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Booster Horizontal and Vertical Aperture

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Booster Horizontal and Vertical Aperture

Study Period: Various

Participants: L. Ahrens, J. Donahue, H. Calvani, MCR Staff

Reported by: S. Y. Zhang

Machine: Booster

Beam: Gold

Tools: Orbit bumps

Aim: To measure the booster transverse aperture

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1 Summary

1. The Booster horizontal physical aperture is larger than 125 *mm* at the dump D6, which is the tightest among others that have been measured, at larger than 140 *mm*.

2. The Booster vertical physical aperture at the dipoles is around 70 *mm*.

2 Introduction

During 1996-97 HIP run, several aperture scans had been performed. In general, the results are more or less agreeable to each other. In the following, some aperture scans at the early acceleration are discussed. Approximate estimates of the horizontal and vertical apertures are given. These apertures are pretty much as same as the machine aperture we know, which implies that these apertures are probably not the problem that affects the injection efficiency. Meanwhile, the machine aperture during the injection period is not necessarily the same as these apertures, therefore, the aperture problem may cause the beam loss and affect the injection efficiency.

3 Horizontal Aperture

The horizontal aperture was first measured by powering the bumps centered at the dump D6, the time was centered at 25 *ms* from Booster T_0, and the bumps rampings took 10 *ms* up and down. Since the beam was injected at 12 *ms* from T_0, therefore, the ramping should not affect the injection. The scan is shown in Fig.1a, where the upper limit is missing, because the bumps are out of range.

During the period of 20 *ms* to 25 *ms* from T_0, the beam was rapidly accelerated, therefore, the beam size at 20 *ms* could be big enough that the upper aperture limit can be found under the same constraint of the bumps. In the second try, the bumps were centered at 20 *ms*, and the rampings were reduced to 5 *ms*, making sure that the injection is not affected. This time, the upper limit can be barely seen at [12 *mm*], meanwhile the lower limit was at [−3 *mm*], the total range was [15 *mm*]. This is shown in Fig.1b. The limit we used here can be seen as the 95% beam size meets the wall. Beyond this limit, the beam loss increases rapidly. In Fig.1a, the lower limit is at [−5 *mm*]. If the upper limit is assumed to be equally extended, then the upper limit is at [14 *mm*], total range is [19 *mm*]. For Gold beam, these ranges need to be multiplied by a factor of 2.5, per L. Ahrens. To identify it clearly, the data directly read from the prints are marked inside parenthesis. Thus, the ranges within the limits are 37.5 *mm* and 47.5 *mm*, for the scans centered at 20 *ms* and 25 *ms*, respectively.

The gold beam horizontal normalized emittance in the Booster is about 6.5 $\pi mmmr$, including 95% particles, see AGS Study Report No.358. The 95%, or full beam size variation with respect to the magnetic cycle is shown in Fig.2, where it is shown that the full beam size is 88.5 *mm* at 20 *ms*, and 80.9 *mm* at 25 *ms*. The sums of the beam lossless range and the 95% beam size are, therefore, are 126.0 *mm* and 128.4 *mm*, at 20 *ms* and 25 *ms*, respectively. The full horizontal aperture of the ring vacuum chambers at D6 is larger than 125 *mm*. This result is summarized in the Table 1.

Time from T_0	**Full Beam size**	**Lossless range**	**Aperture**
25 *ms*	80.9 *mm*	47.5 *mm*	128.4 *mm*
20 *ms*	88.5 *mm*	37.5 *mm*	126.0 *mm*

Table 1: Horizontal Aperture at D6

By the end of run, L. Ahrens used the near zero $\dot{B}$ porch at the injection magnetic field for the horizontal aperture scan around the ring. The 95% beam size at this level is 91.6 *mm*, as shown in Fig.2. Since the magnetic field at the center of scan is a little higher than the injection level, we take it as 91.0 *mm*. The result is summarized in the Table 2.

Scan Center	**High Limit**	**Low Limit**	**Aperture**	**Remark**
A2	32.5 *mm*, no hit	-30 *mm*, no hit	>153.5 *mm*	
A4	30 *mm*, no hit	-20 *mm*	>141.0 *mm*	
A6	40 *mm*	-10 *mm*	141.0 *mm*	A8 functioning?
B4	30 *mm*	-30 *mm*, no hit	>151.0 *mm*	
C2	30 *mm*, no hit	-30 *mm*, no hit	>151.0 *mm*	
C4	35 *mm*	-30 *mm*	156.0 *mm*	
C6	30 *mm*	-30 *mm*, no hit	>151.0 *mm*	
D4	37.5 *mm*, no hit	-37.5 *mm*, no hit	>166.0 *mm*	No step in I(t)
E6	30 *mm*, no hit	-30 *mm*, no hit	>151.0 *mm*	
E8	30 *mm*, no hit	-30 *mm*, no hit	>151.0 *mm*	
F6	30 *mm*, no hit	-45 *mm*	>166.0 *mm*	

Table 2: Horizontal Aperture Around the Ring

The limiting horizontal aperture of the Booster vacuum chamber is 150 *mm*, therefore, the aperture shown in Table 2 might be a little too large. Either the normalized emittance, or the calibration in the 3 bumps scan may carry some error.

4 Vertical Aperture

The vertical aperture was scanned using local bumps centered at A1, A3, A5 and A7, etc. for all 6 superperiods, as shown in Fig.3a. Note that the 50% beam loss range is used in

Fig.3a. After reviewing each scan, such as the one for B1, shown in Fig.3b, a lossless range is taken as [6 *mm*] smaller than the 50% beam loss range. The scan time was centered at 25 *ms*. The Booster vertical normalized emittance is about 2.5 $\pi mmmr$, therefore, the 95% beam size at 25 *ms* is 50.0 *mm*.

The vertical aperture is shown in Table 3.

Scan Center	Lossless	Aperture	Scan Center	Lossless	Aperture
A1	17.5 *mm*	67.5 *mm*	D1	27.5 *mm*	77.5 *mm*
A3	20 *mm*	70 *mm*	D3	30 *mm*	80 *mm*
A5	17.5 *mm*	67.5 *mm*	D5	25 *mm*	75 *mm*
A7	15 *mm*	65 *mm*	D7	20 *mm*	70 *mm*
B1	20 *mm*	70 *mm*	E1	25 *mm*	75 *mm*
B3	25 *mm*	75 *mm*	E3	35 *mm*	85 *mm*
B5	20 *mm*	70 *mm*	E5	12.5 *mm*	62.5 *mm*
B7	22.5 *mm*	72.5 *mm*	E7	20 *mm*	70 *mm*
C1	20 *mm*	70 *mm*	F1	20 *mm*	70 *mm*
C3	27.5 *mm*	77.5 *mm*	F3	25 *mm*	75 *mm*
C5	10 *mm*	60 *mm*	F5	12.5 *mm*	62.5 *mm*
C7	15 *mm*	65 *mm*	F7	17.5 *mm*	67.5 *mm*

Table 3: Vertical Aperture Around the Ring

The vertical limiting aperture at the Booster is known as about 66 *mm*, at the edges of dipole vacuum chambers. Again, the apertures shown in the Table 3 are a little too large, but still in a reasonable range.

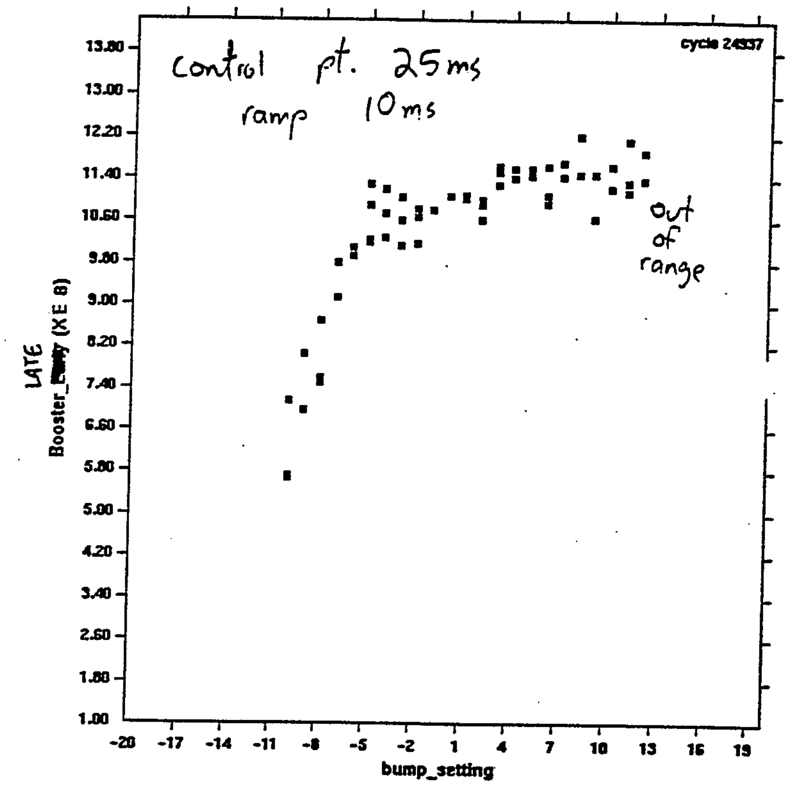

cycle 24937
control pt. 25ms
ramp 10ms
out of range
LATE
Booster_ (X E 8)
bump_setting

Fig.1a

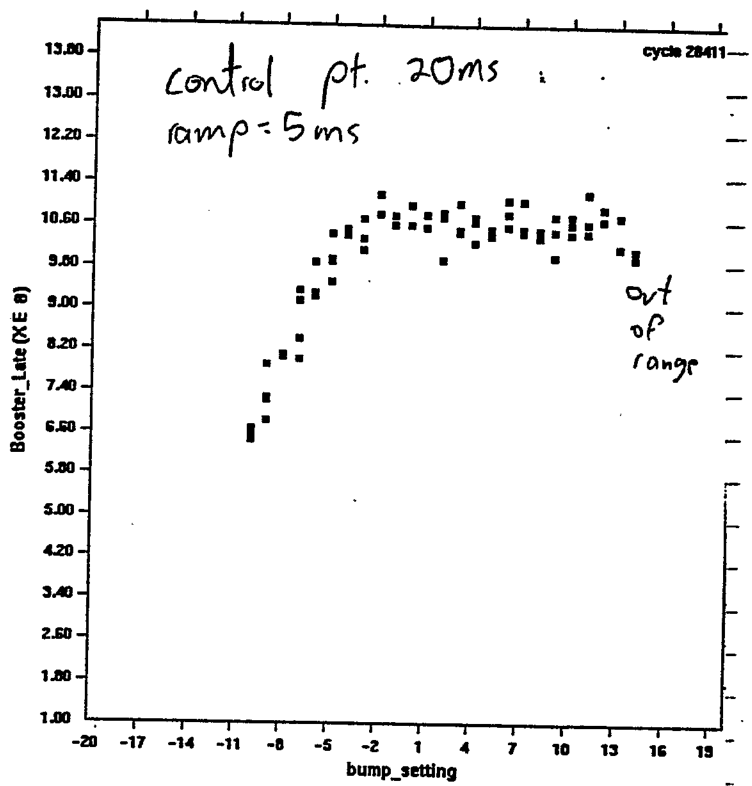

cycle 28411
control pt. 20ms
ramp = 5ms
out of range
Booster_Late (X E 8)
bump_setting

Fig.1b

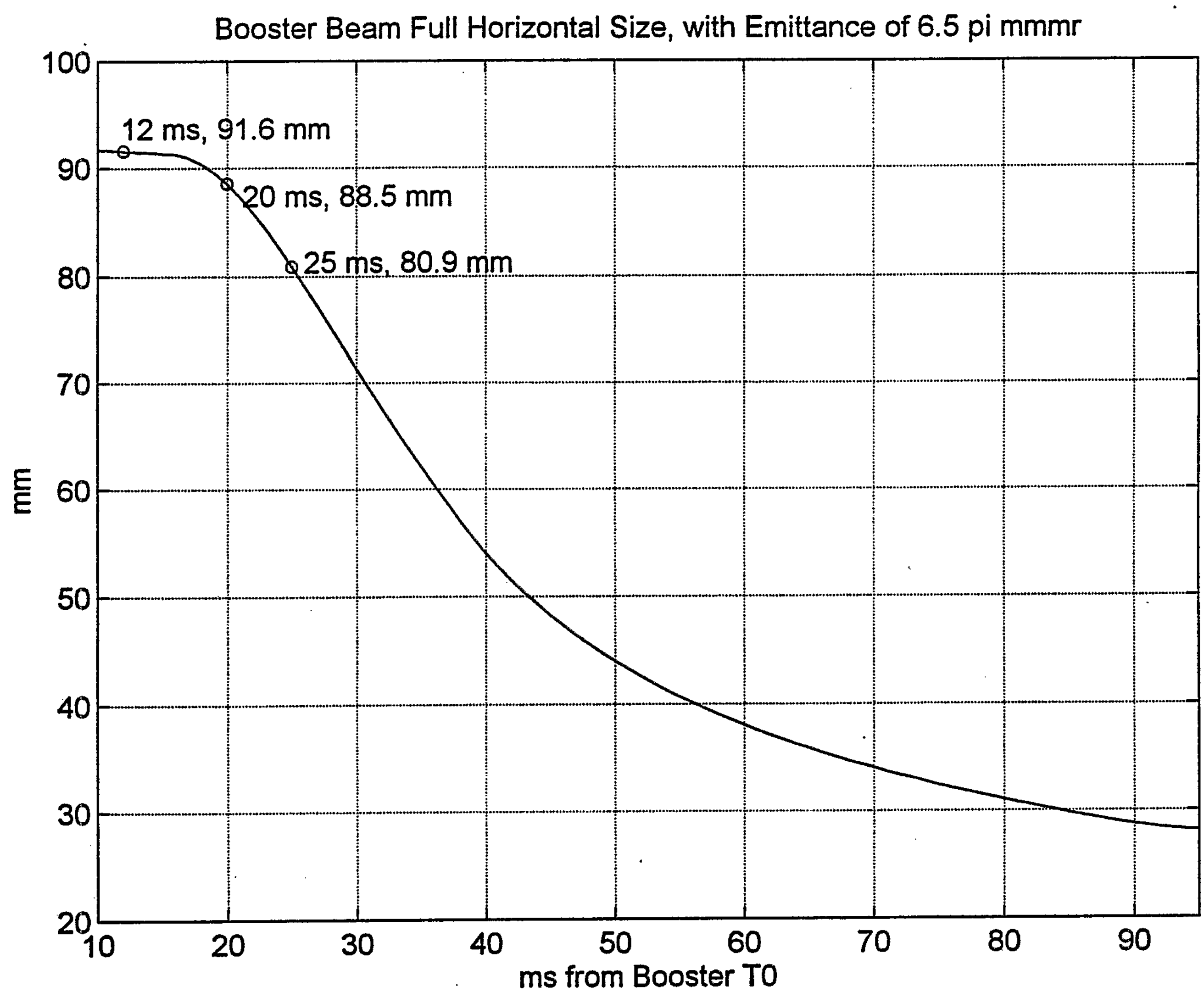
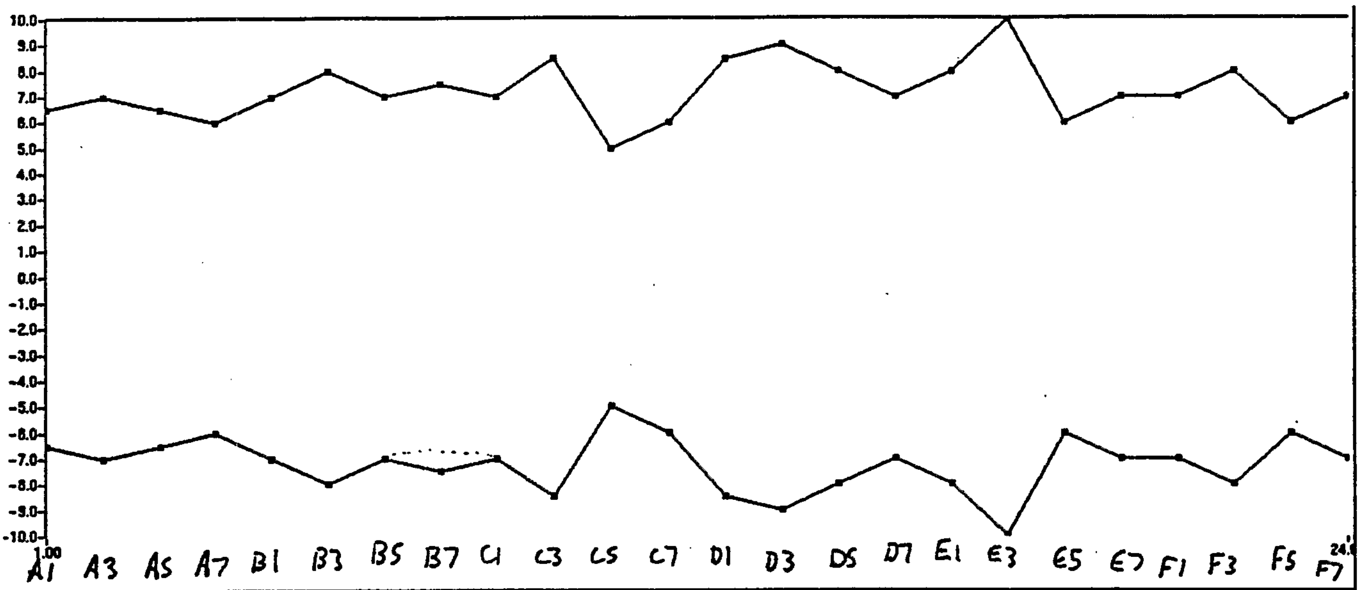
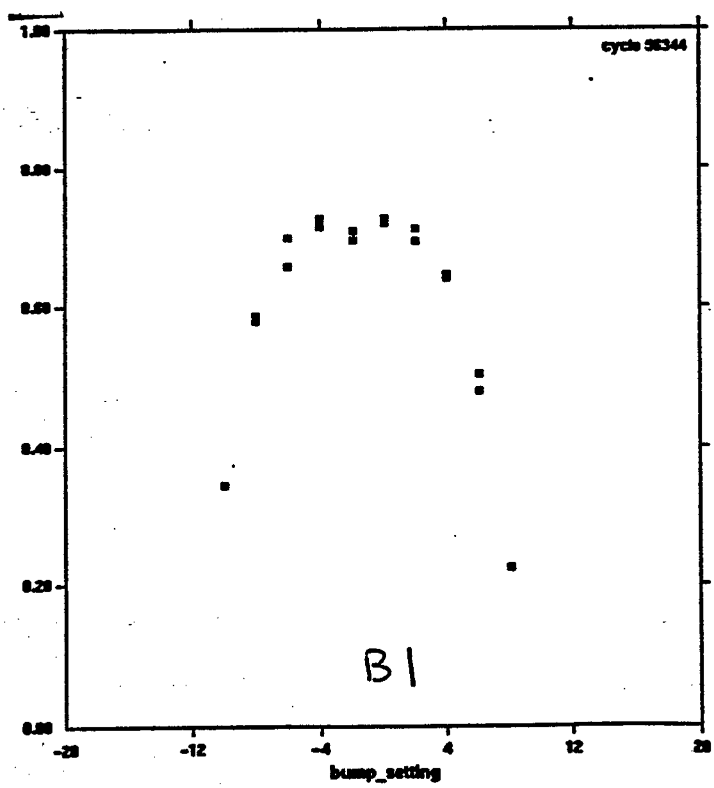

Booster Beam Full Horizontal Size, with Emittance of 6.5 pi mmmr
12 ms, 91.6 mm
20 ms, 88.5 mm
25 ms, 80.9 mm
mm
100
90
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90
ms from Booster T0

Fig.2



10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
1.00
A1 A3 A5 A7 B1 B3 B5 B7 C1 C3 C5 C7 D1 D3 D5 D7 E1 E3 E5 E7 F1 F3 F5 F7

Fig.3a



cycle
1.00
0.80
0.60
0.40
0.20
0.00
-20 -12 -4 4 12 20
bump_setting
B1

Fig.3b