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The Booster Lattice with Enlarged Q5 and 1,2,4,7 Sextupole Configuration

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DISCLAIMER

THE BOOSTER LATTICE

with

ENLARGED Q5

&

1,2,4,7 SEXTUPOLE CONFIGURATION

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ABSTRACT

THIS PAPER DESCRIBES THE AGS - BOOSTER LATTICE WITH THE CHROMATICITY CORRECTION SEXTUPOLES 1,2,4,7 CONFIGURATION AND MODIFICATIONS OF THE INCREASE IN Q5 APPERTURE (LONGER AND WIDER THAN OTHERS BY 40%). RESULTS OBTAINED FROM THE SYNCHROTRON DESIGN PROGRAM SYNCH AND A SCHEMATIC LAYOUT OF THE LATTICE ARE ALSO INCLUDED.

I. INTRODUCTION:

The AGS Booster is designed to be an intermediate synchrotron injector for the AGS, capable of accelerating protons from 200 MeV, the Linac operating energy to 1 GeV, (with the possibility of an upgrade to 2.5 GeV), at 10 Hz repetition rate and Heavy Ions to magnetic rigidity equal to 16.7 Tesla-Meter at a 1 Hz repetition rate.

As presently designed, the Booster will have:[ref.1] A circumference equal to one quarter that of AGS; with six identical superperiods; it will have a FODO lattice with bending magnets missing in some cells in order to accomodate the space needed for RF acceleration, injection, ejection and abort system without otherwise interupting the periodicity; the dipoles of the proposed lattice have an aperture of 3.25" x 10" and injection field of about 1.6 kG (.7 kG for Heavy Ions) [Ref.1].

In total, the Booster will have 36 dipoles, each of 2.4 meter magnetic length, and 48 quadrupoles 42 of which (each) have 0.50375 meter magnetic length, while 6 of which (Q5) have 0.7 magnetic length and increased bore to allow for injection without reducing the Booster aperture. We have chosen a "separated function" structure with quadrupoles and zero-gradient dipoles. Furthermore, for maximum tuning versatility the dipoles and the quadrupoles will be independently powered; the effect of the chromaticity correcting sextupole configuration 1,2,4,7 is given in section III and amplitude (BETAX, BETAY) and dispersion functions of the lattice obtained from our SYNCH run are shown in Figure 3. Booster coordinates and parameter list are given in references 2 and 3 respectively.

This specific lattice structure consists of six identical superperiods, designated A to F, with each superperiod containing:

two full cells with bending magnets;
one empty half cell [bending magnet omitted];
two full cells;
one empty half cell;
two full cells;

as shown in Figure 2.

There is also a one meter free space on one side of each quadrupole which can be utilized for chromaticity - correcting sextupoles and other correcting and monitoring devices. The choice of sextupole layouts [Ref.6] will be discussed in sect. III.

II. SUPERPERIOD STRUCTURE

The AGS-Booster lattice has six superperiods, with the structure formula written symbolically for a complete superperiod as

$$S = D\ b\ F\ b\ D\ n\ F\ b\ D\ b\ F^{*}\ n\ D\ b\ F\ b$$

where the components of the superperiod are the following:

D - Defocusing quadrupoles (0.50375 meters)

F - Focusing quadrupoles (0.50375 meters)

F^{*} - Q5 Focusing quadrupoles (0.7 meters)

O - Drift space (1 meter)

o - Drift space (.3 meters)

N - Drift space (2.4 meters), [section with no magnet]

B - Dipole (bending) magnet (2.4 meters)

b - oBO

n - oNO Drift space (3.7 meters)

Figure 1 shows the overall layout of the Booster ring including the locations and directions of proton (p) injection (at C6), Heavy Ion (H. I.) injection (at A3) and beam extraction (at F6). In addition, we have shown the global labeling of the lattice divided into six superperiods (with the clockwise Beam direction) starting from the AF junction which is located 0.161764 radians South of East with respect to the center of the Booster.

A schematic diagram of the lattice and components of the superperiod are illustrated in Figure 2. There the Focusing Quadrupoles (QF), Defocusing Quadrupoles (QD), Bending Magnets (Dipoles), and two families of sextupoles (X) SF (Focusing) and SD (Defocusing) are shown.

SECTION III

This section describes the effect of the chromaticity correcting sextupoles 1,2,4,7 configuration selected for the AGS-Booster. We have chosen two families of sextupoles, located at 1,7 (SF), 2,4 (SD) per superperiod. Therefore the total number of sextupoles for the AGS-Booster is 24 (12 SF+12 SD); each of 10 cm length; with aperture of 16.52 cm. We note that, at 1 GeV with integrated strength of 1.761 [T/m]; the injection pole tip fields for protons (including polarized protons) is 0.45761 [kG], and for Heavy Ions is 0.03065 A/Q. The ejection pole tip field for protons (including polarized protons) is 1.2015 [kG], and for heavy ions is 3.5504 [kG] respectively.

Following tables give the summary of the parameters obtained for the AGS - Booster from program "SYNCH" [Ref.4] with proton injection at 200 MeV, (BRHO= 2.14962 T-M and B = .156325 T), betatron tune QX = 4.82, QY = 4.83, and the Booster Circumference = 201.78 m . Tables I, II, III and IV shows the betatron functions and the amplitude dependence of tunes for eddy current sextupoles and correction sextupole configuration 1,2,4,7 for DP/P = -0.005, 0, and +0.005 respectively.

We note that Eddy Current sextupole strengths are taken to be 0.12 Tesla per meter square [Ref.5]; and in cases II-IV, chromaticity correction sextupoles are added (to Eddy Current sextupoles) to make the overall chromaticity zero. Alternate sextupole configurations were studied but the 1,2,4,7 configurations was selected since it exhibits reasonably small amplitude dependence of tunes, and sextupole strength; also accommodates the space required for the injection and ejection; (although we will continue with our studies of other sextupole configurations which may become more suitable for the Booster) [Ref. 6, 7].

References:

1. The Booster Lattice, Booster Tech. Note No. 1, E. Courant, Z. Parsa, (January 15, 1986).

2. Booster Coordinates, Booster Tech. Note No. 6, Z. Parsa, (January 28,1986).

3. Booster Parameter List, Booster Tech. Note No. 25, Z. Parsa, (April 17, 1986).

4. usig BNLDAG::DUA0:[PARSA1.BOOSTER]SYNBOOST26.DAT as input. We obtained similar results using program MAD403 with [PARSA1.BOOSTER]MADBOOST.DAT as input).

5. Calculation of Eddy Currents, Booster Tech. Note No. 4, G. Morgan and S. Kahn, (January 1986).

6. Chromaticity Correction for the AGS Booster with 1,2,4,7 Sextupole Configuration, E. Courant and Z. Parsa, (March 5, 1986)

7. Evaluation of the Chromaticity Sextupoles for the AGS Booster, Booster Tech. Note No. 23, J. Kats, (March 20, 1986)

TABLE I

NO CHROMATICITY SEXTUPOLE
[EDDY CURRENT SEXTUPOLES +.12 TM2 @ PROTON INJECTYION]

CIRCUMFERENCE = 201.7800 M
RADIUS = 32.1143 M

THETY = 0.00000000 RAD NUY = 4.83000
THETX = 6.28319424 RAD NUX = 4.82000

DNUX/(DP/P) = 4.15001 (DS/S)/(DP/P)= .0422564
DNUY/(DP/P) = -13.20929 TGAM=(4.86467, 0.00000)

MAXIMA

BETX(21) = 14.08163 BETY(30) = 13.69922
XEQ(37) = 2.86404 YEQ(56) = 0.00000

MINIMA

BETX(18) = 3.54452 BETY(9) = 3.67807
XEQ(1) = .56104 YEQ(56) = 0.00000

SEXTUPOLE CORRECTIONS

DKSF = .59030476E-01 DKSD = -.80413799E+00
KSF = .59030476E-01 KSD = -.80413799E+00

AMPLITUDE DEPENDENCE OF TUNES DUE TO SEXTUPOLES

NU-X = 4.820000 - .226E+02EX + .113E+02EY
NU-Y = 4.829999 + .113E+02EX - .189E+02EY

TABLE II

CHROMATICITY SEXTUPOLES AT 1,2,4,7 FOR DP/P = -.00500

CIRCUMFERENCE = 201.7374 M
RADIUS = 32.1075 M

THETX = 6.31476808 RAD NUX = 4.82338
THETY = 0.00000000 RAD NUY = 4.82931

DNUX/(DP/P) = -.24146 (DS/S)/(DP/P)= .0416755
DNUY/(DP/P) = .37631 TGAM=(4.89846, 0.00000)

MAXIMA

BETX(78) = 13.89618 BETY(131) = 13.84187
XEQ(134) = 2.91944 YEQ(337) = 0.00000

MINIMA

BETX(131) = 3.52123 BETY(218) = 3.56981
XEQ(169) = .52142 YEQ(337) = 0.00000

MAXIMA	XCO(225)= -2.70204	YCO(337)= 0.00000
MINIMA	XCO(190)= -14.43496	YCO(337)= 0.00000

AMPLITUDE DEPENDENCE OF TUNES DUE TO SEXTUPOLES

NU-X = 4.823377 + .118E+02EX - .211E+01EY
NU-Y = 4.829309 - .211E+01EX + .859E+02EY

TABLE III

CHROMATICITY SEXTUPOLES AT 1,2,4,7 FOR DP/P = 0.0000

CIRCUMFERENCE = 201.7800 M
RADIUS = 32.1143 M

THETX = 6.28319424 RAD NUX = 4.82000
THETY = 0.00000000 RAD NUY = 4.83000

DNUY/(DP/P) = -.00000 TGAM=(4.86467, 0.00000)
DNUX/(DP/P) = .00000 (DS/S)/(DP/P)= .0422564

MAXIMA

BETX(190) = 14.08163 BETY(199) = 13.69922
XEQ(150) = 2.86404 YEQ(337) = 0.00000

MINIMA

BETX(75) = 3.54452 BETY(178) = 3.67807
XEQ(1) = .56104 YEQ(337) = 0.00000

MAXIMA XCO(337)= 0.00000 YCO(337)= 0.00000
MINIMA XCO(337)= 0.00000 YCO(337)= 0.00000

AMPLITUDE DEPENDENCE OF TUNES DUE TO SEXTUPOLES

NU-X = 4.820000 -- .109E+02EX - .806E+00EY
NU-Y = 4.829999 -- .806E+00EX + .866E+02EY

TABLE IV

CHROMATICITY SEXTUPOLES AT 1,2,4,7 FOR DP/P = 0.00500

CIRCUMFERENCE = 201.8226 M
RADIUS = 32.1211 M

THETX = 6.25193457 RAD NUX = 4.81783
THETY = 0.00000000 RAD NUY = 4.82930

DNUX/(DP/P) = .22449
DNUY/(DP/P) = -.38283

(DS/S)/(DP/P)= .0427763 TGAM=(4.83502, 0.00000)

MAXIMA

BETX(78) = 14.27068 BETY(265) = 13.87339
XEQ(150) = 2.83535 YEQ(337) = 0.00000

MINIMA

BETX(131) = 3.56773 BETY(246) = 3.57317
XEQ(113) = .59948 YEQ(337) = 0.00000

MAXIMA	XCO(262)= 14.24853	YCO(337)= 0.00000
MINIMA	XCO(225)= 2.90593	YCO(337)= 0.00000

AMPLITUDE DEPENDENCE OF TUNES DUE TO SEXTUPOLES
NU-X = 4.817828 + .101E+02EX + .103E+00EY
NU-Y = 4.829296 + .103E+00EX + .877E+02EY

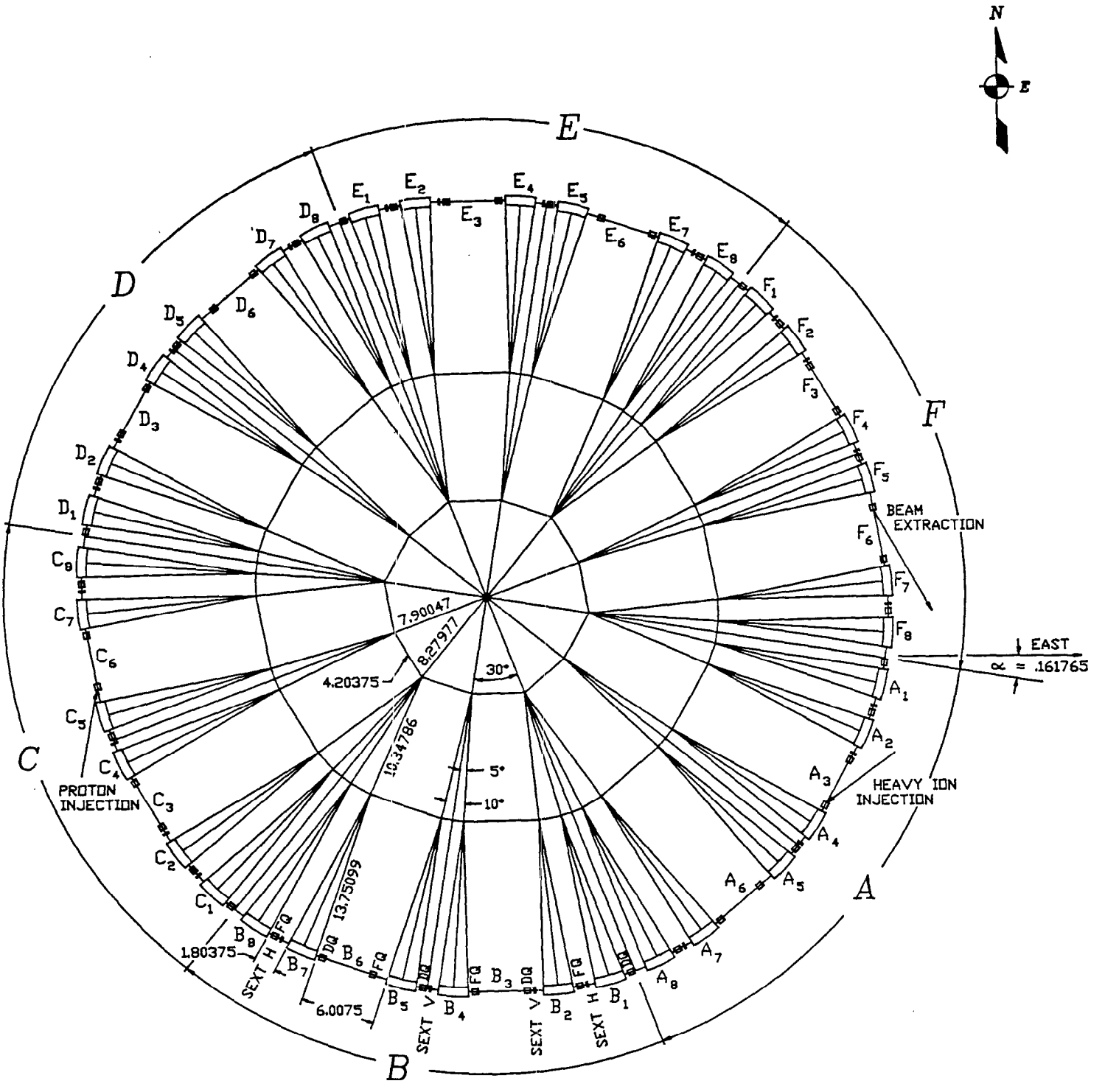
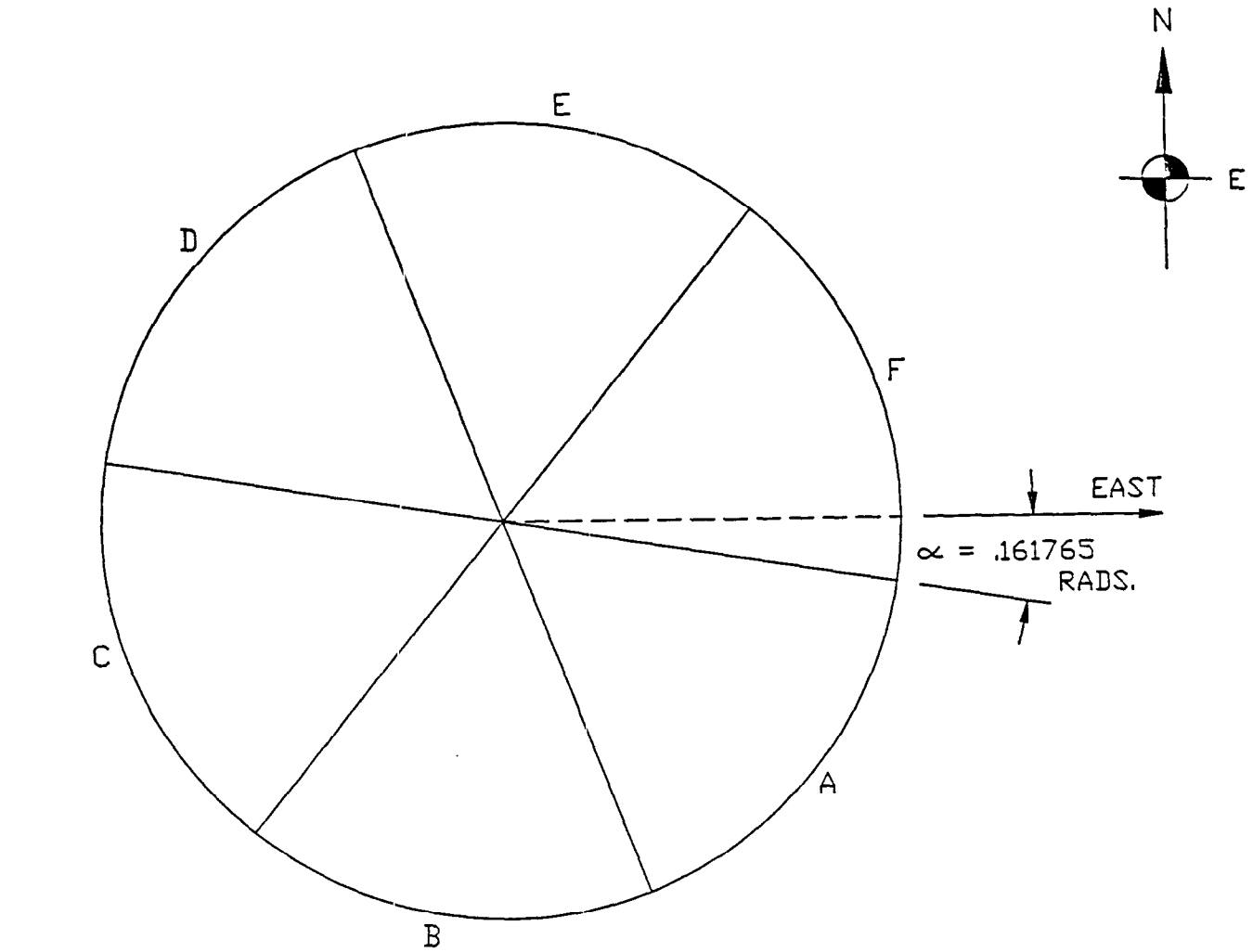
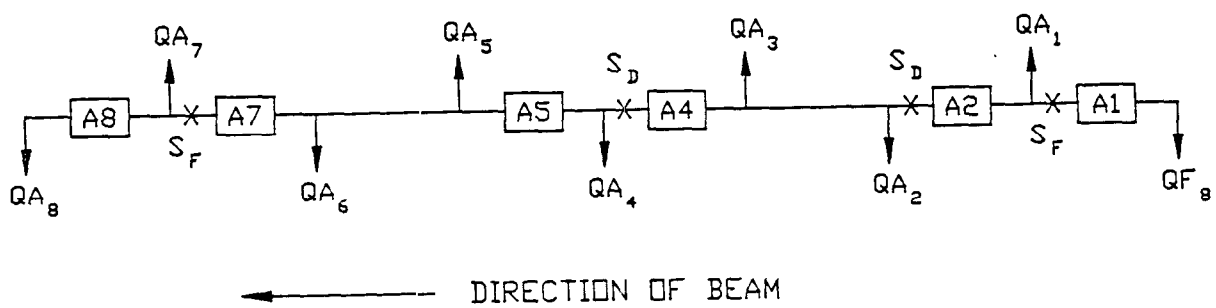


Fig. 1 Overall Layout of the Booster





= FOCUSING QUADRUPOLE

= DEFOCUSING QUADRUPOLE

= BENDING MAGNET (DIPOLE)

X = SEXTUPOLE

FIG. 2 a) Schematic Diagram of the Booster and
b) Components of the Superperiod

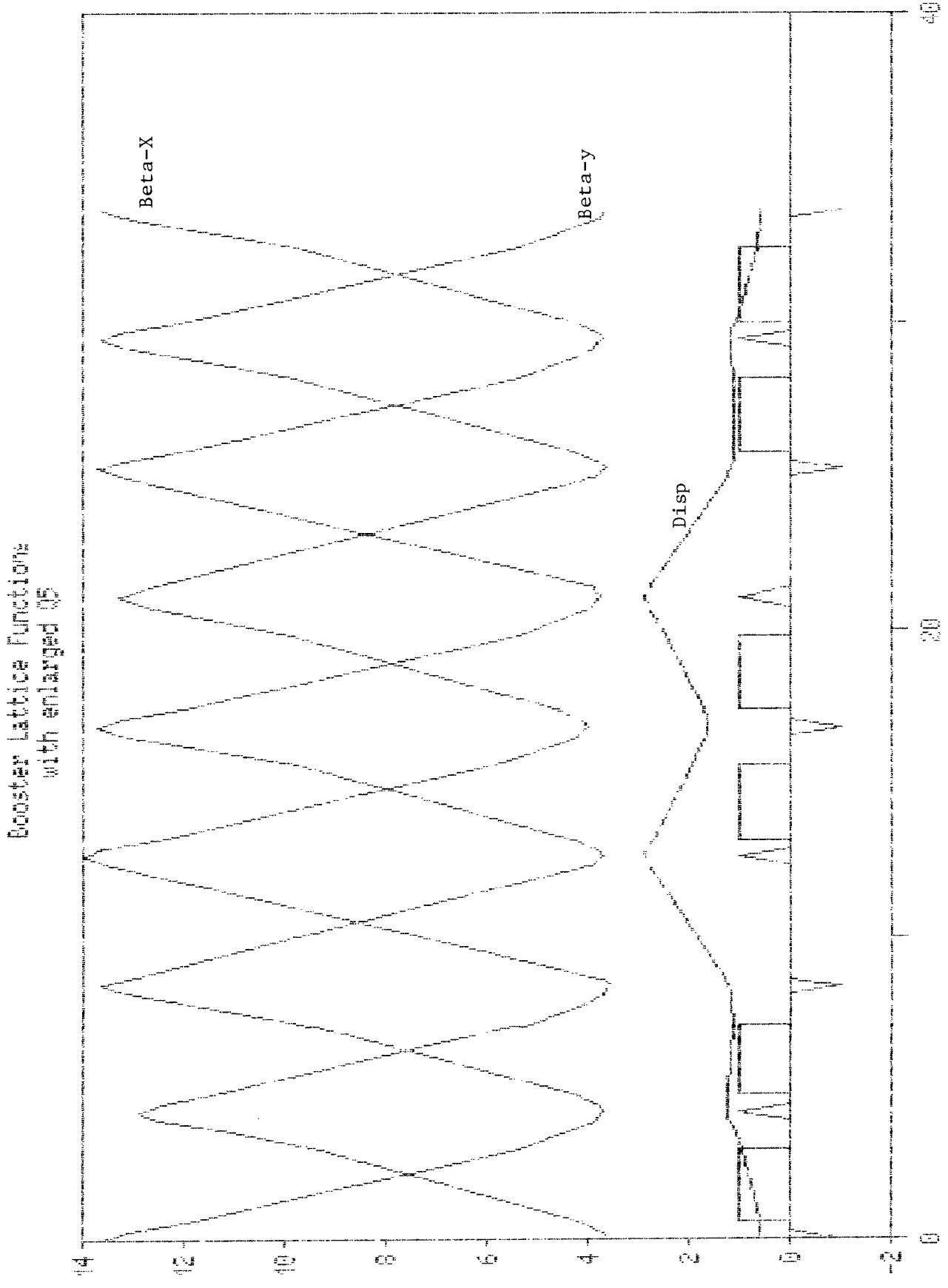

Booster Lattice Function
with Arlange 95
Beta-X
Beta-y
Disp
Distance (m)
Beta-x Beta-y Disp
Beta function (m)

FIG. 3