Bumping the orbit to calibrate the SyncLite 2 scale

Harry W. K. Cheung
Fermilab, Batavia, IL 60510, USA

June 27, 2002

1 Introduction

The SyncLite 2 (SL2) system [1] measures the center positions of the proton and pbar beams and the sigmas of the 2-dimensional profiles. The scale for these measurements have to be calibrated. The synchrotron light is viewed by a CID camera with 640×480 pixels, so the calibration is given as mm/pixel.

The inital mm/pixel calibration was done on the bench by viewing an image with known sizes and measuring the size of the image in pixels using the SL2 imaging system [2]. This was done for the Run 1b and Run 1c and the scale has not been recalibrated after the reinstallation of the system at C11.

The scale calibration was done by producing a bump in the beam position of a known amount and comparing to that seen in the SL2 system. The mm/pixel scales for the horizontal and vertical should be the same, this should provide a good check of the calculated bump orbits. Also a check of the tilt of the SL2 system relative to the Tevatron can be made with this calibration data.

2 Description of Data Taken

The calibration bump data for pbars were taken on 1st May 2002. Closed orbit 3-bumps were made to produce shifts in position of the beam at the SL2 radiation point for the pbars (`end SLPBHDIP` in the lattice file.) The horizontal bumps were produced using HDB49, HDC11 and HDC13 while the vertical bumps were produced using VDB49, VDC11 and VDC14.

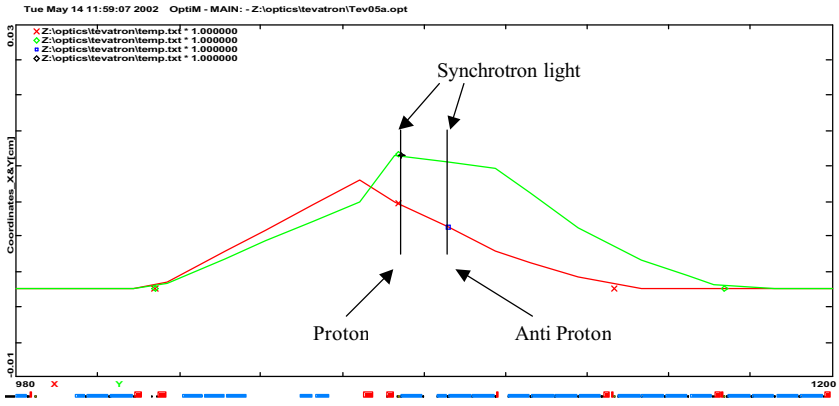
Table 1 shows the data for the pbar bumps. Four vertical bumps and three horizontal bumps were used, and the average shift from nominal of the SL2 profiles were calculated for 3 bunches. The error gives an indication of the statistical fluctuations in the shifts for several data points for each bunch, and between bunches. The size of the bumps at HDC11 and VDC11 are quoted in the table and have to be translated into sizes of bumps at the radiation point of the pbar synchrotron light. This is also quoted in the table and was obtained using orbit calculations by A. Xiao [3]. The results of her study are reproduced in Figure 1.

3 Results From Fitting the Data

The data were fitted to obtain relative calibration scales. The results of the vertical bump and horizontal bump fits are shown in Figures 2 and 3 respectively. The results are also

Table 1: Bump data for pbars, for vertical and horizontal bumps. The Measured SL2 shifts are averages for 3 different bunches, and for approximately 3 data points for each bunch. The errors quoted only include the statistical fluctuations in these 9 measurements. (Other errors may dominate.)

Vertical bump at VDC11 (mm)	**Bump at $\bar{p}$ SL2 (mm)**	**Vertical SL2 shift (mm)**	**Horizontal SL2 shift (mm)**
-3	-2.84	-1.635 ± 0.018	-0.010 ± 0.003
1	0.946	0.578 ± 0.010	0.010 ± 0.004
2	1.89	1.117 ± 0.007	0.021 ± 0.003
4	3.78	2.177 ± 0.012	0.067 ± 0.001
Horizontal bump at HDC11 (mm)	**Bump at $\bar{p}$ SL2 (mm)**	**Vertical SL2 shift (mm)**	**Horizontal SL2 shift (mm)**
-3	-2.16	0.087 ± 0.007	-1.131 ± 0.004
3	2.16	0.015 ± 0.005	1.197 ± 0.003
3	2.16	-0.028 ± 0.010	1.203 ± 0.003



N	L	NAME	X[cm]	Y[cm]	Px[mrad]	Py[mrad]	Bx_ef[kG]	By_ef[kG]
1386	95679.44	kVDB47	0 0	0 0	0	0		
1431	98531.79	kHDB48	0 0	0 0	0	0		
1479	101734.59	kVDB49	6.12163e-27	9.99328e-11	1.22433e-19	0.00199866	6.12574e-13	10000
1480	101734.59	kHDB49	9.99328e-11	2.99798e-10	0.00199866	0.00199866	10000	0
1527	108318.97	kHDC11	0.009737	0.0152271	-0.00206654	0.000735054	-9291	0
1528	108318.97	kVDC11	0.009737	0.0152271	-0.00206654	-0.000633026	-4.19307e-13	-6845
1532	108387.44	isPSYNC	0.0095955	0.0151837	-0.00206654	-0.000633026	0	0
1546	109639.66	isPBSYNC	0.00700233	0.0143984	-0.00207524	-0.0006197	0	0
1574	111130.88	kVDC12	0.0039869	0.0132083	-0.0013132	-0.0031146	0	0
1618	114143.32	kHDC13	5.30855e-07	0.00418526	-1.09435e-07	-0.00140247	7109	0
1661	117117.66	kVDC14	2.20676e-07	-3.27357e-07	-2.39993e-08	-8.01672e-07	4.6182e-13	7539
1704	120094.55	kHDC15	1.37253e-07	-2.90747e-06	-8.16151e-08	-1.7781e-06	0	0

Figure 1: Orbit calculations at SyncLite 2 from A. Xiao [3]. Horizontal orbit displacements at SL2 (x_p and x_{pbar}) are related to that at HDC11 (x_{bump}) by: $x_p = 0.9855 \times x_{bump}$ and $x_{pbar} = 0.7191 \times x_{bump}$. Vertical orbit displacements at SL2 are related to those at VDC11 by: $y_p = 0.9971 \times y_{bump}$ and $y_{pbar} = 0.9456 \times y_{bump}$.

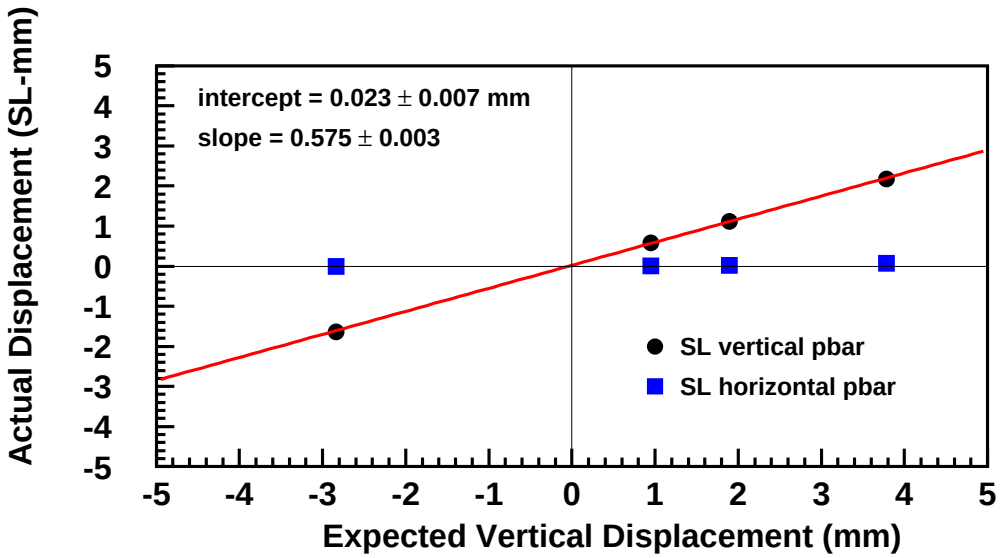


Figure 2: Vertical and horizontal displacements of the $\bar{p}$ beam as seen by SyncLite compared to expected vertical displacements. The slope of the fitted line gives the correct SL2 vertical scale factor.

summarized in Table 2. The vertical and horizontal SL2 scales are in fairly good agreement. (Note that the errors quoted for the slopes only include statistical uncertainties in the data taken. One expects the true error to be dominated by the uncertainties in the expected bump displacements.) Taking a simple average, this study shows that the pbar SL2 scale should be larger by a factor of $\frac{1}{0.558} = 1.79$. Since the two scales should agree I estimate that the error in this scale factor to be about 5%.

The smallness of the horizontal beam position shifts for vertical beam displacements and vice versa show that there is no evidence for a significant tilt in the pbar SL2 system. From the fits to the data and taking into account the factor of 1.79 difference in scale, vertical and horizontal bump data would indicate that the SL2 system is slightly rotated counter clockwise with respect to the Tevatron system by 1.3° and 1.9° respectively. This is illustrated in Figure 4 where we have taken the average tilt of $\theta = 1.6°$. Again the two tilt angles should agree, using this I estimate that the error in the tilt is about 25%.

4 Conclusions

The pbar beam bump study shows that the SyncLite pbar scale should be increased by a factor of 1.79[4]. The current scale is 0.083 mm/pixel, so the new scale factor should be 0.149 mm/pixel. This will significantly increase the calculated pbar emittances. There is no evidence of a significant tilt in the SyncLite system compared to the Tevatron system.

This study needs to be repeated for the proton system.

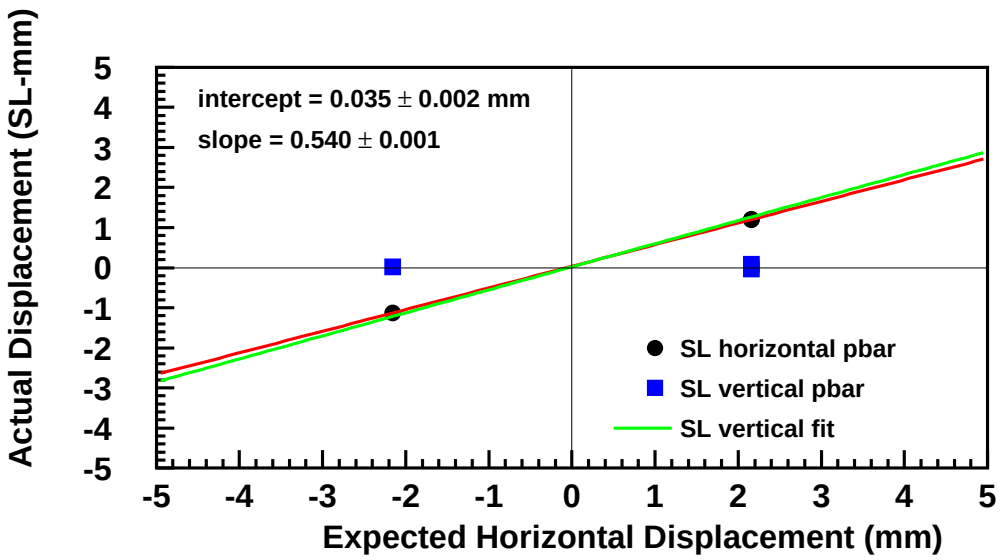


Figure 3: Horizontal and vertical displacements of the $\bar{p}$ beam as seen by SyncLite compared to expected horizontal displacements. The slope of the fitted line (red) gives the correct SL2 horizontal scale factor. The vertical slope (green line) is shown for comparison. Ideally the two should agree.

Table 2: Summary of results for pbar bump data fits.

Quantity	**Slope in Vertical SL2 fit**	**Slope in Horizontal SL2 fit**
Vertical bump	0.575	0.0128
Horizontal bump	-0.0187	0.540

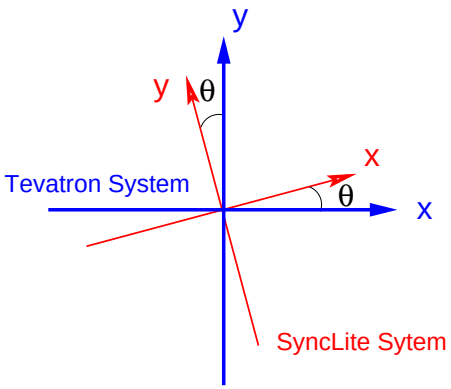


Figure 4: Schematic showing a possible small tilt of the SL2 system with respect to the Tevatron system of $\theta \approx 1.6°$. The positive y axis points up and the positive x axis points away from the center of the Tevatron orbit.

References

[1] `http://home.fnal.gov/~cheung/synclite/`.

[2] Alan Hahn, private communication.

[3] A. Xiao, `http://www-bdnew.fnal.gov/beam-physics-studies/Notes/2002/syncLorb.pdf`

[4] According to Alan Hahn the scale of the system set by viewing an image of known size on the bench should not be off by anything near as large as 80%. So currently this is a mystery. One should check the software to make sure there isn't a factor of 2 missing somewhere. The alternative is to repeat the test of imaging something in the system of known size.