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Alternate conceptual lattice for the AGS - RHIC Booster

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ABSTRACT

The conceptual design of the booster lattice is slightly modified to have higher superperiodicity at a different tune. We found that the new lattice may have the advantage over the present proposed lattice that
There is no systmatic stop-band within the possible space charge tune shift for the proton operation. The machine can be tuned to q=5.8 for the heavy ion operation,where the maximum beta function is smaller(14m vs. 15.5 m)

I) Introduction

The booster lattice is known to suffer a minor difficulty that the tune of the booster is operating at Qx=Qy=4.83 ,while the systmatic fourth order resonance is located at the tune of 4.5. The Laslett tune shift due to the space charge at the injection energy of 200 MeV is of the order of 1, therefore the fourth order resonance may be important in determining the performance of the machine. Although this systmatic rsonance can be corrected, it would be nice if one can avoid it in the first place. In this short note we shall address the problem and study the feasibility of designing the booster lattice to stay away from the systmatic stop band up to 4th order. The goal can be achieved with the machine superperiodicity 8 with the machine tune of around 6.83 , where the nearest is located at 5 1/3(3rd) and 6(4th). Therefore the machine performance should be comparable to that of the AGS where the tune is 8.8 with resonances at 8(3rd) and 9(4th).

II) The Lattice

The magnitude of the maximum beta function is dictated by the cell length. To obtain the same betatron functions, we shall retain the same basic csell structure as that of the reference booster lattice(ref. 1). Therefore there are 24 basic FODO cells in the booster ring, and 3 FODO cells per superperiod. To ease the extraction problem, we shall have 4 dipoles in a superperiod. Thus the dipole should have a length of 2.7m (with a maximum B field of 1.2145 T at BRHO=16.7 Tesla-m). The quadrupoles should remain the same length of 0.50375m. Therefore the available space between quadrupoles will be 3.7m . This may be or may not be so tight for the cells with dipoles. I consider this situation to be appropriate. The basic superperiod structure is arranged as following:

```
QD        QF    B     QD    B     QF          QD    B     QF    B    QD
                ___         ___                     ___         ___
          II  I   I       I   I  II                 I   I  II  I   I
--------------I---I-------I---I---------------------I---I-------I---I---
I             I___I  II   I___I                II   I___I       I___I  I
```

The phase advance in each FODO cell shall be 102 degree to have a tune of 6.8 for the machine. The straight section is arranged to minimize the extraction kicker strength. Since the machine is far away from the systmatic stop-bands, it can be tuned for a large range of the tune. As an example, we may operate the machine at a tune of 5.83 for heavy ion to obtain a smaller betatron function amplitude. Fig. 1 shows the betatron amplitude in the superperiod at q=6.83. The maximum betatron function is about 15.5m . The dispersion function is however smaller. The sextupoles should be placed at some where in the begining of the superperiod. With these sextupoles, the chromatic variation of the betatron amplitude within .25% is shown in Fig.2 with two sextupoles per superperiods.

Since the machine is far away from the systmatic resonances, we can tune the machine to q=5.83. Figs. 3 and 4 show the corresponding betatron function amplitudes and chromatic variations. Table 1 lists the parameters and the chromatic properties of the lattice incomparison with the reference lattice.

Table 1. Comparison of booster lattices

	STANDARD SEP.FN.	ALTERNATE SEP.FN.			SEP.FN.
Circumference	1/4AGS	1/4AGS	1/4AGS	1/4AGS	1/3AGS
(m)	201.78	201.78	201.78	201.78	269.04
SUPERPERIOD	6	8	8	8	8
TUNE(Qx, Qy)	4.83	6.83	5.83	4.83	6.83
Phase/cell(deg.)	72	102	87	72	76.5
Systmatic stop bands					
order 2	3,6,9	4,8	4,8	4,8	4,8
order 3	4,6,8	5+1/3,8	5+1/3,8	5+1/3,8	5+1/3,8
order 4	4.5,6	4,6,8	4,6,8	4,6,8	4,6,8
Magnet specifications					
BRHO(Tm)	16.7	16.7	16.7	16.7	16.7
dip.length(m)	2.4	2.7	2.7	2.7	2.4
No. dipoles	36	32	32	32	40
B^@brho=16.7Tm	1.214	1.214	1.214	1.214	1.093
quad.length(m)	0.50375	0.50375	0.50375	0.50375	0.50375
No. quads.	48	48	48	48	64
quad.qradients					
QF(T/m)	9.84	12.53	11.04	9.33	
QD(T/m)	-10.1	-12.77	-11.29	-9.6	
Sextupoles	without eddy current				
Cx	-4.9	-8.9	-6.62		
Cy	-5.3	-9.3	-6.95		
SF(m^-2)	0.63	0.67	0.58		
SD(m^-2)	-0.483	-1.38	-1.18		
Axx	99	128	16.8		
Axy	-57	49	-53.1		
Ayy	55	110	20.3		
	with eddy current				
Cx	4.04	-5.11	-0.86	4.19	
Cy	-13.16	-12.68	-12.03	-13.45	
SF(m^-2)	0.069	0.46	0.25	0	
SD(m^-2)	-0.81	-1.74	-1.71	-1.35	
Axx	10	53	-0.88	3.23	
Axy	0.4	44	-47.6	30.5	
Ayy	104	226	105	91.8	
	with saturation				
Cx	-7.69	-10.04	-8.296	-7.51	
Cy	-2.72	-8.27	-5.481	-2.8	
SF(m^-2)	0.799	0.73	0.68	0.52	
SD(m^-2)	-0.381	-1.27	-1.02	-0.55	
Axx	144	157	26.7	53.7	
Axy	-71	45	-60.1	19.4	
Ayy	47	83	3.05	21.7	
	(1)	(2)			

(1) 4 sextupoles/superperiod at 1247 locations are assumed
(2) 2 sextupoles/superperiod at 23 locations are assumed

III) conclusion

Based on the present study, rearrangement of the lattice cell structure has the advantage of gaining the superperiod structure so that the systmatic stop-band for the operation tune can be avoided. The present study assume that the negative H ion injection through a dipole magnet will not cause any problem in the operation of the machine. In this event, we do not need a 5m long straight section for the proton injection. Therefore separated function machine may be advantageous to have the tunability. Arrangement of the present lattice enable the machine to be tuned within a large range without encounter any systmatic resonances of the order less or equal to 4.

REFERENCES

1) Y. Y. LEE, private communication and
BNL-34989 R, AGS BOOSTER CONCEPTUAL DESIGN REPORT

Figures caption:

Fig.1 (lower)The betatron amplitudes of the 8 superperiod booster machine is shown here. Note that the dipole length is 2.7m *32 in the whole ring.The tune is 6.8.

Fig.2 (upper)The chromatic variation of the betatron functions is shown in the figure vs. dp/p. The sextupole location is assumed to be at the locations of the first qf and second qd on figure 1. Two sextupoles is assumed in the present calculation .

Fig.3 (lower)Same as that of fig. 1 except that the tune is operated at Q=5.83 instead of 6.83.

Fig.4 (upper)Same as that of fig.2 except that the tune is Q=5.83.

Fig.5 Beam sizes(assuming emittance=50 pi mmmrad and dp/p=.25%) for q=6.83 and q=5.83 respectively(upper and lower).

Fig.6 The corresponding betatron functions and beam size at q=4.83.

Fig. 2

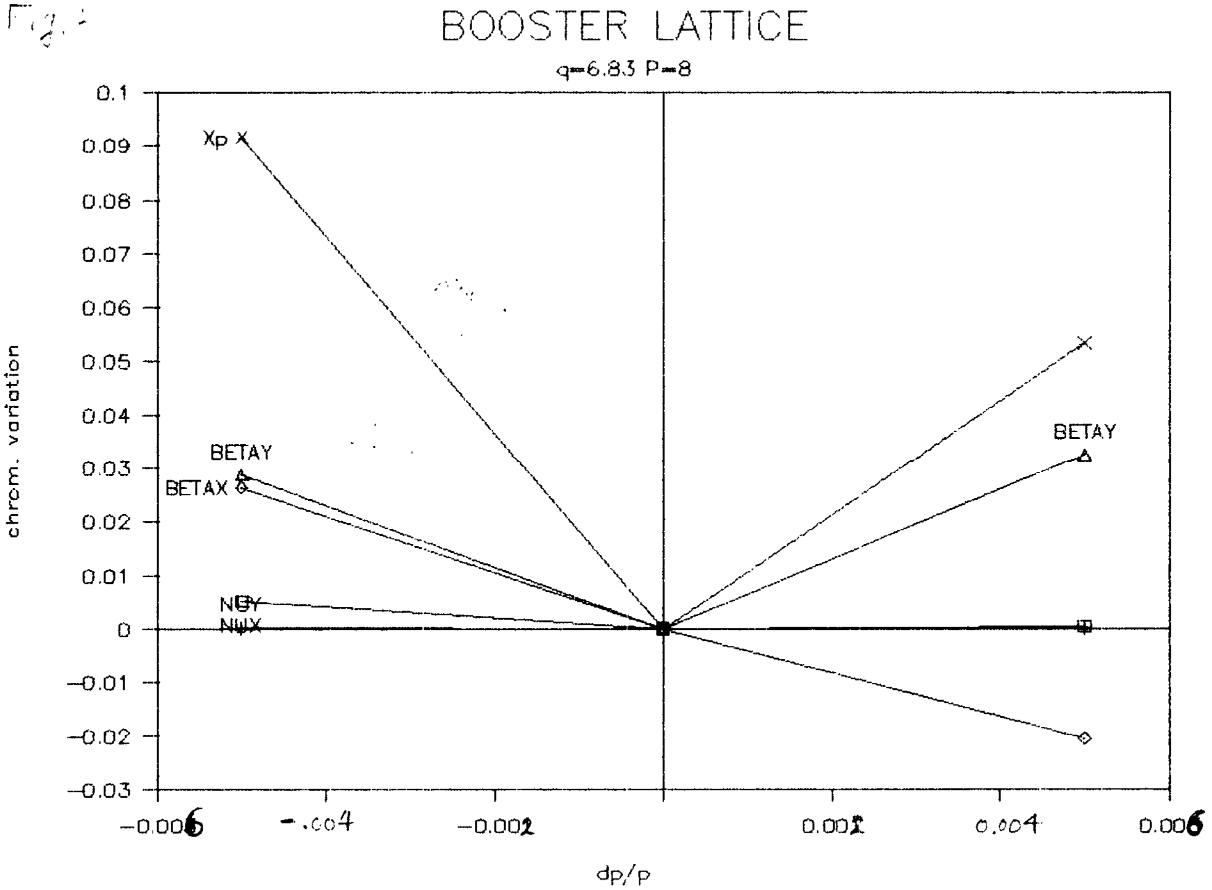

BOOSTER LATTICE
q=6.83 P=8
chrom. variation
dp/p
Xp
BETAY
BETAX
NUY
NUX
-0.006
-.004
-0.002
0.002
0.004
0.006

Fig. 1

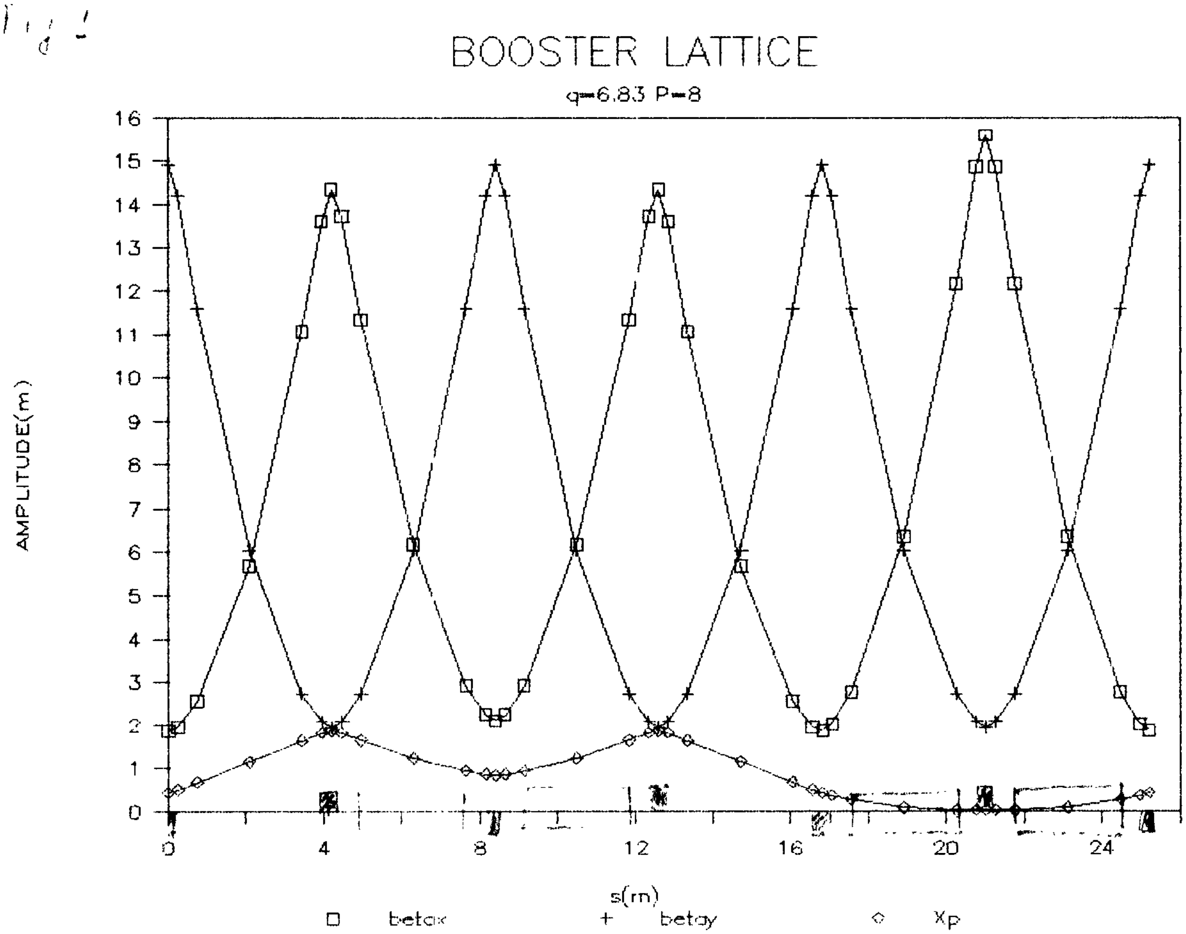

BOOSTER LATTICE
q=6.83 P=8
AMPLITUDE(m)
s(m)
betax
betay
Xp

Fig 4

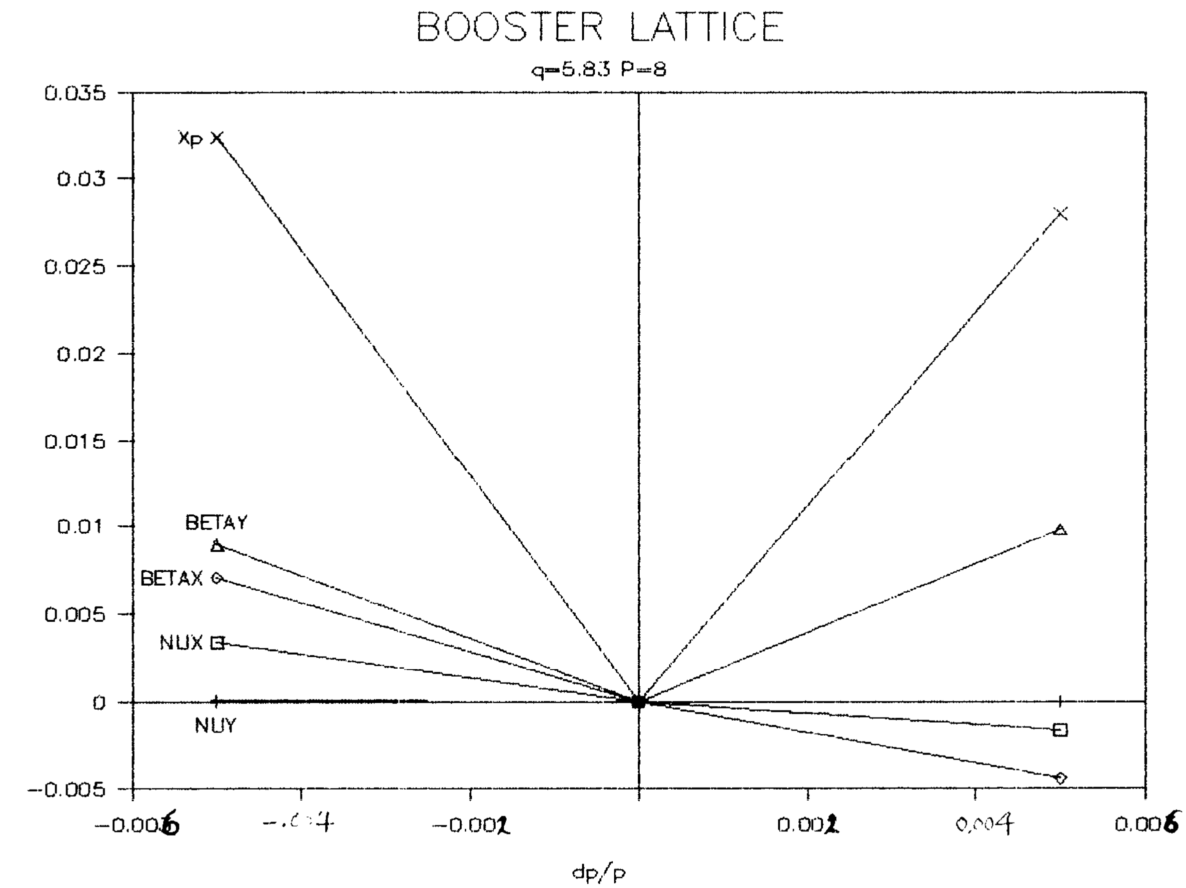
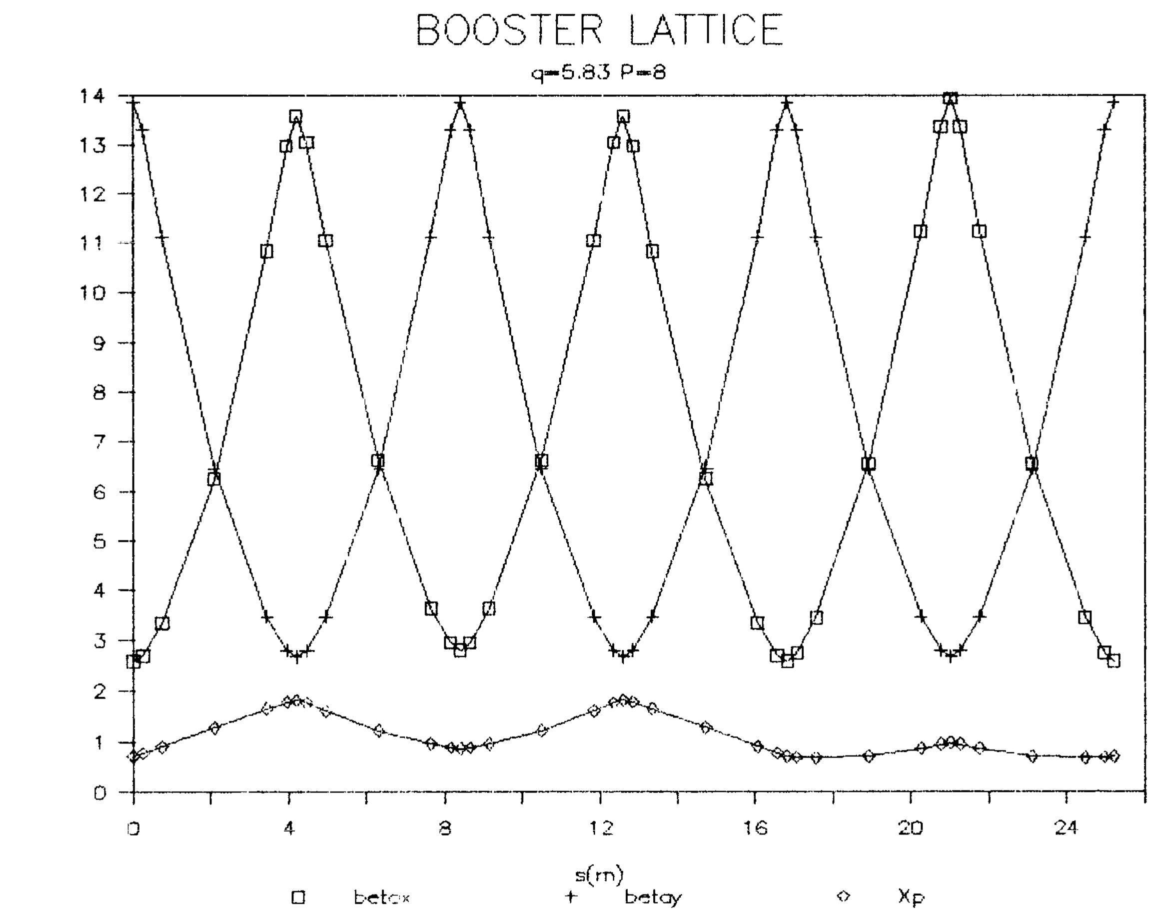
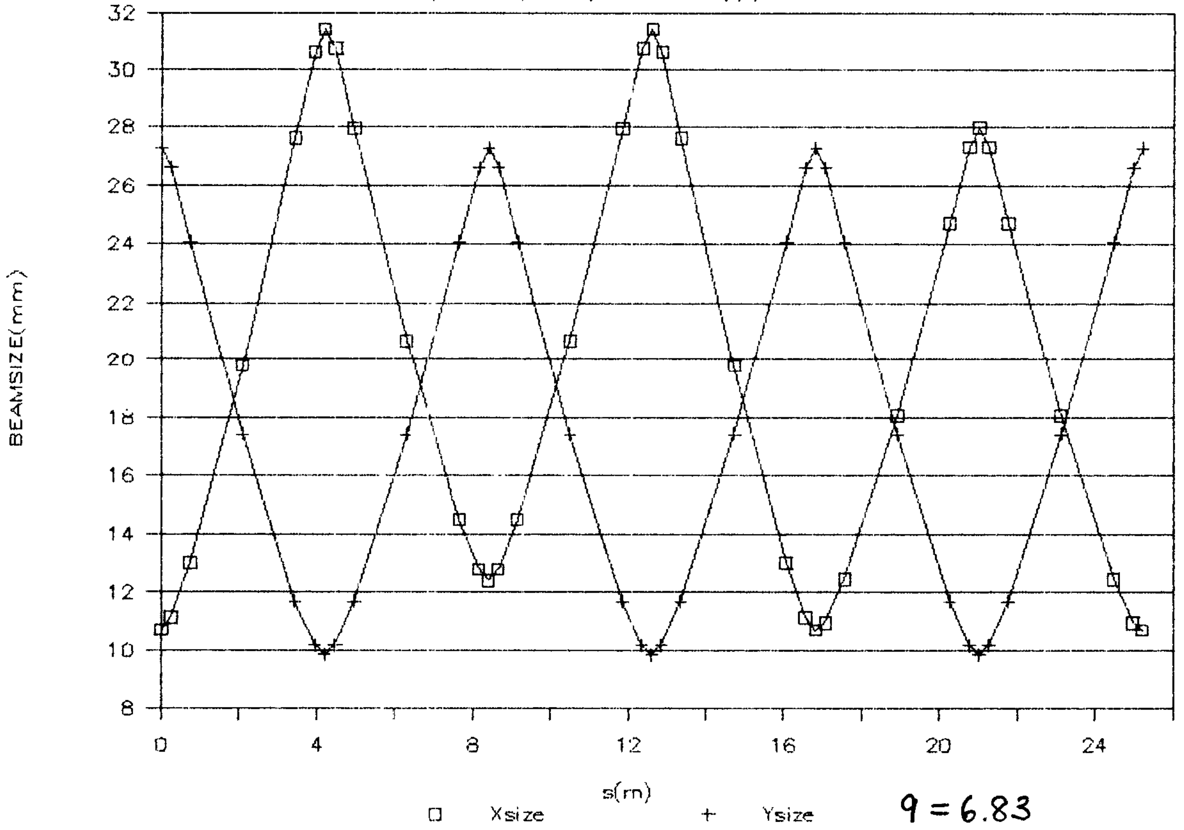

BOOSTER LATTICE
q=5.83 P=8
chrom.deviation
dp/p
Xp
BETAY
BETAX
NUX
NUY
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.006
-.004
-0.002
0.002
0.004
0.006

Fig. 3


BOOSTER LATTICE
q=5.83 P=8
AMPLITUDE(m)
s(m)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
4
8
12
16
20
24
betax
betay
Xp

BOOSTER P=8 C=1/4AGS LATTICE

q=6.83,eps=50pim-mrad,dp/p=.25%



BOOSTER P=8 C=1/4AGS LATTICE

q=5.83,eps=50pimmmrad,dp/p=.25%

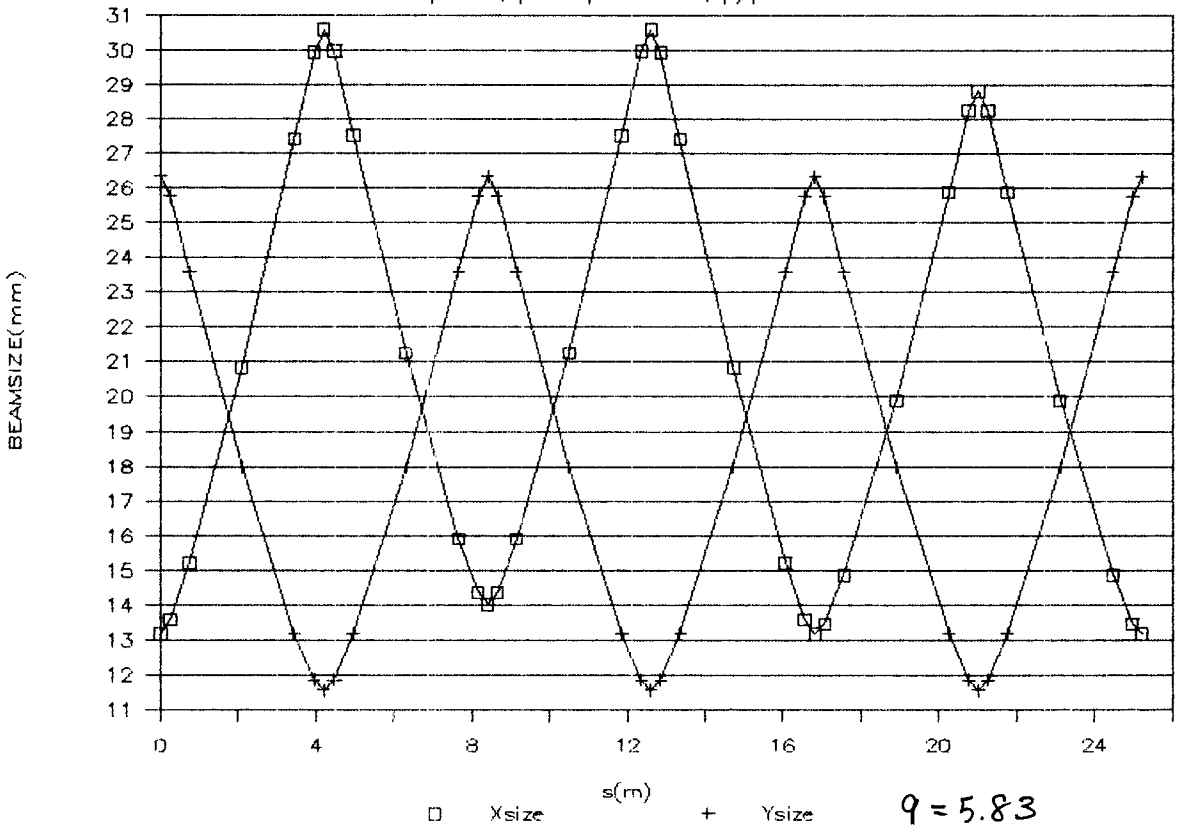
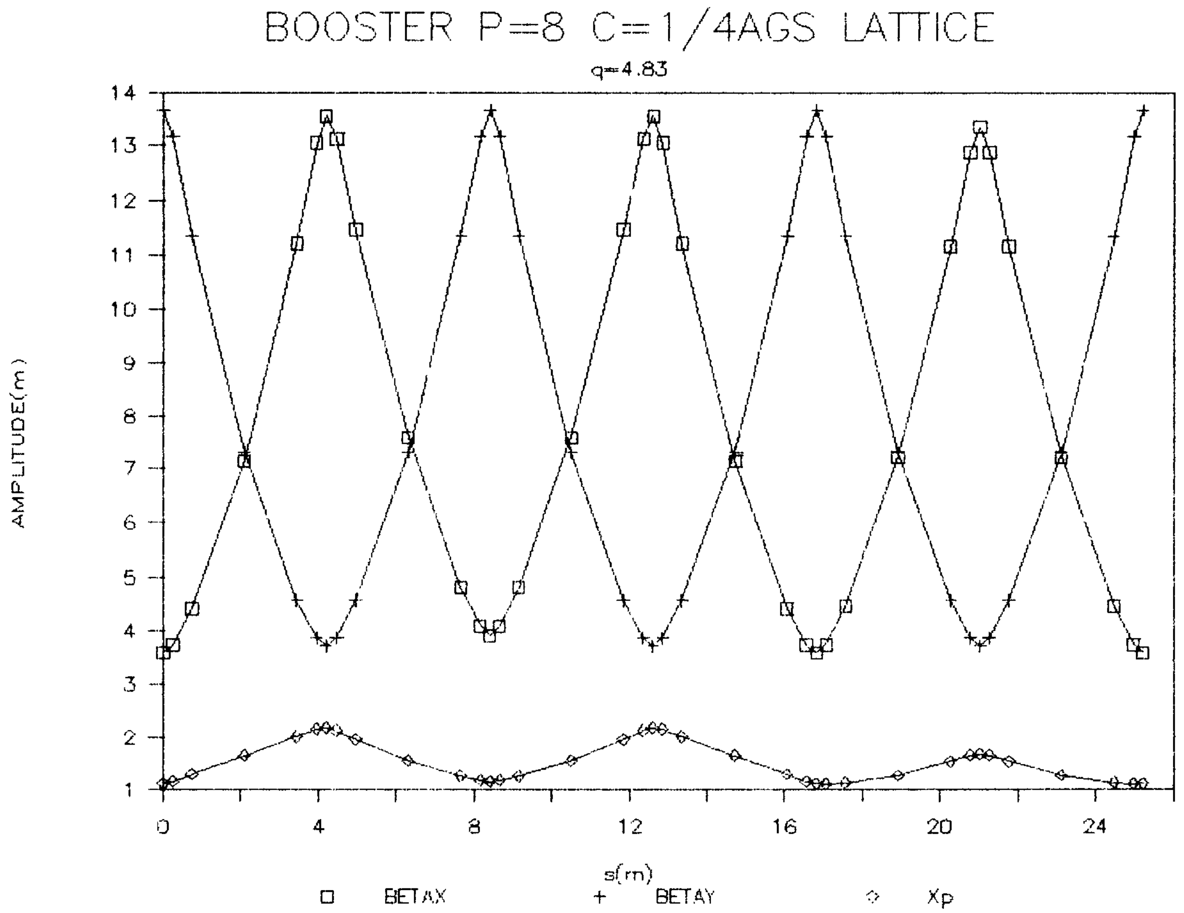


Fig. 5


BOOSTER P=8 C=1/4AGS LATTICE
q=4.83
AMPLITUDE(m)
s(m)
BETAX
BETAY
Xp

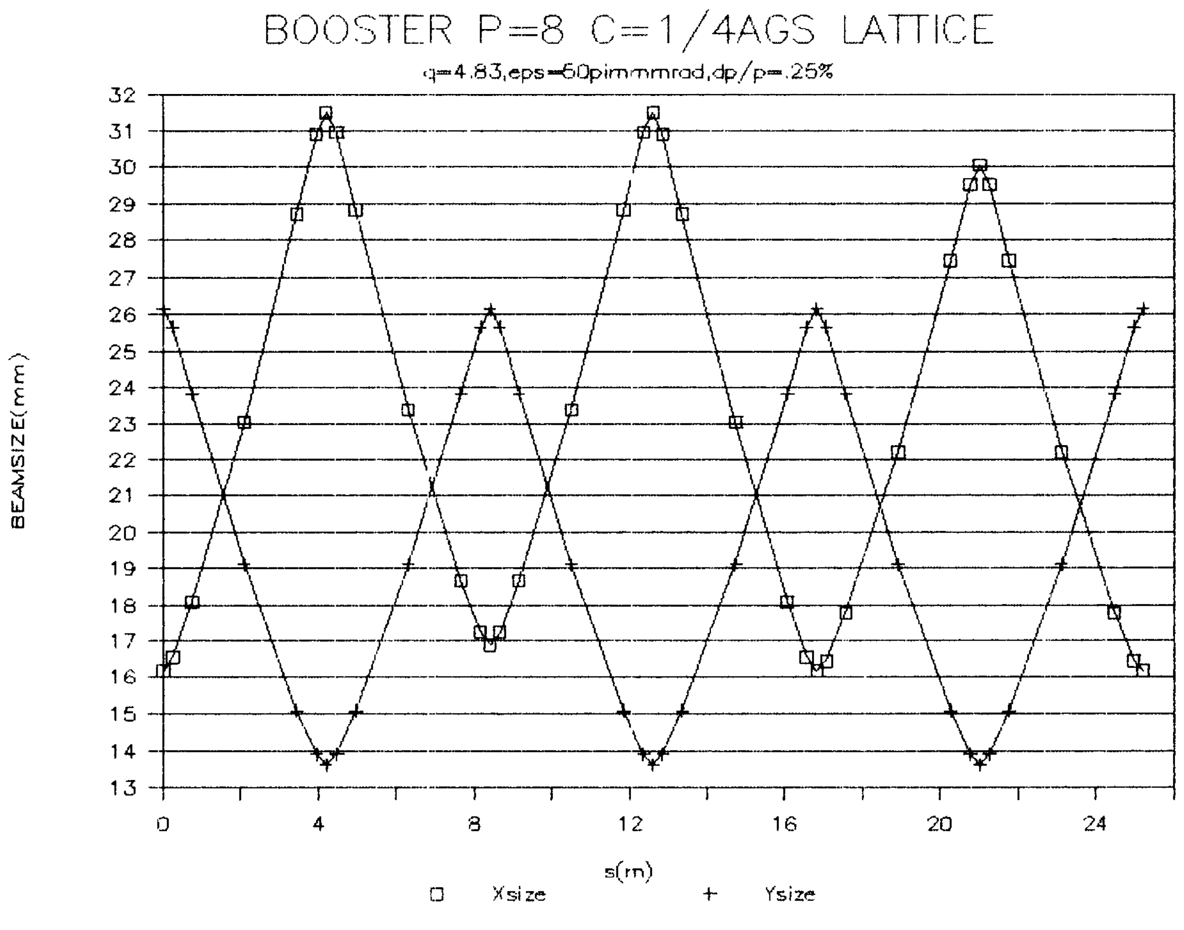

BOOSTER P=8 C=1/4AGS LATTICE
q=4.83,eps=60pimmmrad,dp/p=.25%
BEAMSIZE(mm)
s(m)
Xsize
Ysize

Fig. 6