14	-.0221	-.0181
T:VC16	.0661	.0701
T:VC18	.0435	.0387
T:VC21	-.0046	-.0043
T:VC23	.0784	.0739
T:VC25	.0195	.0182
T:VC27	.0087	.005
T:VC29	.0025	-.0011
T:VC33	-.046	-.046
T:VC35	-.0057	-.0122
T:VC37	-.0257	-.0234
T:VC39	.0193	.0128
T:VC43	.0198	.0209
T:VC45	.0015	-.0016
T:VC47	.0216	.023
C:VC48	0	0
T:VC49	.1105	.0945
T:VD11	.0168	.0117
T:VD12	-.05	-.05
T:VD14	.0539	.0553
T:VD16	-.0468	-.0384
T:VD18	.0364	.0335
T:VD21	.0115	.0171
T:VD23	.0377	.0293
T:VD25	.0329	.0435
T:VD27	-.012	-.0216
T:VD29	.0112	.0122
T:VD33	-.0437	-.0412
T:VD35	0	0
T:VD37	.0137	.0162
T:VD39	.0036	.0055
T:VD43	.0376	.0414
T:VD45	.0402	.0436
T:VD47	.0929	.0917
T:VD49	-.0372	-.0387

Appendix B: Tune drift at 150 GeV over period of days.

Also of interest is the repeatability of the tunes at 150 GeV over the period of several days. The measured tunes and C49 tune settings at 150 GeV over several days during and after the tune drift compensation system was implemented are listed in Table 1. These show that the tune is kept constant (after adjustment for setting changes) to within about 0.002 units over the period of several days.

Measurement	Date	Setting Qh (C49)	Setting Qv (C49)	Measured ν_x	Measured ν_x	Time at 150 GeV
Measurement #2	9/23/02	.607	.576	.5872	.5729	3.7
Measurement #3	9/23/02	.607	.576	.5872	.5731	5.5
Shot setup 1787	9/24/02	.602	.579	.5832	.5749	???
Octupole studies	9/25/02	.6025	.579	.583	.575	???
Shot setup 1797	9/27/02	.603	.578	.5837	.5749	???
Shot setup 1799	9/28/02	.602	.5785	.5832	.5749	???
TEL studies	9/29/02	.6025	.578	.5833	.5748	???
Shot setup 1806*	9/30/02	.6025	.582	.583	.575	???
Shot setup 1810	10/1/02	.6015	.579	.583	.575	???

Table 1 Measured tunes and settings at 150 GeV over several days during and after the tune drift compensation system was implemented. After adjusting for the intentional changes to the tune settings, the measured tunes drifted by less than 0.002 over several days. (* During tune-up for shot 1806 the TECAR energy on the front porch was changed from 150.02 to 150.00 GeV. This was also after the Tevatron was off for repairs to the A3 power supply unit.)