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Resonance analysis for standard Booster lattice with split tunes

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DISCLAIMER

RESONANCE ANALYSIS
FOR STANDARD BOOSTER LATTICE
WITH SPLIT TUNES

Booster Technical Note
No. 35

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ABSTRACT

WE HAVE INVESTIGATED THE NONLINEAR EFFECTS (E.G. THE STRUCTURE RESONANCES) OF THE STANDARD BOOSTER LATTICE WITH SPLIT TUNES AND ANOTHER ALTERNATE LATTICE WITH SHORT AND LONG STRAIGHT SECTIONS AND PERIODICITY OF 8. IN THIS NOTE, WE WILL GIVE THE RESULTS OF OUR ANALYSIS FOR THESE LATTICES IN COMPARISON TO THE STANDARD BOOSTER LATTICE WITH OPERATING TUNES OF Qx = 4.82 AND Qy = 4.83. RESONANCES ARE CROSSED AT INJECTION BECAUSE OF THE SPACE CHARGE TUNE SHIFTS. THE STOP BANDWIDTHS ARE CALCULATED AND DISCUSSED. TUNE DIAGRAMS FOR THE STRUCTURE RESONANCES ARE INCLUDED.

I. INTRODUCTION

We have studied the nonlinear effects on the Dynamical systems with the emphasis on nonlinear resonances. Some of our results were incorporated into a program "NONLIN" that we have used to study resonances of the AGS - Booster [1]. In this paper we present some of our findings (e.g. the structure resonances) for the standard booster lattice with split tunes and another (alternate) lattice with short and long straight sections and periodicity of 8 (also with the split tunes). We also give the results of our analysis for these lattices in comparison to the standard booster lattice [2,3] with operating tunes of $Qx = 4.82$ and $Qy = 4.83$. Resonances are crossed at injection because of the space charge tune shifts. The stop bandwidths were calculated using the program HARMON (through program MAD403 [4]). The resonances crossed due to the space charge tune shift are shown in Figures 1 and 2 for the above lattices.

SECTION II

The structure resonances for three alternate booster lattices are investigated. In this note, the stop bandwidths were obtained using HARMON [4]. These stop bandwidth calculations assume that we are close to the resonance in question but far from all the others. The results of our studies of the resonances in other alternate AGS - booster lattices are given elsewhere [1,5,6].

The method used to calculate stop bandwidths in HARMON are given in detail by Guignard [7]. The perturbing part of the Hamiltonian near a given resonance can be expressed as:

$$G = f(r1,r2) + g(r1,r2) \cos \psi \qquad (1)$$

where r1 and r2 are the actions (proportional to the square root of the emittance) and conjugate phase ψ. As long as the contribution of the other resonances are small in the Hamiltonian (G) then the Eq.(1) is an approximate invariant. The stop bandwidths are defined as the limit at which the "emittances" r1 and r2 cannot grow without bounds.

The lattices includes the eddy current sextupoles and chromaticity correcting sextupoles [2]. The stop bandwidths are calculated with the lattices tuned (to the betatron tunes) close to the resonances in question. The stop bandwidths for these lattices are calculated and discussed in the following sections.

SECTION III

We investigate the standard lattice with split tunes for passing through resonances due to space charge tune shifts. The lattice is the standard AGS - Booster lattice but with tunes at Qx = 4.82 and Qy = 3.83 and also Qx = 3.82 and Qy = 4.83. The possible resonances crossed (see Fig. 1) due to space charge tune shifts are Qx + 2Qy = 12, 4Qx = 18, 2Qy = 6, 3Qx = 12 and 4Qy = 12 for the former case and 4Qy = 18, Qx + 2Qy = 12, 2Qx = 6 and 4Qx = 12 for the latter choice of tunes. The stop bandwidths for each of these resonances along with the orbit parameters are given in Tables I and II for the two choices of split tunes in question.

We find that the stop bandwidth for the second order resonance in both cases is extremely large. This suggests that the split tune configuation may be more troublesome than the original choice of tunes of Qx = 4.82 and Qy = 4.83.

SECTION IV

In this section we have analyzed a separate function lattice with (a higher) periodicity of 8 and with short and long straight sections [8].

The operating tunes are split as Qx = 4.82 and Qy = 5.83. The resonances that we investigated are Qx + 2Qy = 16, 2Qx =8 and 4Qx = 16 (see Fig. 2). Our results are given in Tables III . Here as with the above split tune lattices (Section III) the second order resonance proves to be very strong. Furthermore, the third order resonance will be very difficult to cross (i.e.to tune out).

V. CONCLUSION

The three alternate lattices investigated here have a strong second order resonances near the point where the space charge can shift the tune. From the comparison of these resonances with those of the standard booster lattice [5,6] given in Tables IV, we conclude that tuning out the fourth order resonances in the standard booster lattice (at tune Qx = 4.82 and Qy = 4.83) is a better choice than the others considered here (see Figs.1,2). These resonances could possibly be tuned out using a larger family of sextupoles and/ or octupoles.

REFERENCES:
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4. M. Donald, D. Schofield, a Users Guide to the Harmon Program' LEP Note 420 (1982); M. Donald private communication (May 1986); using [PARSA1.MAD]MAD403.EXE.

5. Z. Parsa, S. Tepikian, Alternate AGS - Booster Lattices, Booster Tech. Note No. 32 (May 1986)

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8. E. Courant, Private communication.

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[In the followng tables COS, SIN and MODULUS are the resonance strengths, and DE(S), DQ(S) and DQ20(S) are the stop bandwidths. Where "S" means Systemmatic and "R" means Random].

TABLE IA

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT OPERATING TUNES (Qx = 4.82, Qy = 3.83)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 4.819999	QY	= 3.830001
QX'	= -0.000004	QY'	= -0.000008
ALFA	= 0.416074E-01	GAMMA(TR)	= 4.902470
BETAX	= 3.80934E+00	BETAY	= 1.51943E+01
ETAX	= 5.71156E-01		
BETAX(MAX)	= 13.284572	BETAY(MAX)	= 15.364436
DX(MAX)	= 2.757794	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SXF	5.15764E-02
SXD	-7.48396E-01
SXV	1.35000E-01

Q SHIFT EFFECTS [PERTURBATION OF TUNES]

G22000		DQXDEX	DQX
4.93770E+00	3.69541E-16	9.87540E+00	6.74490E-04
G00220		DQYDEY	DQY
5.74386E+01	2.06207E-15	1.14877E+02	7.84612E-03
G11110		DQXDEY	DQYDEX
-4.41655E+01	5.48864E-15	-4.41655E+01	-4.41655E+01

DQX	DQY
-3.01650E-03	-3.01650E-03

TABLE IB

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 4.501, Qy = 3.511)

SEPARATED FUCTION AGS-BOOSTER LATTICE NSUP = 6
DELTA(P)/P = 0.000000

TOTAL LENGTH = 201.780000

QX	= 4.500821	QY	= 3.510902
QX'	= 1.568697	QY'	= -0.213745
ALFA	= 0.487108E-01	GAMMA(TR)	= 4.530929
BETAX	= 4.21684E+00	BETAY	= 1.56740E+01
ETAX	= 8.66694E-01		
BETAX(MAX)	=13.363965	BETAY(MAX)	= 15.936994
DX(MAX)	= 2.785418	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SXF	5.15764E-02
SXD	-7.48396E-01
SXV	1.35000E-01

Q SHIFT EFFECTS [PERTURBATION OF TUNES]

G22000		DQXDEX	DQX
3.57222E+00	3.98153E-16	7.14443E+00	4.87965E-04
G00220		DQYDEY	DQY
5.58769E+01	1.04727E-15	1.11754E+02	7.63278E-03
G11110		DQXDEY	DQYDEX
-2.90430E+01	-4.11767E-15	-2.90430E+01	-2.90430E+01

DQX	DQY
-1.98364E-03	-1.98364E-03

TABLE IC

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURTH ORDER EFFECTS OF SETUPOLES [RESONANCE EFFECTS]

4Qx = 18

COSINE	SINE	MODULUS	RANDOM	DE(S)
-1.1265E-01	7.3267E-02	1.3438E-01	1.9692E-01	3.5452E-04

DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
5.1953E-04	8.8630E-05	1.2988E-04	1.2822E-04	1.8790E-04

TABLE ID

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 4.01, Qy = 3.02)

SEPARATED FUCTION AGS-BOOSTER LATTICE NSUP = 6
DELTA(P)/P = 0.000000

TOTAL LENGTH = 201.780000

QX	= 4.009842	QY	= 3.019958
QX'	= 3.970762	QY'	= -0.259775
ALFA	= 0.621845E-01	GAMMA(TR)	= 4.010134
BETAX = 4.94361E+00		BETAY	= 1.44310E+01
ETAX = 1.34289E+00			
BETAX(MAX)	= 13.819729	BETAY(MAX)	= 20.627309
DX(MAX)	= 3.045880	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SXF	5.15764E-02
SXD	-7.48396E-01
SXV	1.35000E-01

Q SHIFT EFFECTS [FOURTH ORDER EFFECTS OF SEXTUPOLES]

G22000		DQXDEX	DQX
-5.39073E+00	2.39243E-15	-1.07815E+01	-7.36374E-04
G00220		DQYDEY	DQY
5.40201E+01	-9.14974E-16	1.08040E+02	7.37915E-03
G11110		DQXDEY	DQYDEX
-5.77895E+01	4.13282E-16	-5.77895E+01	-5.77895E+01

DQX	DQY
-3.94702E-03	-3.94702E-03

TABLE IE

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

SECOND ORDER EFFECTS OF SEXTUPOLES [RESONANCE EFFECTS]
2Qy = 6

COSINE	SINE	MODULUS	RANDOM	DE(S)
3.7943E+00	-2.2381E+00	4.4052E+00	3.5156E+00	1.7621E+01
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
1.4062E+01	8.8105E+00	7.0311E+00	8.8105E+00	7.0311E+00

FOURIER ANALYSIS. ORDER OF RESONANCE =3
3Qx = 12

COSINE	SINE	MODULUS	RANDOM	DE(S)
1.4996E-01	-6.2946E-02	1.6263E-01	6.6932E-01	2.4193E-02
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
9.9568E-02	8.0643E-03	3.3189E-02	1.6666E-02	6.8591E-02

FOURIER ANALYSIS. ORDER OF RESONANCE = 4
4Qy = 12

COSINE	SINE	MODULUS	RANDOM	DE(S)
-3.4003E-01	-1.8945E-01	3.8924E-01	1.2352E+00	1.0269E-03
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
3.2587E-03	2.5673E-04	8.1468E-04	3.7142E-04	1.1786E-03

TABLE IF

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 4.67, QY = 3.68)

SEPARATED FUCTION AGS-BOOSTER LATTICE NSUP = 6
DELTA(P)/P = 0.000000

TOTAL LENGTH = 201.780000

QX	= 4.669806	QY	= 3.680207
QX'	= 0.750768	QY'	= -0.135290
ALFA	= 0.448424E-01	GAMMA(TR)	= 4.722324
BETAX	= 3.99415E+00	BETAY	= 1.54051E+01
ETAX	= 7.12403E-01		
BETAX(MAX)	= 13.302322	BETAY(MAX)	= 15.607883
DX(MAX)	= 2.754428	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SXF	5.15764E-02
SXD	-7.48396E-01
SXV	1.35000E-01

Q SHIFT EFFECTS [FOURTH ORDER EFFECTS OF SEXTUPOLES]

G22000		DQXDEX	DQX
4.21477E+00	4.39129E-16	8.42954E+00	5.75737E-04
G00220		DQYDEY	DQY
2.47824E+01	1.68949E-14	4.95648E+01	3.38528E-03
G11110		DQXDEY	DQYDEX
-1.61819E+02	7.21102E-14	-1.61819E+02	-1.61819E+02

DQX	DQY
-1.10522E-02	-1.10522E-02

TABLE IG

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURIER ANALYSIS. ORDER OF RESONANCE = 3

Qx+2Qy=12

COSINE	SINE	MODULUS	RANDOM	DE(S)
9.7275E-01	-3.4598E-02	9.7337E-01	3.3420E+00	8.0443E-02
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
2.7619E-01	3.5975E-02	1.2352E-01	7.4349E-02	2.5527E-01

TABLE IIA

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT OPERATING TUNES (Qx = 3.82, Qy = 4.83)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 3.819998	QY	= 4.830000
QX'	= -0.000004	QY'	= -0.000006
ALFA	= 0.707480E-01	GAMMA(TR)	= 3.759611
BETAX	= 4.62031E+00	BETAY	= 1.28928E+01
ETAX	= 1.49867E+00		
BETAX(MAX)	= 16.047983	BETAY(MAX)	= 12.940117
DX(MAX)	= 3.459309	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SXF	-1.93739E-01
SXD	-6.82097E-01
SXV	1.35000E-01

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS [PERTURBATION OF TUNES]

G22000		DQXDEX	DQX
3.49180E+00	2.22445E-16	6.98360E+00	4.76980E-04
G00220	DQYDEY	DQY	
-3.32647E+01	1.15672E-15	-6.65294E+01	-4.54396E-03
G11110		DQXDEY	DQYDEX
2.00599E+02	5.90557E-15	2.00599E+02	2.00599E+02
		DQX	DQY
		1.37009E-02	1.37009E-02

TABLE IIB

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 3.501, QY = 4.502)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 3.500878	QY	= 4.502188
QX'	= 0.965781	QY'	= 0.934611
ALFA	= 0.841653E-01	GAMMA(TR)	= 3.446939
BRTAX	= 4.96124E+00	BETAY	= 1.29891E+01
ETAX	= 1.90161E+00		
BETAX(MAX)	= 17.195597	BETAY(MAX)	= 13.041884
DX(MAX)	= 3.854957	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SXF	-1.93739E-01
SXD	-6.82097E-01
SXV	1.35000E-01

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS [PERTURBATION OF TUNES]

G22000		DQXDEX	DQX
3.50514E+00	2.86906E-16	7.01028E+00	4.78802E-04
G00220		DQYDEY	DQY
-2.57585E+00	1.71454E-15	-5.15171E+00	-3.51862E-04
G11110		DQXDEY	DQYDEX
6.01745E+01	7.35472E-15	6.01745E+01	6.01745E+01
		DQX	DQY
		4.10992E-03	4.10992E-03

TABLE IIC

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURTH ORDER EFFECTS OF SEXTUPOLES [RESONANCE EFFECTS]
4Qy=18

COSINE	SINE	MODULUS	RANDOM	DE(S)
4.7689E-01	4.0294E-01	6.2432E-01	5.5601E-01	1.6471E-03
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
1.4669E-03	4.1178E-04	3.6672E-04	5.9574E-04	5.3055E-04

TABLE IID

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 3.01, QY = 4.02)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 3.010151	QY	= 4.020158
QX'	= 6.037958	QY'	= 2.576143
ALFA	= 0.109313E+00	GAMMA(TR)	= 3.024576
BETAX	= 1.22766E+00	BETAY	= 1.33334E+01
ETAX	= 2.64756E+00		
BETAX(MAX)	=211.310990	BETAY(MAX)	= 13.401659
DX(MAX)	= 4.656692	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SXF	-1.93739E-01
SXD	-6.82097E-01
SXV	1.35000E-01

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS

G22000	DQXDEX	DQX
5.34555E+02 4.37152E-13	1.06911E+03	7.30202E-02
G00220	DQYDEY	DQY
6.28613E+00 -3.62599E-15	1.25723E+01	8.58686E-04
G11110	DQXDEY	DQYDEX
1.09986E+02 -4.07215E-14	1.09986E+02	1.09986E+02
	DQX	DQY
	7.51201E-03	7.51201E-03

TABLE IIE

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURIER ANALYSIS. ORDER OF RESONANCE = 2

2QX = 6

COSINE	SINE	MODULUS	RANDOM	DE(S)
1.2479E+00	7.7481E-01	1.4689E+00	1.7635E+01	5.8755E+00
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
7.0539E+01	2.9378E+00	3.5269E+01	2.9378E+00	3.5269E+01

FOURIER ANALYSIS. ORDER OF RESONANCE = 4

4QX = 12

COSINE	SINE	MODULUS	RANDOM	DE(S)
-1.8352E+01	-1.0566E+01	2.1176E+01	4.3150E+01	5.5869E-02
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
1.1384E-01	1.3967E-02	2.8460E-02	2.0207E-02	4.1175E-02

TABLE IIF

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 3.33, QY = 4.34)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 3.329820	QY	= 4.339808
QX'	= 1.489621	QY'	= 1.496112
ALFA	= 0.928495E-01	GAMMA(TR)	= 3.281786
BETAX	= 4.94754E+00	BETAY	= 1.30637E+01
ETAX	= 2.15777E+00		
BETAX(MAX)	= 18.772303	BETAY(MAX)	= 13.119966
DX(MAX)	= 4.128330	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SXF	-1.93739E-01
SXD	-6.82097E-01
SXV	1.35000E-01

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS

G22000		DQXDEX	DQX
3.97356E+00	2.43621E-16	7.94712E+00	5.42788E-04
G00220		DQYDEY	DQY
-7.80774E+01	8.18510E-14	-1.56155E+02	-1.06654E-02
G11110		DQXDEY	DQYDEX
-2.70047E+02	3.26858E-13	-2.70047E+02	-2.70047E+02

DQX	DQY
-1.84442E-02	-1.84442E-02

TABLE IIG

STANDARD AGS - BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

THIRD ORDER EFFECTS OF SEXTUPOLES [RESONANCE EFFECTS]
FOURIER ANALYSIS. ORDER OF RESONANCE = 3

QX+2QY=12

COSINE	SINE	MODULUS	RANDOM	DE(S)
8.5277E-01	1.6930E-01	8.6941E-01	3.2858E+00	7.1851E-02
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
2.7155E-01	3.2133E-02	1.2144E-01	6.6408E-02	2.5098E-01

TABLE IIIA

ALTERNATE BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS (WITH SHORT AND LONG STRAIGHT SECTS.) AT OPERATING TUNES (Qx = 4.82, Qy = 5.83)

TOTAL LENGTH = 201.780000 NSUP = 8

QX	= 4.820000	QY	= 5.830000
QX'	= 0.000000	QY'	= 0.000000
ALFA	= 0.434514E-01	GAMMA(TR)	= 4.797314
BETAX = 3.71783E+00		BETAY = 1.26347E+01	
ETAX = 1.22212E+00			
BETAX(MAX) = 14.845045		BETAY(MAX) = 13.056088	
DX(MAX)	= 2.442651	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SF	2.80984E-01
SD	-1.57786E+00
SV	4.46595E-02

FOURTH ORDER EFFECTS OF SEXTUPOLES

Q SHIFT EFFECTS

G22000		DQXDEX	DQX
1.34370E+01	4.43651E-01	2.68740E+01	1.83549E-03
G00220		DQYDEY	DQY
-8.69426E+01	4.40566E-01	-1.73885E+02	-1.18764E-02
G11110		DQXDEY	DQYDEX
-2.46908E+02	5.87421E-01	-2.46908E+02	-2.46908E+02
		DQX	DQY
		-1.68638E-02	-1.68638E-02

TABLE IIIB

ALTERNATE BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS (WITH SHORT AND LONG STRAIGHT SECTS.)
AT TUNES NEAR RESONANCE (Qx = 4.67, QY = 5.68)

TOTAL LENGTH = 201.780000 NSUP = 6

QX	= 4.669727	QY	= 5.679805
QX'	= 0.482878	QY'	= 0.560711
ALFA	= 0.463236E-01	GAMMA(TR)	= 4.646210
BETAX	= 3.93919E+00	BETAY	= 1.25606E+01
ETAX	= 1.29773E+00		
BETAX(MAX)	= 15.138198	BETAY(MAX)	= 12.968586
DX(MAX)	= 2.522402	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SF	2.80984E-01
SD	-1.57786E+00
SV	4.46595E-02

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS

G22000		DQXDEX	DQX
1.22198E+01	4.71219E-01	2.44396E+01	1.66922E-03
G00220		DQYDEY	DQY
-1.55413E+03	4.64310E-01	-3.10827E+03	-2.12295E-01
G11110		DQXDEY	DQYDEX
-6.13724E+03	6.19081E-01	-6.13724E+03	-6.13724E+03

DQX	DQY
-4.19174E-01	-4.19174E-01

TABLE IIIC

ALTERNATE BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS (WITH SHORT AND LONG STRAIGHT SECTS.)
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

THIRD ORDER EFFECTS OF SEXTUPOLES [RESONANCE EFFECTS]
FOURIER ANALYSIS. ORDER OF RESONANCE = 3

Qx+2Qy=16.

COSINE	SINE	MODULUS	RANDOM	DE(S)
-6.7492E+00	-4.5363E-01	6.7644E+00	4.2806E+00	5.5904E-01
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
3.5376E-01	2.5001E-01	1.5821E-01	5.1669E-01	3.2696E-01

TABLE IIID

ALTERNATE BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS (WITH SHORT AND LONG STRAIGHT SECTS.)
AT TUNES NEAR RESONANCE (Qx = 4.01, QY = 5.02)

TOTAL LENGTH = 201.780000 NSUP = 8

QX	= 4.009912	QY	= 5.020079
QX'	=-13.657917	QY'	= 3.139946
ALFA	= 0.615457E-01	GAMMA(TR)	= 4.030893
BETAX	= 3.85585E+01	BETAY	= 1.24667E+01
ETAX	= 1.70938E+00		
BETAX(MAX)	=158.546396	BETAY(MAX)	= 12.822298
DX(MAX)	= 2.987292	DY(MAX)	= 0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SF	2.80984E-01
SD	-1.57786E+00
SV	4.46595E-02

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS

G22000		DQXDEX	DQX
7.49421E+02	1.71222E+02	1.49884E+03	1.02371E-01
G00220		DQYDEY	DQY
3.78625E+01	2.98517E+00	7.57249E+01	5.17201E-03
G11110		DQXDEY	DQYDEX
1.27683E+03	3.98023E+00	1.27683E+03	1.27683E+03

DQX	DQY
8.72077E-02	8.72077E-02

TABLE IIIE

ALTERNATE BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS (WITH SHORT AND LONG STRAIGHT SECTS.)
DELTA(P)/P = 0.000000 [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURIER ANALYSIS. ORDER OF RESONANCE = 2

2Qx = 8.

COSINE	SINE	MODULUS	RANDOM	DE(S)
-1.7393E+00	-1.6306E+00	2.3842E+00	1.3676E+01	9.5366E+00
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
5.4704E+01	4.7683E+00	2.7352E+01	4.7683E+00	2.7352E+01

FOURIER ANALYSIS. ORDER OF RESONANCE = 4

4Qx = 16.

COSINE	SINE	MODULUS	RANDOM	DE(S)
4.9350E+00	-4.8135E+00	6.8937E+00	1.1397E+01	1.8187E-02
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
3.0069E-02	4.5469E-03	7.5171E-03	6.5781E-03	1.0875E-02

TABLE IVA

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT OPERATING TUNES (Qx = 4.82, Qy = 4.83)

SEPARATED FUNCTION AGS-BOOSTER LATTICE
DELTA(P)/P = 0.000000

TOTAL LENGTH =	201.780000	NSUP =	6
QX =	4.819999	QY =	4.829999
QX' =	-0.000004	QY' =	-0.000009
ALFA =	0.422563E-01	GAMMA(TR) =	4.864680
ETAX =	5.61040E-01		
BETAX(MAX) =	14.081628	BETAY(MAX) =	13.699223
DX(MAX) =	2.864031	DY(MAX) =	0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SXF	5.90305E-02
SXD	-8.04138E-01
SXV	1.35000E-01

FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS

G22000		DQXDEX	DQX
5.45504E+00	6.00591E-16	1.09101E+01	7.45158E-04
G00220		DQYDEY	DQY
4.33051E+01	1.25521E-16	8.66101E+01	5.91547E-03
G11110		DQXDEY	DQYDEX
-8.06082E-01	1.55576E-15	-8.06082E-01	-8.06082E-01

DQX	DQY
-5.50554E-05	-5.50554E-05

TABLE IVB

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
AT TUNES NEAR RESONANCE (Qx = 4.01, Qy = 4.11)

SEPARATED FUNCTION AGS-BOOSTER LATTICE
DELTA(P)/P = 0.000000

TOTAL LENGTH =	201.780000	NSUP =	6
QX =	4.010087	QY =	4.110047
QX' =	4.380868	QY' =	0.364414
ALFA =	0.631572E-01	GAMMA(TR) =	3.979134
BETAX(MAX) =	14.766930	BETAY(MAX) =	14.019838
BETAX =	4.62840E+00	BETAY =	1.39299E+01
		ETAX =	1.31580E+00
DX(MAX) =	3.169083	DY(MAX) =	0.000000

NORMALIZED STRENGTHS

ID	STRENGTH
SXF	5.90305E-02
SXD	-8.04138E-01
SXV	1.35000E-01

Q SHIFT EFFECTS

G22000		DQXDEX	DQX
-4.56809E+00	6.12823E-16	-9.13617E+00	-6.24001E-04
G00220		DQYDEY	DQY
2.80864E+01	2.85772E-15	5.61727E+01	3.83660E-03
G11110		DQXDEY	DQYDEX
-2.14197E+01	1.42251E-14	-2.14197E+01	-2.14197E+01
		DQX	DQY
		-1.46296E-03	-1.46296E-03

TABLE IVC

STANDARD AGS - BOOSTER WITH CHROMATICITY SEXTUPOLES AND EDDY CURRENTS
DELTA(P)/P= 0.000000 [EX0 =6.8300E-05 EY0 =6.8300E-05]

THIRD ORDER EFFECTS OF SEXTUPOLES [RESONANCE EFFECTS]

3Qx = 12

COSINE	SINE	MODULUS	RANDOM	DE(S)
1.3100E-01	-7.6377E-02	1.5164E-01	6.9477E-01	2.2558E-02

DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
1.0335E-01	7.5193E-03	3.4451E-02	1.5540E-02	7.1199E-02

Qx + 2Qy = 12

COSINE	SINE	MODULUS	RANDOM	DE(S)
9.2324E-01	1.0306E-02	9.2329E-01	3.5080E+00	7.6304E-02

DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
2.8992E-01	3.4124E-02	1.2965E-01	7.0524E-02	2.6795E-01

Table IVD

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS
PARAMETERS AT START OF LATTICE

TOTAL LENGTH = 201.780000 NSUP = 6

QX = 4.501049 QY = 4.5109
QX'= 1.699386 QY'= 0.010820

ALFA = 0.494546E-01 GAMMA(TR) = 4.496729
BETAX = 3.98217E+00 BETAY = 1.37381E+01
ETAX = 8.51585E-01
BETAX(MAX) = 14.176944 BETAY(MAX) = 13.812846
DX(MAX) = 2.890904 DY(MAX)= 0.000000

NORMALIZED STRENGTHS [m^{-2}]

ID	STRENGTH
SFCH	5.90305E-02
SDCH	-8.04138E-01
SFED	1.35000E-01

Q SHIFT EFFECTS [PERTURBATION OF TUNES]

G22000	DQXDEX	DQX
3.76592E+00 -8.91030E-17	7.53183E+00	5.14424E-04

G00220	DQYDEY	DQY
3.74536E+01 3.32694E-16	7.49072E+01	5.11616E-03

G11110	DQXDEY	DQYDEX
-5.44314E+00 1.24852E-15	-5.44314E+00	-5.44314E+00

DQX	DQY
-3.71766E-04	-3.71766E-04

Table IVE

AGS BOOSTER LATTICE WITH CHROMATICITY SEXTUPOLES
AND EDDY CURRENTS | [EX0 = 6.8300E-05 EY0 = 6.8300E-05]

FOURTH ORDER EFFECTS OF SEXTUPOLES
RESONANCE EFFECTS, DELTA(P)/P = 0.000000

COS	SIN	DE	DQ	DQ(20)
4Qx = 18				
1.3792E+00	-1.0106E+00	1.8685E-03	1.1277E-03	1.6315E-03
4Qy = 18				
3.4649E+00	-8.1212E-01	3.8891E-03	2.3473E-03	3.3959E-03
2Qx+2Qy=18				
1.1083E+01	-2.7383E+00	6.2380E-03	5.3245E-03	7.7031E-03
2Qx-2Qy= 0				
-3.7045E+01	3.0767E+00	3.7173E+01		

FOURIER ANALYSIS. ORDER OF RESONANCE

4Qx = 18

COSINE	SINE	MODULUS	RANDOM	DE(S)
-1.4047E-01	7.4337E-02	1.5893E-01	2.1098E-01	4.1929E-04
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
5.5663E-04	1.0482E-04	1.3916E-04	1.5165E-04	2.0132E-04

2Qx+2Qy=18

COSINE	SINE	MODULUS	RANDOM	DE(S)
8.6603E-01	1.0192E+00	1.3375E+00	1.7686E+00	1.7643E-03
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
2.3330E-03	6.2378E-04	8.2483E-04	9.0245E-04	1.1933E-03

4Qy = 18

COSINE	SINE	MODULUS	RANDOM	DE(S)
5.9395E-01	5.4899E-01	8.0881E-01	7.1490E-01	2.1338E-03
DE(R)	DQ(S)	DQ(R)	DQ20(S)	DQ20(R)
1.8861E-03	5.3346E-04	4.7152E-04	7.7177E-04	6.8217E-04

2Qx-2Qy= 0

COSINE	SINE	MODULUS	RANDOM
1.8614E-01	0.0000E+00	1.8614E-01	1.7686E+00

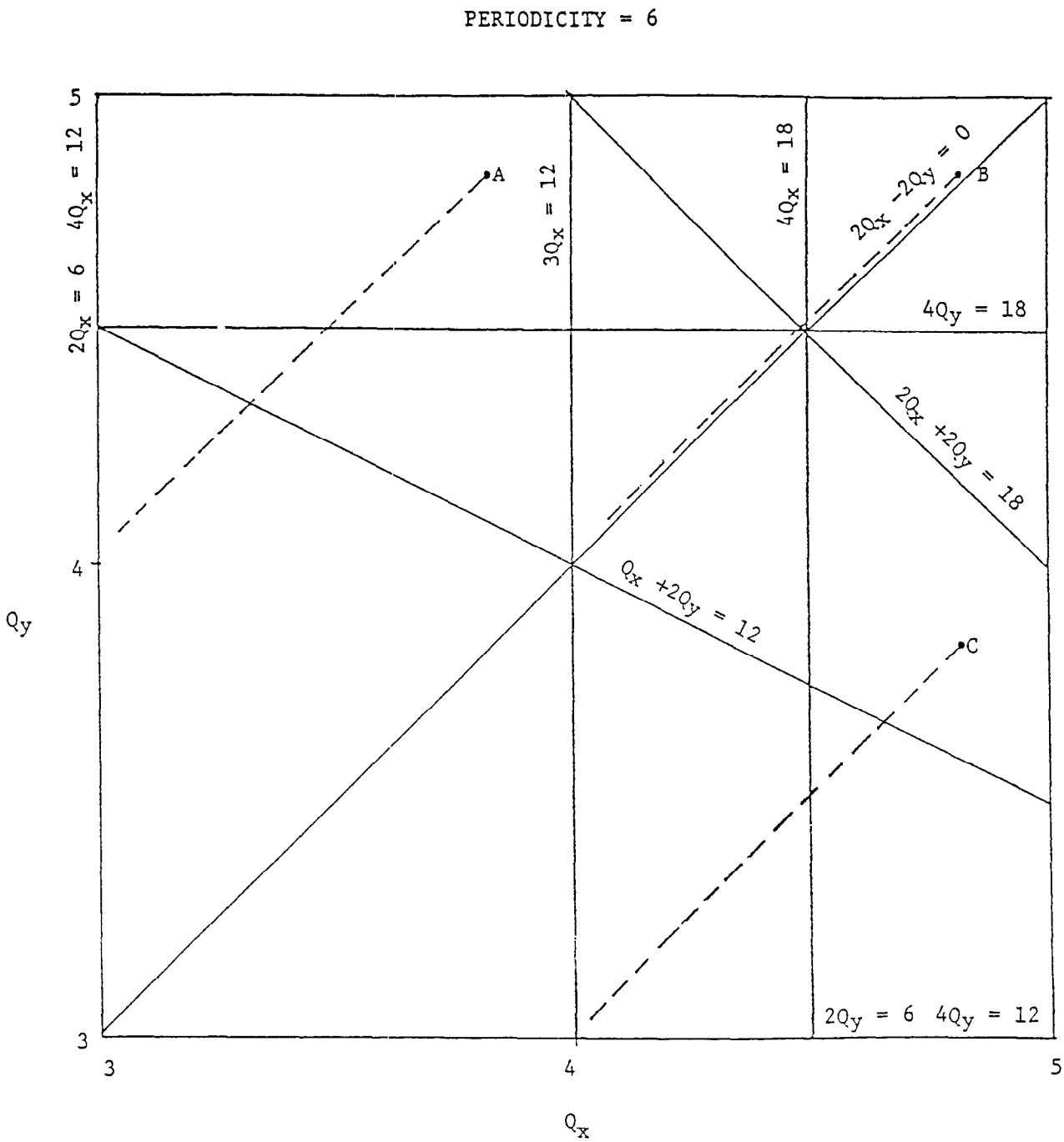

Fig. 1 The standard AGS - Booster lattice at three different operating points: C = (4.82,3.83), B = (4.82,4.83) and A = (3.82,4.83). The dotted lines give the tune shift due to space charge.

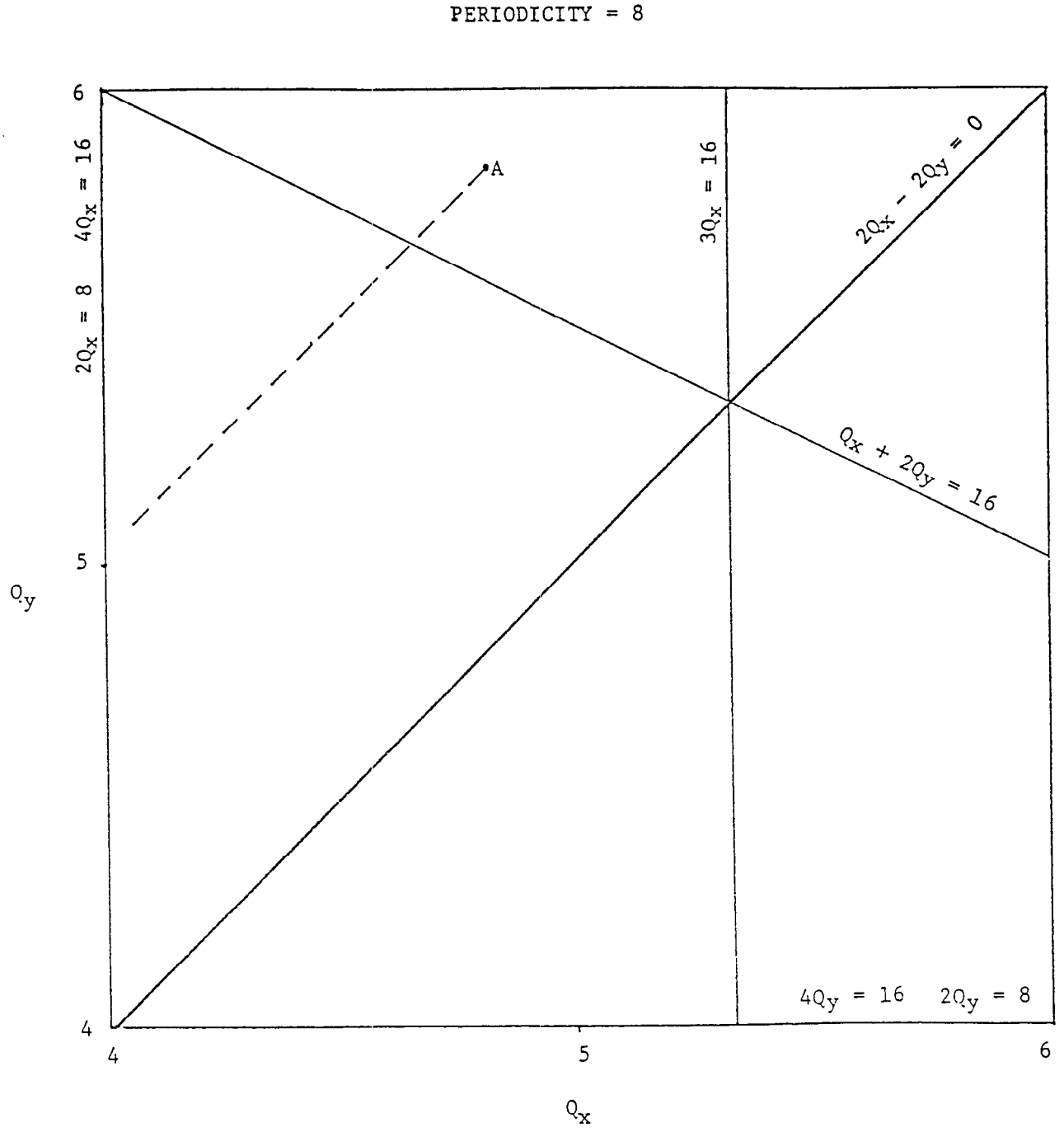

Fig. 2 Tune diagram for the 8 peridicity lattice with long and short straight sections. The point A is the operating tunes of Qx = 4.82 and Qy = 5.83. The tune shift due to space charge is shown in the dotted line.