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1. Summary

- Longitudinal acceptance of the Booster:
  - Two different measurements (one by varying the linac beam energy, another by varying RPOS) give similar result: $\Delta p/p = \pm 0.15\text{-}0.2\%$

- Transverse emittance dilution during injection:
  - The first 50-turn IPM data shows a fast dilution during the 10-turn injection. After that the dilution slows down.
  - This dilution is intensity dependent.
  - The results agree with space charge simulation using the code ORBIT.
  - Lower linac current and longer pulse (while keeping the total injected beam intensity a constant) seem to reduce the dilution in the first 50 turns. (But this gain could be washed away in 200 turns according to simulation.)

- Injection painting:
  - Painting by using the falling side of the orbit bump pulse seems to reduce the dilution. But this result is inconclusive.

- AC chromaticity:
  - Chromaticity throughout the cycle was measured with the normal sextupole setting.
  - The vertical chromaticity in the early stage of the cycle is measured positive. This causes concerns

about possible head-tail instability. (It will be adjusted in the follow-up study.)

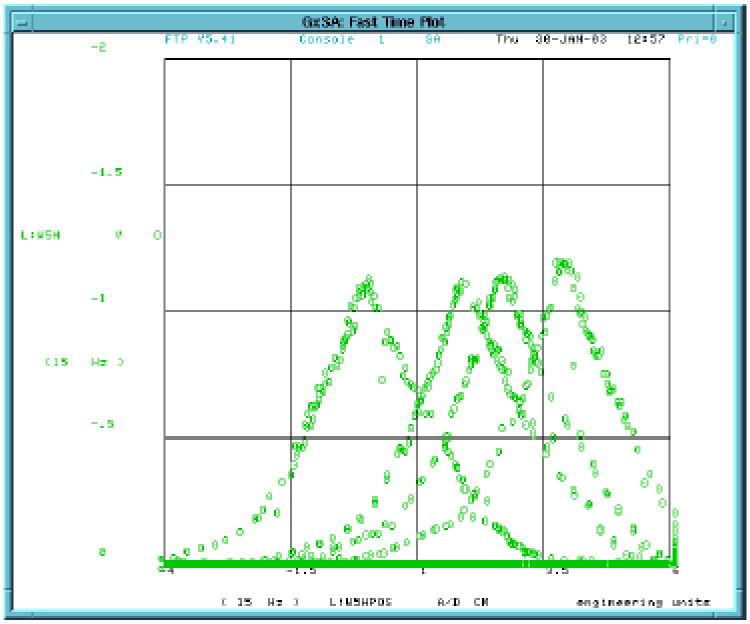
- DC chromaticity:
  - It was measured at 400 MeV for nine different sextupole settings.
  - The data were used to find the unknown body sextupoles of the main magnets. The results:

    sd = -0.0454, sf = -0.003
  - These two parameters are now included in the MAD lattice model.

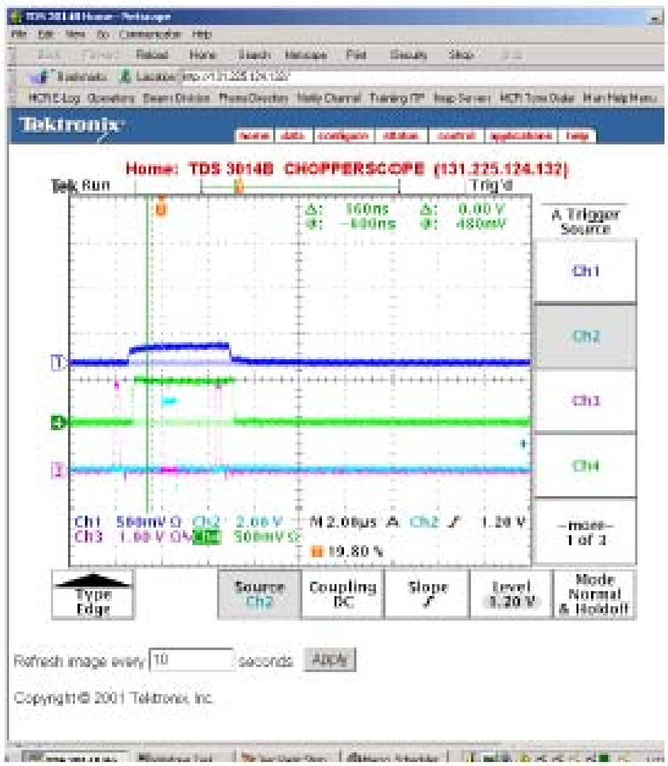
- Acceptance decrease due to orbit bumps and doglegs:
  - There is a good pattern match between the MAD prediction and measurement on the changes of tune and dispersion due to edge focusing of the orbit bumps and doglegs at 400 MeV.
  - This effect leads to about a factor of two reduction in the machine acceptance at injection.
  - Investigations of possible corrections are under way.

2. Longitudinal Acceptance Measurement

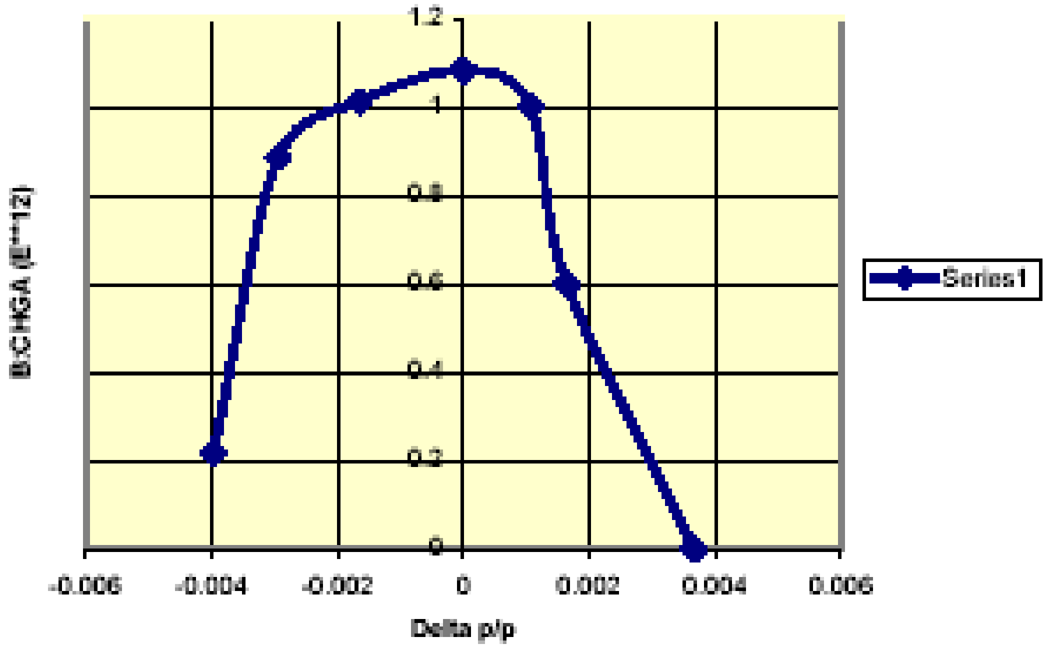
Linac beam energy calibration (1 cm = 1 MeV)



Linac beam pulse (green trace)



Measured momentum acceptance



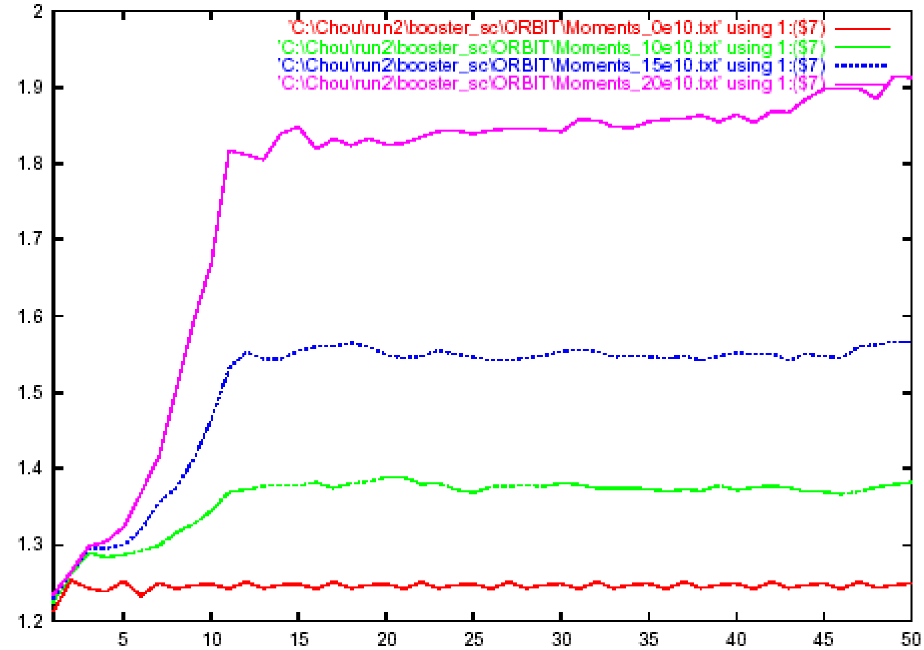
Notes:

1. The 400 MeV line was not retuned when the linac beam energy was varied. So the result is a combination of the acceptance of the 400 MeV line and that of the Booster.

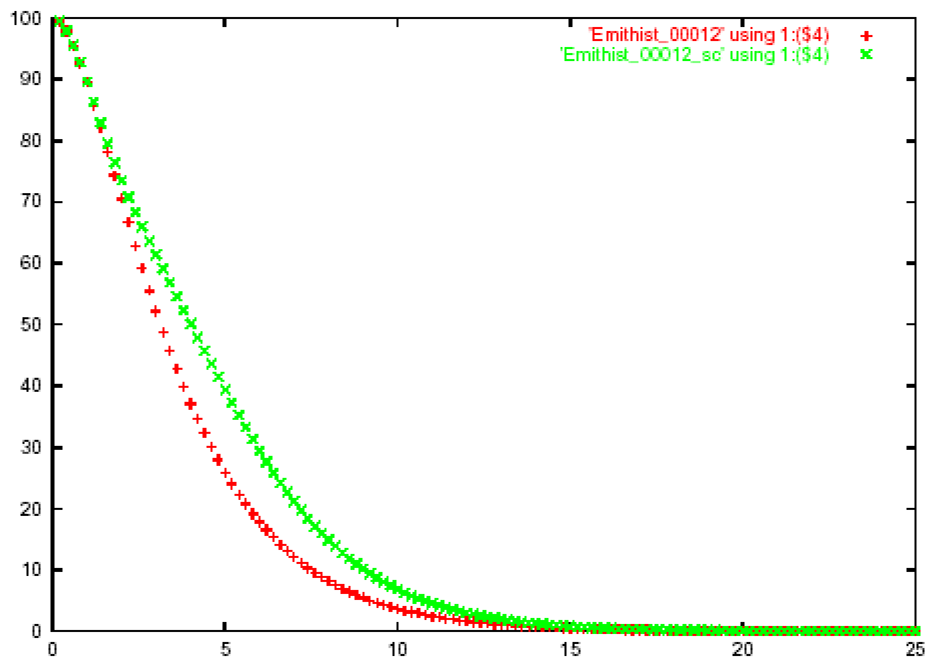
2. A separate measurement by varying RPOS gives the Booster acceptance in the range of ±0.15-0.2%, consistent with this result. (see the dc chromaticity measurement)

3. Transverse Emittance Dilution during First 50 Turns

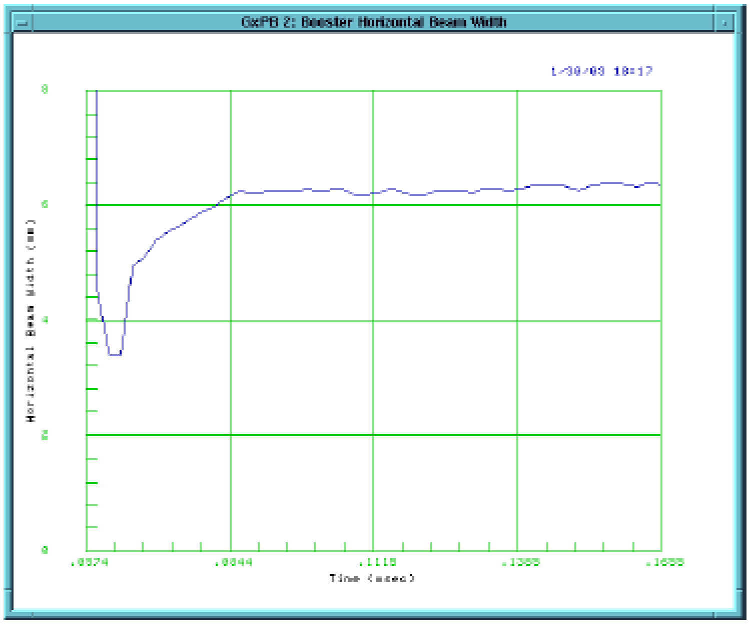
ORBIT simulation:
different bunch intensity, same number of injection turns (11)



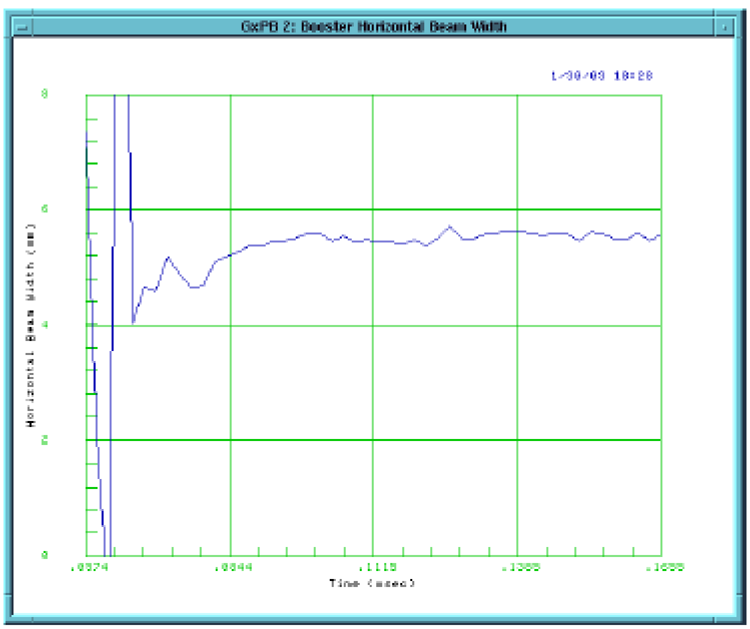
ORBIT simulation:
emittance histogram at 12th turn, with and without space charge



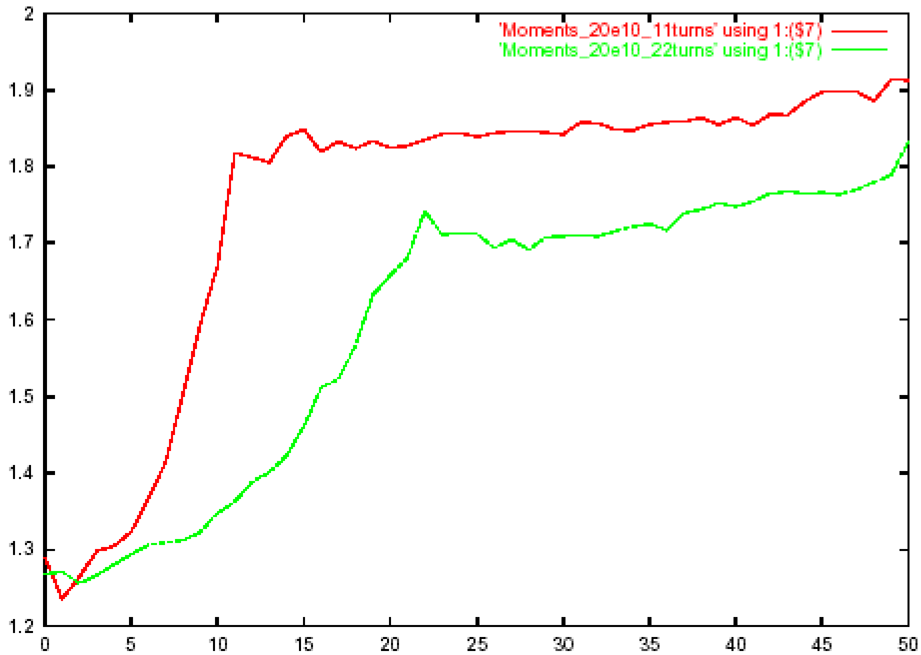
Measurement at 43 mA, 10 turns



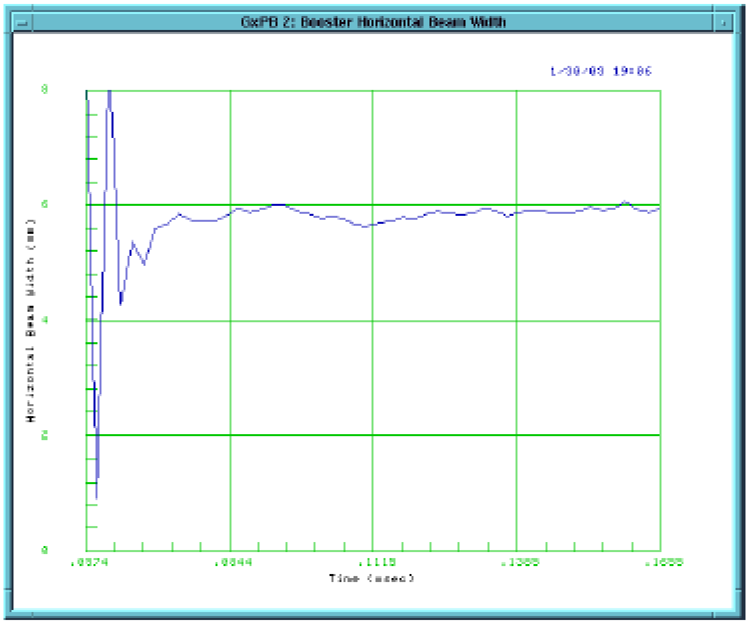
Measurement at 20 mA, 10 turns



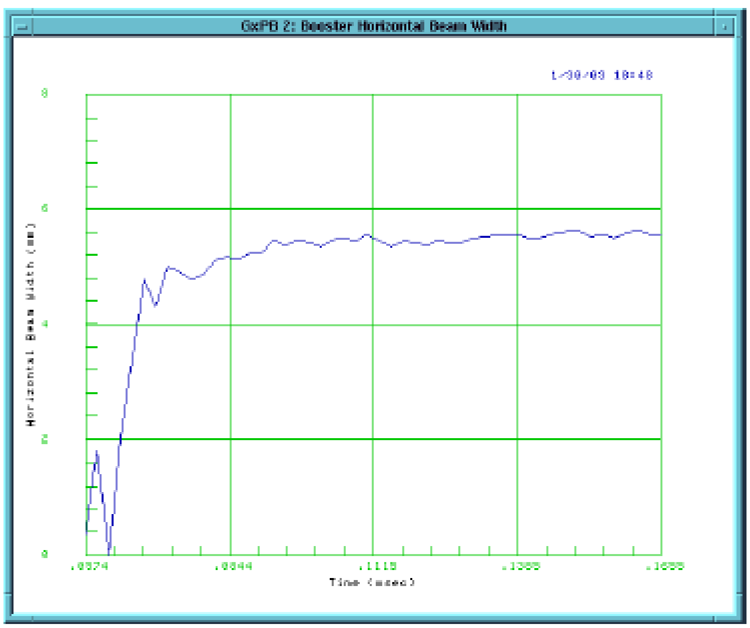
ORBIT simulation:
same bunch intensity, different number of injection turns
(tracking 50 turns)



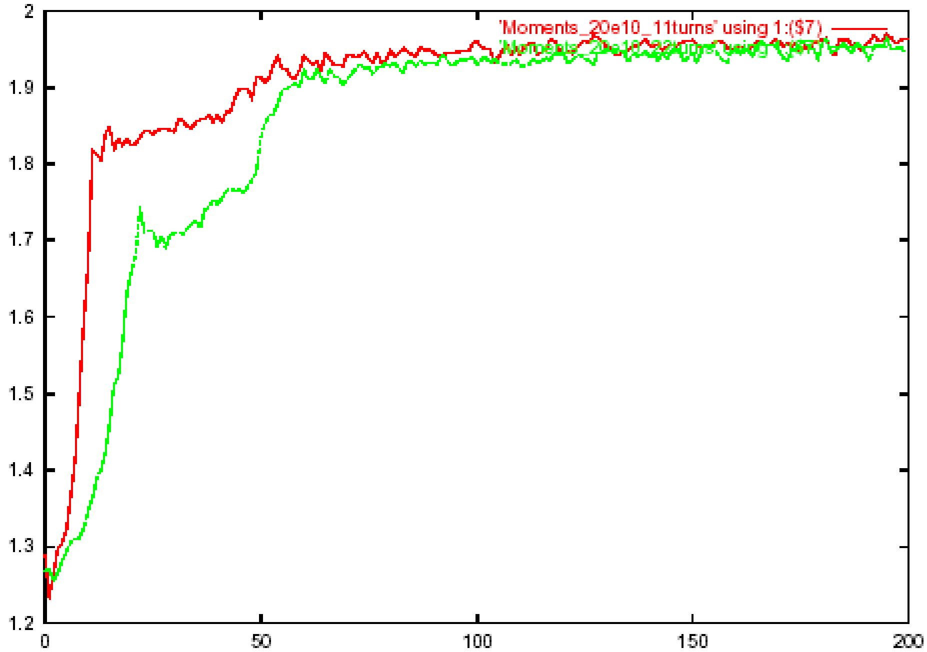
Measurement at 43 mA, 6 turns



Measurement at 20 mA, 12 turns

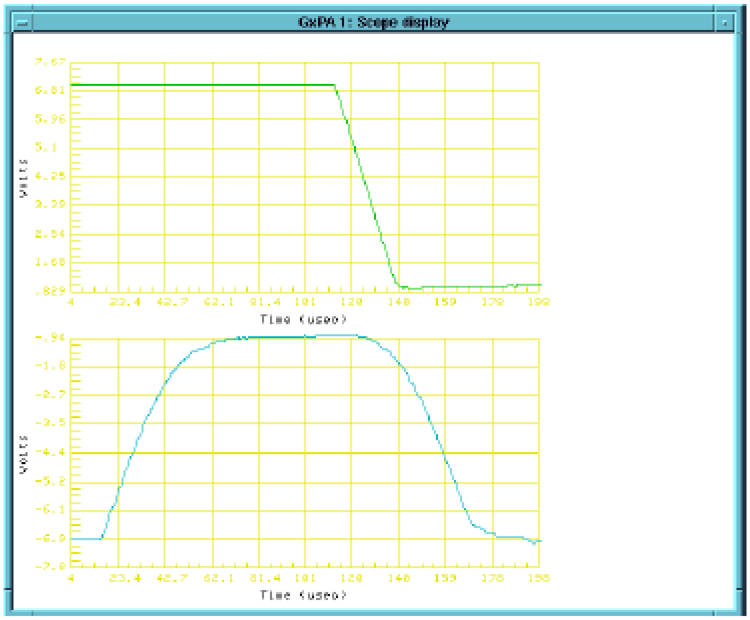


ORBIT simulation:
same bunch intensity, different number of injection turns
(tracking 200 turns)

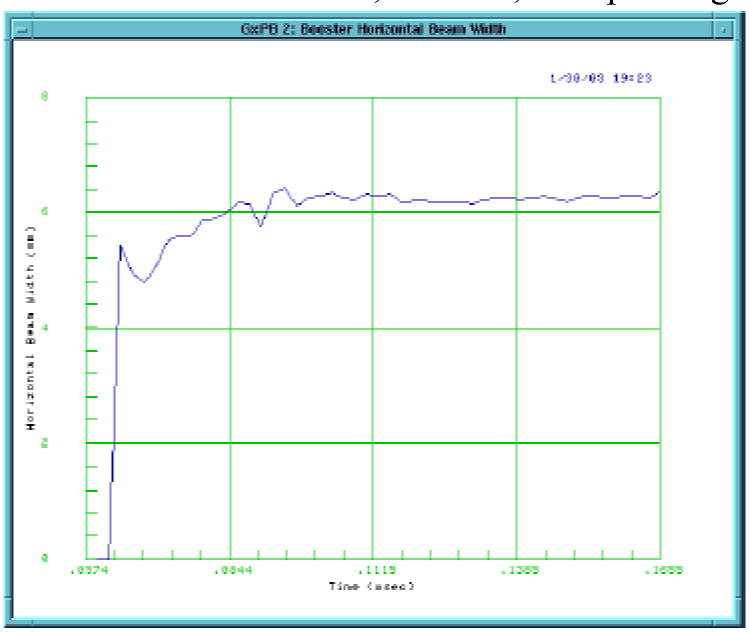


4. Painting Study:

Painting study: injection timing

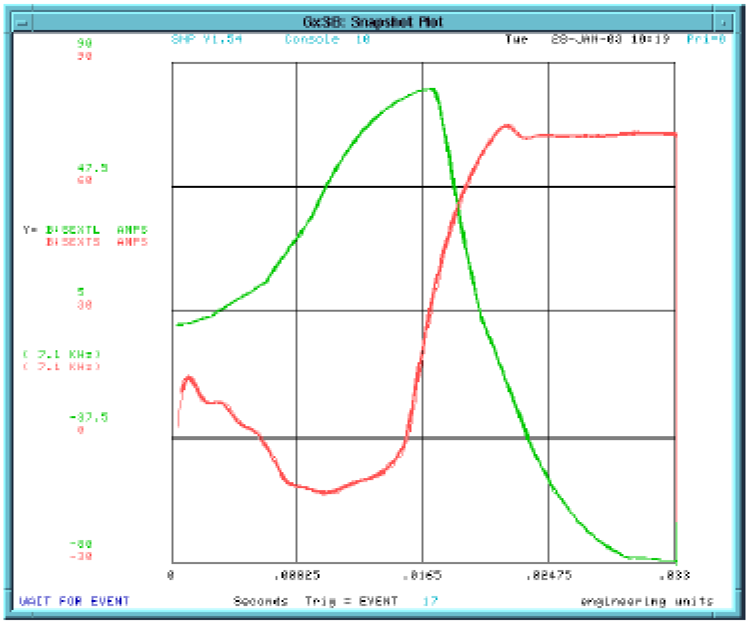


Measurement at 43 mA, 12 turns, with painting

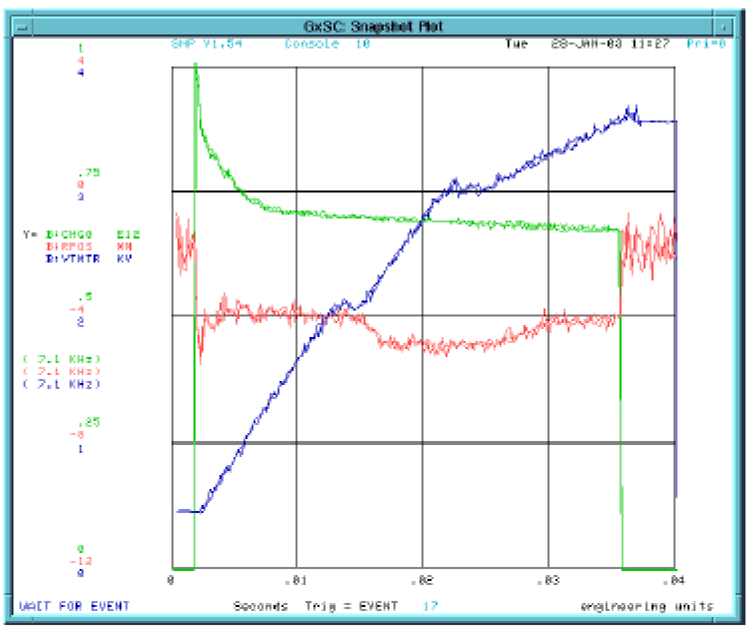


5. AC Chromaticity Measurement

Chromaticity sextupole setting (normal operation)

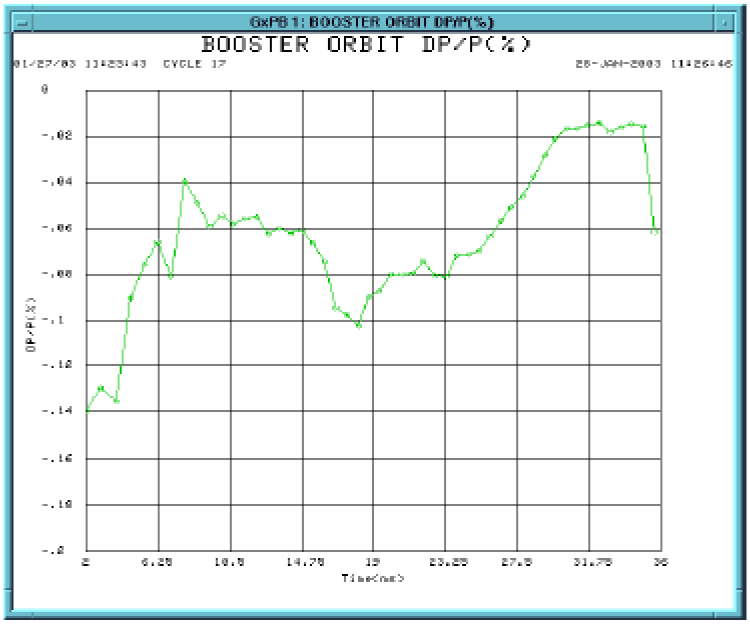


Beam (2-turn), pinger and Roff setting

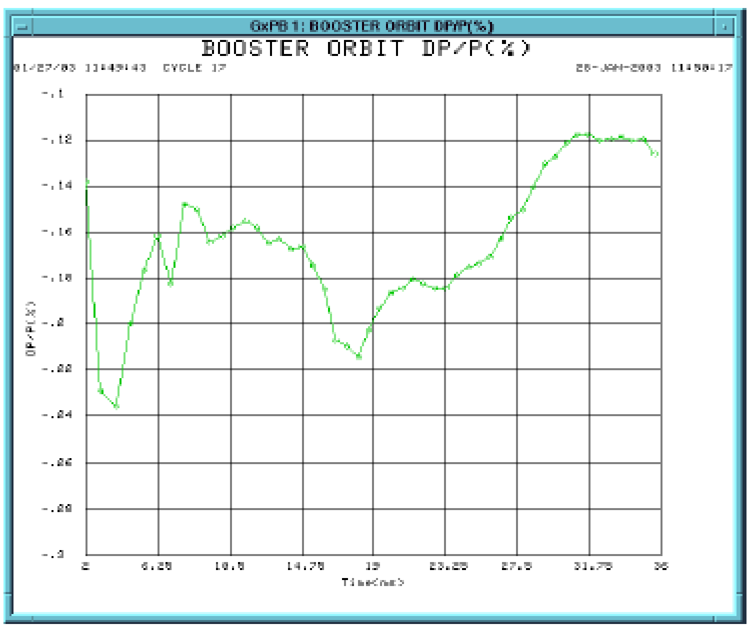


Note: The measurement was done at four different Roff values: 0, +2 mm, -2 mm, -4 mm. In this plot, Roff = 0.

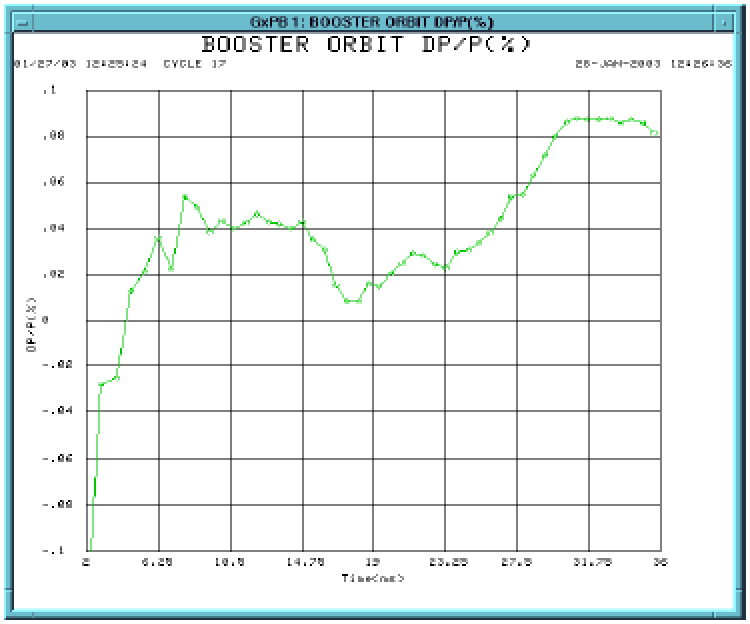
Dp/p for Roff = 0 mm



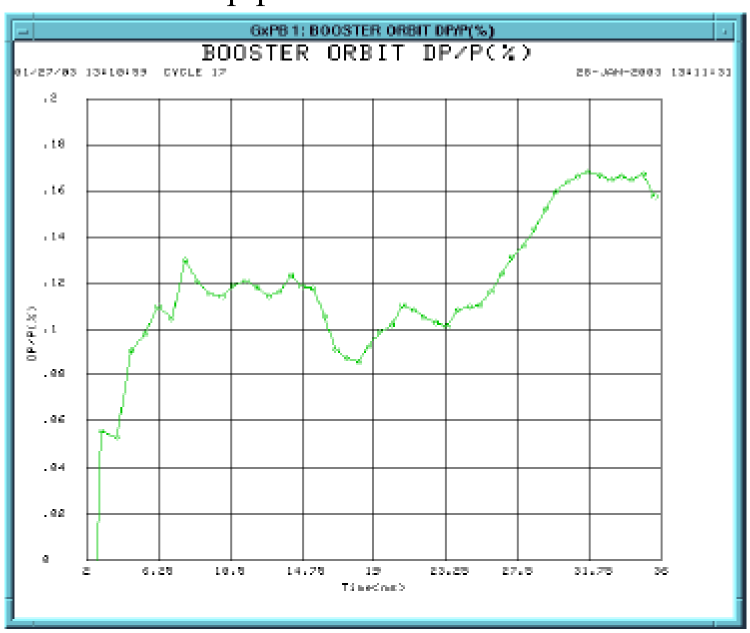
Dp/p for Roff = +2 mm



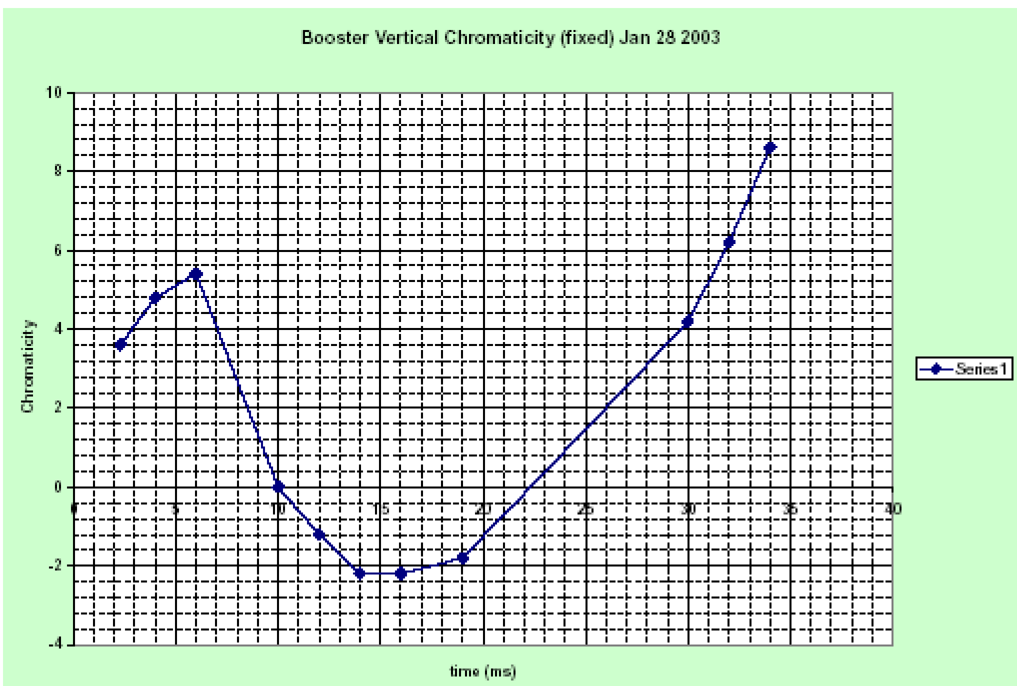
Dp/p for Roff = –2 mm



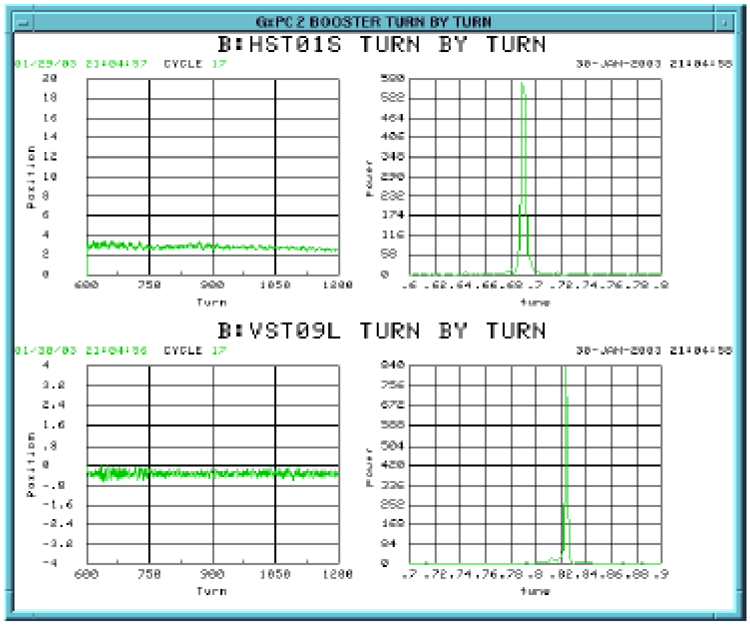
Dp/p for Roff = –4 mm

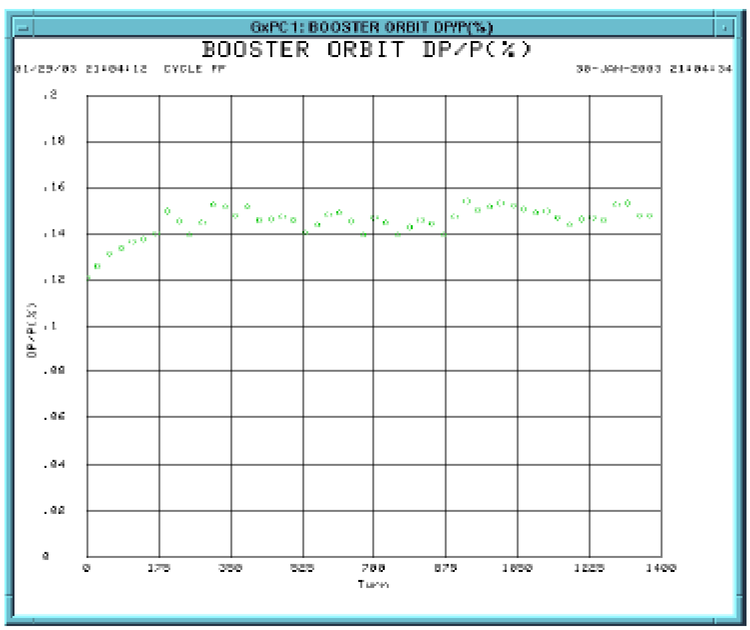



Booster Horizontal Chromaticity (fixed) Jan 28 2003
10
5
0
-5
-10
-15
-20
0
5
10
15
20
25
30
35
40
Chromaticity
time (ms)
chroma


Booster Vertical Chromaticity (fixed) Jan 28 2003
10
8
6
4
2
0
-2
-4
0
5
10
15
20
25
30
35
40
Chromaticity
time (ms)
Series1

6. DC Chromaticity Measurement

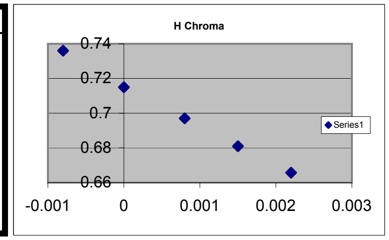


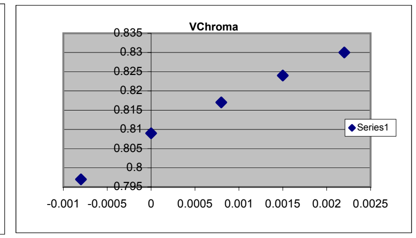


Booster Chromaticity Measurement
Jan 30 2003
R. Tomlin, W. Chou, F. Ostiguy

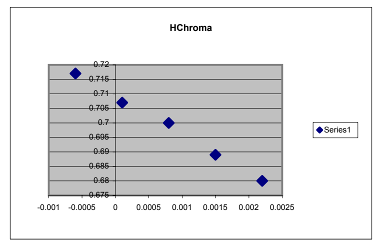
Note: VGOOD and HGOOD are correlation coefficients for the linear regression

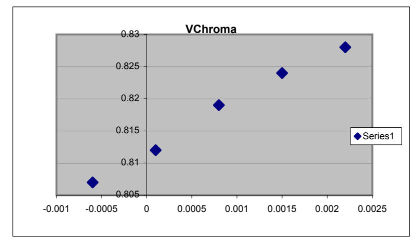
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	0	0	0.0022	0.6657	0.83				
1	0	0	0.0015	0.681	0.824				
2	0	0	0.0008	0.697	0.817				
3	0	0	0	0.715	0.809				
4	0	0	-0.0008	0.736	0.797				
						-23.302202	0.99878	10.834517	0.98793



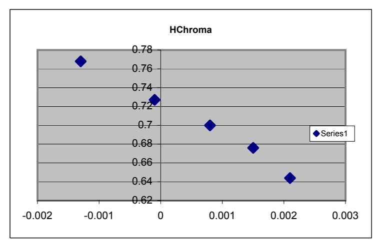


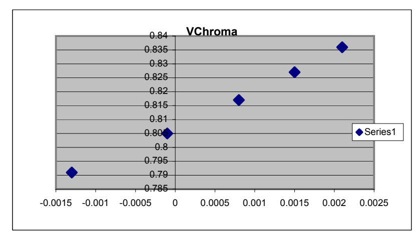
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	10	10	0.0022	0.68	0.828				
1	10	10	0.0015	0.689	0.824				
2	10	10	0.0008	0.7	0.819				
3	10	10	0.0001	0.707	0.812				
4	10	10	-0.0006	0.717	0.807				
						-13.142857	0.9967	7.7142857	0.99184



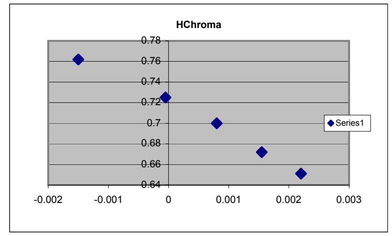


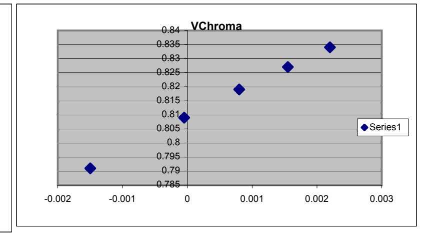
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	-10	-10	0.0021	0.644	0.836				
1	-10	-10	0.0015	0.676	0.827				
2	-10	-10	0.0008	0.7	0.817				
3	-10	-10	-0.0001	0.727	0.805				
4	-10	-10	-0.0013	0.768	0.791				
						-35.236111	0.99106	13.236111	0.99731



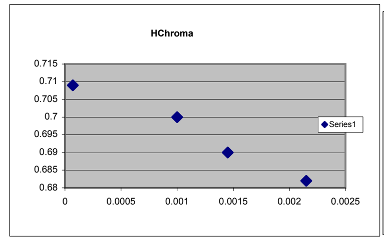


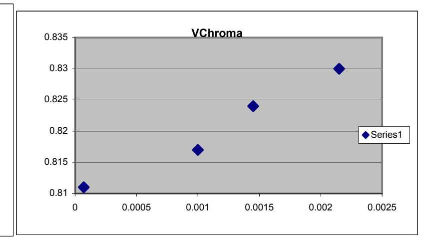
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	0	-10	0.0022	0.651	0.834				
1	0	-10	0.00155	0.672	0.827				
2	0	-10	0.0008	0.7	0.819				
3	0	-10	-0.00005	0.725	0.809				
4	0	-10	-0.0015	0.762	0.791				
						-30.167966	0.99368	11.625675	0.99869



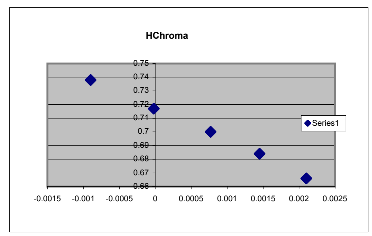


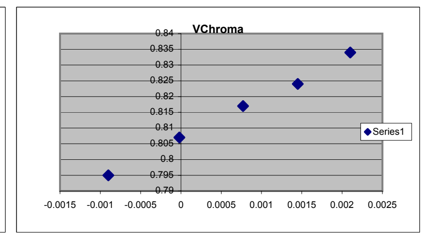
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	0	10	0.00215	0.682	0.83				
1	0	10	0.00145	0.69	0.824				
2	0	10	0.001	0.7	0.817				
3	0	10	0.00007	0.709	0.811				
4	0	10							
						-13.341456	0.97749	9.367008	0.97485



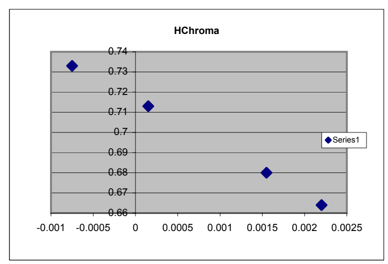


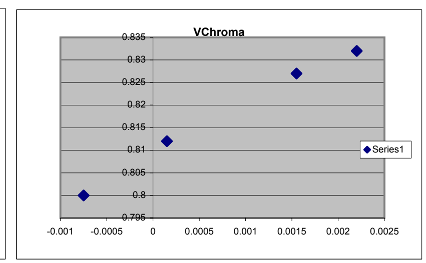
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	-10	0	0.0021	0.666	0.834				
1	-10	0	0.00145	0.684	0.824				
2	-10	0	0.00077	0.7	0.817				
3	-10	0	-0.00002	0.717	0.807				
4	-10	0	-0.0009	0.738	0.795				
						-23.651808	0.99835	12.721725	0.99751



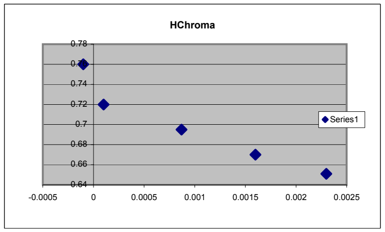


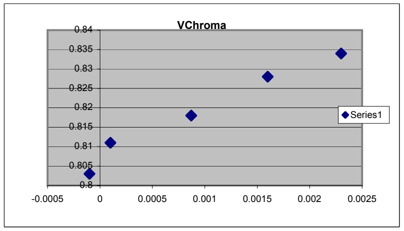
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	10	0	0.0022	0.664	0.832				
1	10	0	0.00155	0.68	0.827				
3	10	0	0.00015	0.713	0.812				
4	10	0	-0.00075	0.733	0.8				
2	10	0		0.697	0.819				
						-23.40152	0.9997	10.873174	0.99276



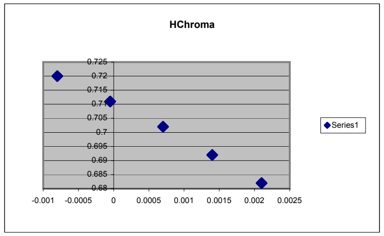


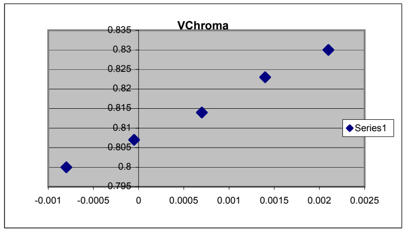
RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	10	-10	0.0023	0.651	0.834				
1	10	-10	0.0016	0.67	0.828				
2	10	-10	0.00087	0.695	0.818				
3	10	-10	0.0001	0.72	0.811				
4	10	-10	-0.0001	0.76	0.803				
						-40.53509	0.91465	12.212976	0.97002
	Improved by removing last point ---------->					-31.674217	0.99794	10.777903	0.99193





RPOS	SEXTL	SEXTS	DP/P	NUH	NUV	HCHROMA	HGOOD	VCHROMA	VGOOD
[mm]	[A]	[A]							
0	-10	10	0.0021	0.682	0.83				
1	-10	10	0.0014	0.692	0.823				
2	-10	10	0.0007	0.702	0.814				
3	-10	10	-0.00005	0.711	0.807				
4	-10	10	-0.0008	0.72	0.8				
						-13.092431	0.99788	10.473564	0.99651





7. Acceptance Decrease due to Orbit Bumps and Doglegs

$$A = \{\beta_{max} \times \varepsilon_N/\beta\gamma\}^{-1/2} + D_{max} \times \Delta p/p + \text{C.O.D.}$$

Good field region (horizontal): ± 1 inch (TM-405)

At injection (400 MeV):

$\beta\gamma = 1.0$

$\Delta p/p = \pm 0.13\%$ (measured)

C.O.D.= 2 mm (optimal)

Without orbit bumps and doglegs:

$\beta(x)_{max} = 33.7$ m, $D_{max} = 3.19$ m, $\beta(y)_{max} = 20.5$ m

Max allowable beam emittance: $\varepsilon_N(x) = 11\ \pi$ mm-mrad

With orbit bumps and doglegs:

$\beta(x)_{max} = 46.1$ m, $D_{max} = 6.13$ m, $\beta(y)_{max} = 27.0$ m

Max allowable beam emittance: $\varepsilon_N(x) = 5.2\ \pi$ mm-mrad

→ a factor of 2 reduction in acceptance due to large β and D!