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A Chromatic Correction Scheme for the RHIC3 Lattice

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ABSTRACT

The RHIC3 lattice is the current design for the Relativistic Heavy Ion Collider. In this note we use special families of sextupoles in the arcs to reduce, in insertions, momentum dependence of machine functions.

1. Introduction

A sextupole scheme has been proposed[1,2] for the chromaticity correction of the symmetric RHIC3 lattice. In such schemes, 3 families of sextupoles have been placed very close to the arcs. An attempt to improve the chromatic behavior has been made manually by decoupling the 3 families in 6. There was improvement, but they were not very significative.

In order to avoid the small dispersion and the lack of symmetry in the insertions, in x and y directions, we analyse the placement of the sextupoles in the arcs. The method we follow is a mix of mathematics and intuition. The linear part of $\Delta\beta/\beta\ (\phi, \Delta p/p)$ help us to understand that we must have symmetry around the center of the arcs,[3] and intuition the rest.

2. Description of the RHIC3 Lattice

The RHIC3 lattice has 6 arcs and 6 insertions with supersymmetry 6. Each typical cell has the structure

$$\text{Cell} = C = \boxed{\tfrac{QF}{2}}\ \boxed{\text{BENDING}}\ \boxed{\tfrac{QD}{2}}\ \underset{SD}{\boxtimes}\ \underset{X_1}{\boxtimes}\ \boxed{\tfrac{QD}{2}}\ \boxed{\text{BENDING}}\ \boxed{\tfrac{QF}{2}}\ \underset{SF}{\boxtimes}\ \underset{X_2}{\boxtimes}$$

where X_1 and X_2 are available sextupoles. Each arc has 12 cells. One of the insertions is as follows:

I = Q8I Q7I Q6I BS Q5I BS Q4I Q3I Q2I Q1I Q1* BC2I QC BC1I
CR BC10 QC BC20 Q1* Q10 Q20 Q30 Q40 BS Q50 BS Q60 Q70 Q80

Each superperiod is made as follows:

$$6\{C_{\text{Inner}}\} + I + 12\ \{C_{\text{out}}\} + I^{-1} + 6\{C_{\text{Inner}}\}\ .$$

In the arcs,

	β_x	β_y	η_x
QF	51.6	7.6	1.3
QD	7.6	51.6	.66

The natural chromaticity is

$$\xi_x = -73.9 \ , \ \xi_y = -64.8$$

and the nominal tunes are

$$\nu_x = 34.41847, \ \nu_y = 34.41628 \quad .$$

For a chromaticity of

$$\xi_x = 1 = \xi_y$$

the two families of sextupoles have values ($B''\ell$ sex/$B o\rho$ m^{-2})

$$SF = -.19460$$
$$SD = +.41529 \ .$$

3. Method for Choosing Special Families of Sextupoles

The linear expression[4] of $\Delta\beta/\beta$ (ϕ, $\Delta\rho/\rho$) has been used for obtaining the contribution of each sextupole to the β's max in the insertions. We can see that the contribution is symmetric around the center of each arc. However, as our lattice is symmetric, we must expect the same distribution of the families in all the arcs. This idea is enhanced by Figure I, as we now explain. Figure I.a. shows the behavior of β_x,β_y in one superperiod, for a deviation in the momentum of 0%. Figures I.b,c have the same meaning for $\Delta p/p$ = +1.0% and -1.0% respectively. In both cases β_y has been shifted up in one arc in order to have clarity in the drawing. With the help of Patricia, we have observed some general properties for RHIC.

1. The sextupoles in the center of the arcs (Z) are necessary to maintain the symmetry of the machine functions.

2. The sextupoles placed where β_x has locally a maximum (S8, B, D, F, H, J, Z) change practically only the x direction ($\beta_x, \nu_x, \ldots$), and the same is applicable to β_y and the y direction for A, C, E, G, I, K.
3. The sextupoles connected by the (---) line have the same sign and opposite to the sign of those connected by the (-·-·) line which also have the same sign.

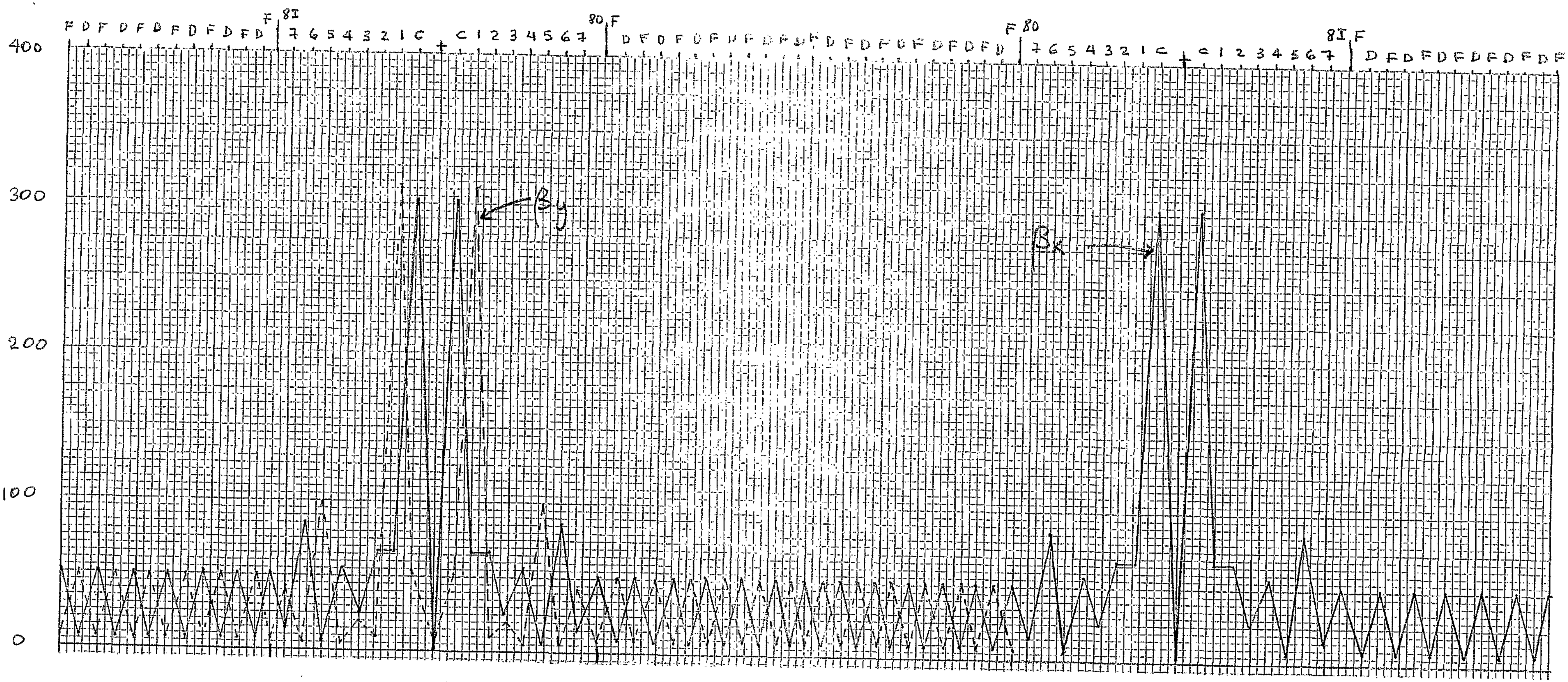


Fig. I.a. β_x and β_y for one superperiod and momentum deviation of 0%. β_y is not plotted in and after the second insertion for clarity, but there is complete symmetry around the center of the arcs.

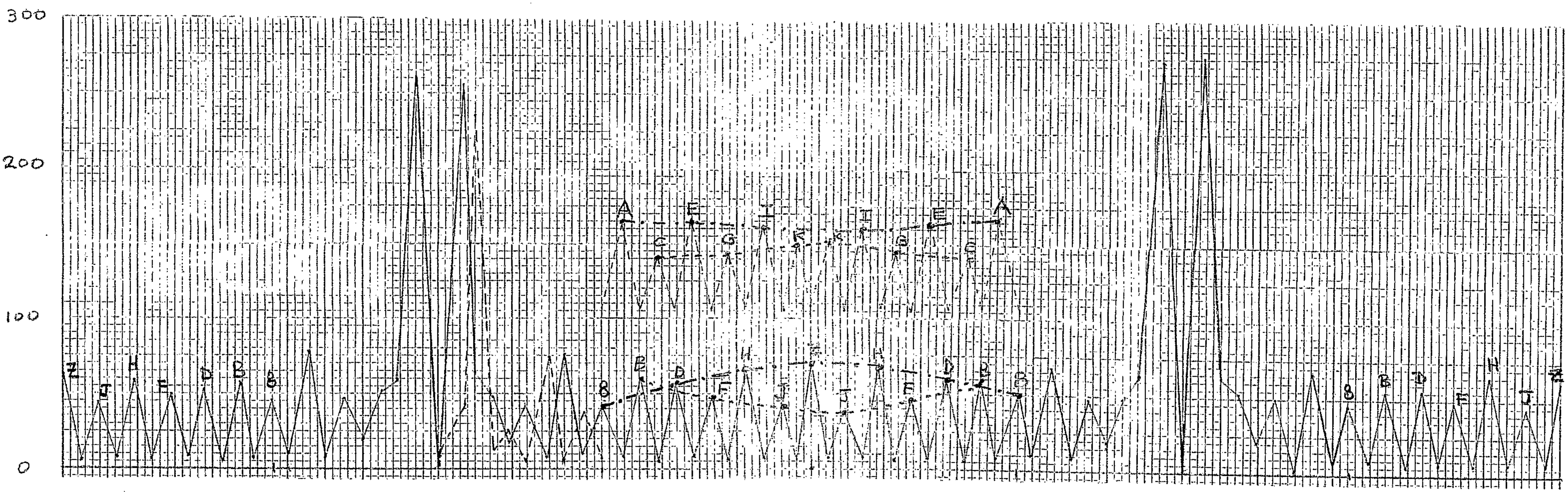


Fig. I.b. β_x and β_y for momentum deviation of +1%. β_y has been shifted up in the central arc to avoid overlapping with β_x. The sextupoles S8, B, D, F, H, J, Z correct practically only x direction, and A, C, E, G, I, K correct practically only y direction.

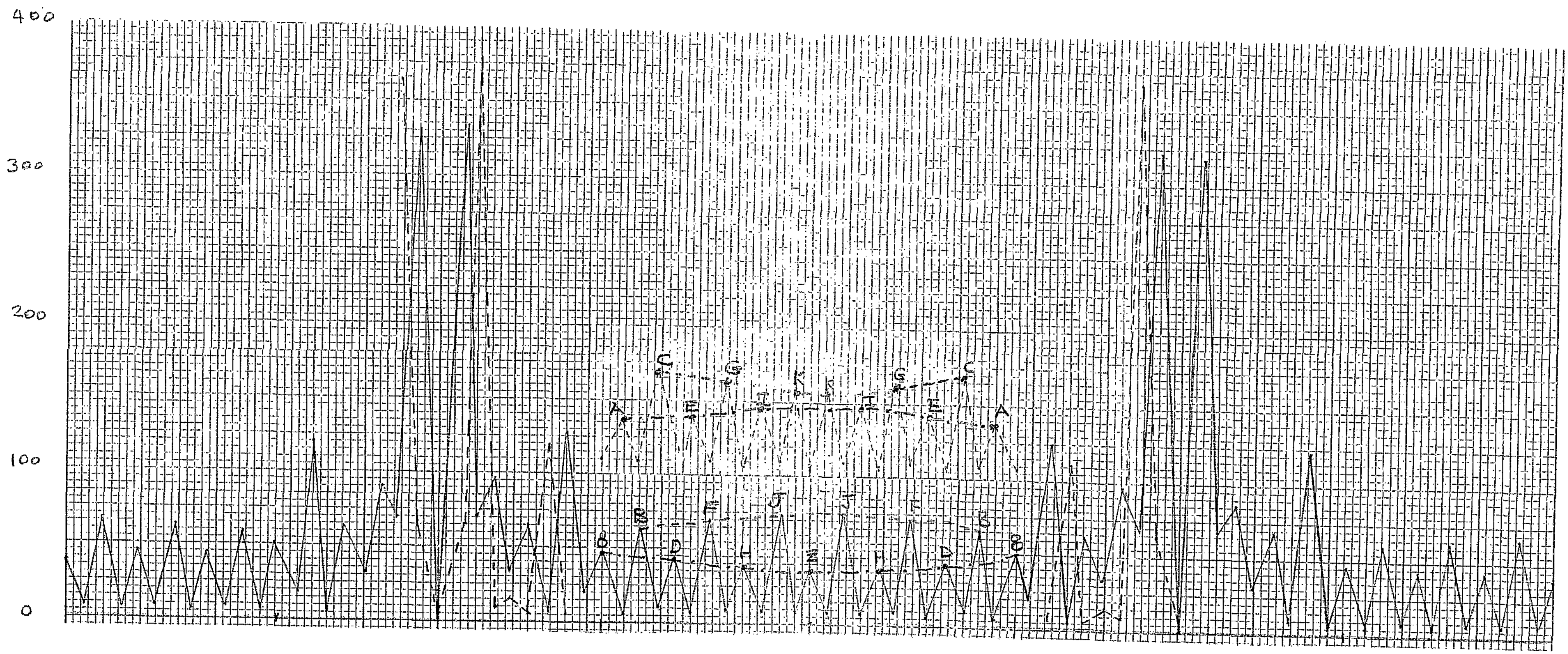


Fig. I.c. β_x and β_y for momentum deviation of -1%.

Only a few runs of Patricia have shown that good values for this sextupoles are

A = -0.21803	C = 0.22142
E = -0.18914	G = 0.12302
I = -0.	K = 0.
S8 = 0.	
D = 0.	B = -0.
H = 0.0535	F = -0.01837
Z = 0.21057	J = -0.02316

In order to keep $\xi_x = \xi_y = 1$, SF and SD now have the values

$$SD = 0.42513$$
$$SF = -0.21240 \quad .$$

In Figure II, we compare the machine functions for the case of two families, SF and SD (continuous line) and the latter case of 8 extra families of sextupoles (dashed line). The chromatic behavior has been improved even without an optimization of the sextupoles.

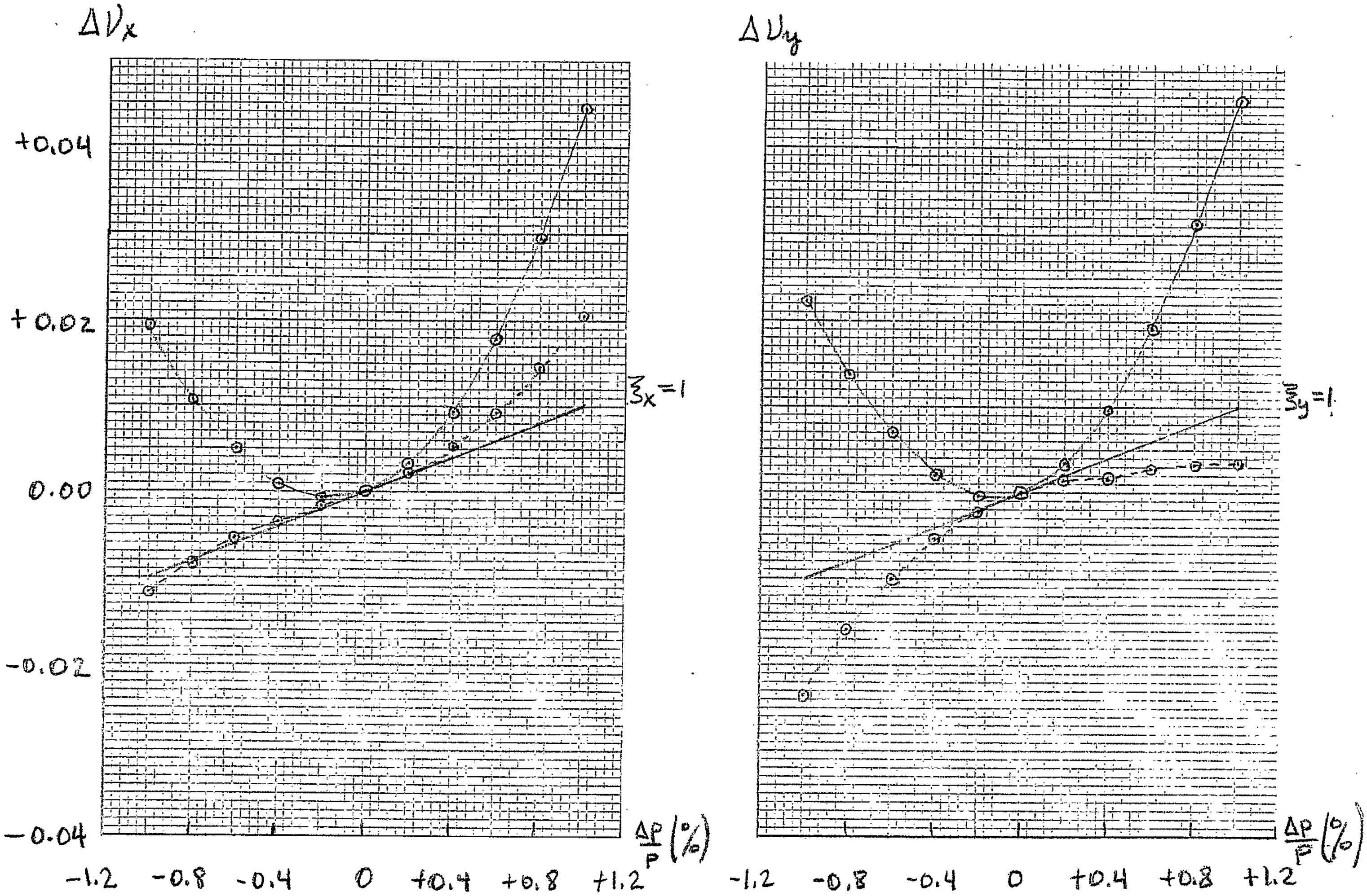


Fig. IIa

Fig. II. In this figure the continuous lines give the momentum dependance of machine functions for two standard sextupole families, SF and SD. The dashed lines represent the same with special families of sextupoles (not optimized) a) change in the tune, b) fractional change of the β's in the insertions (QC, Q1), c) fractional change of the β's at the crossing points, and d) dispersion function at the crossing point.

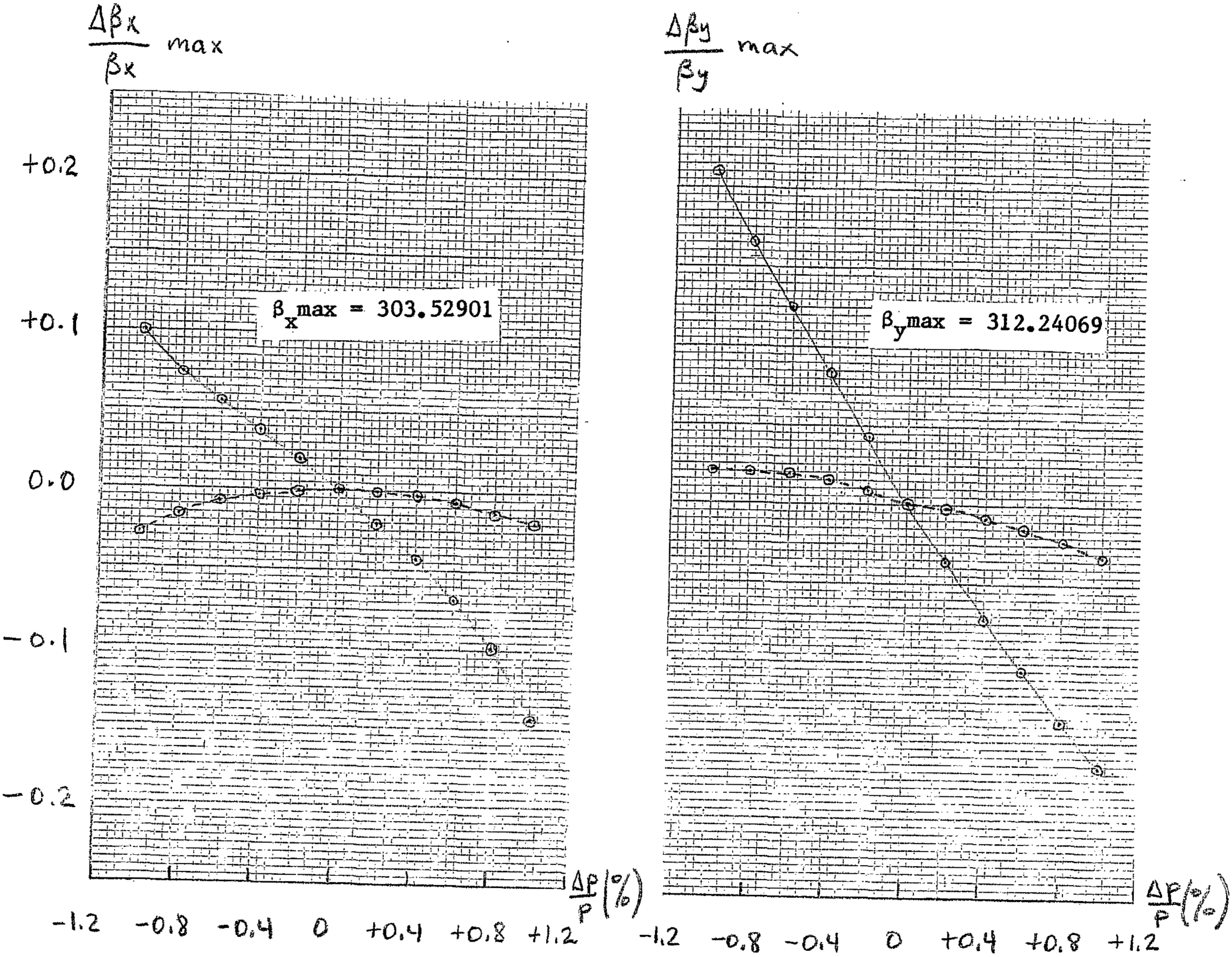
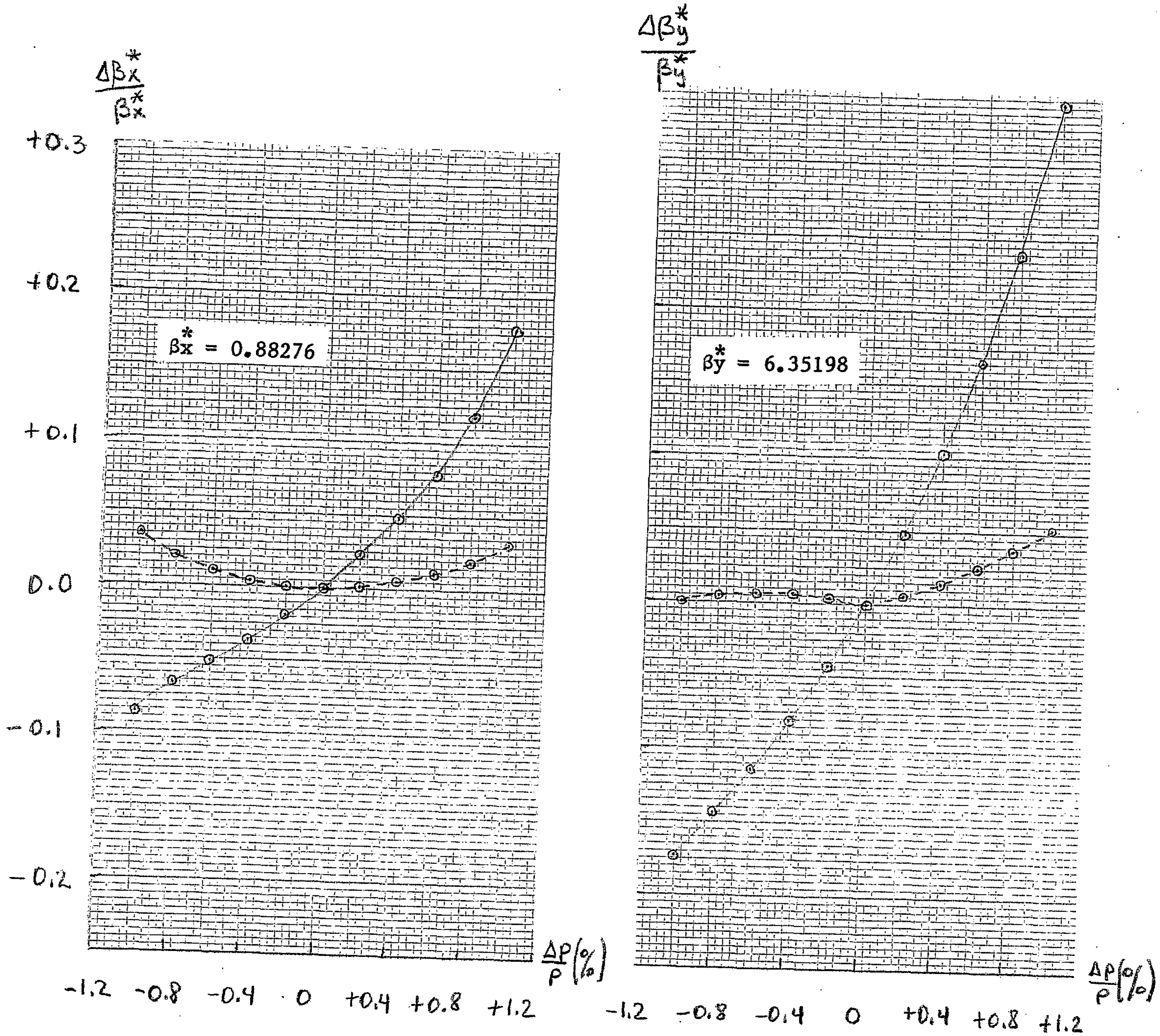
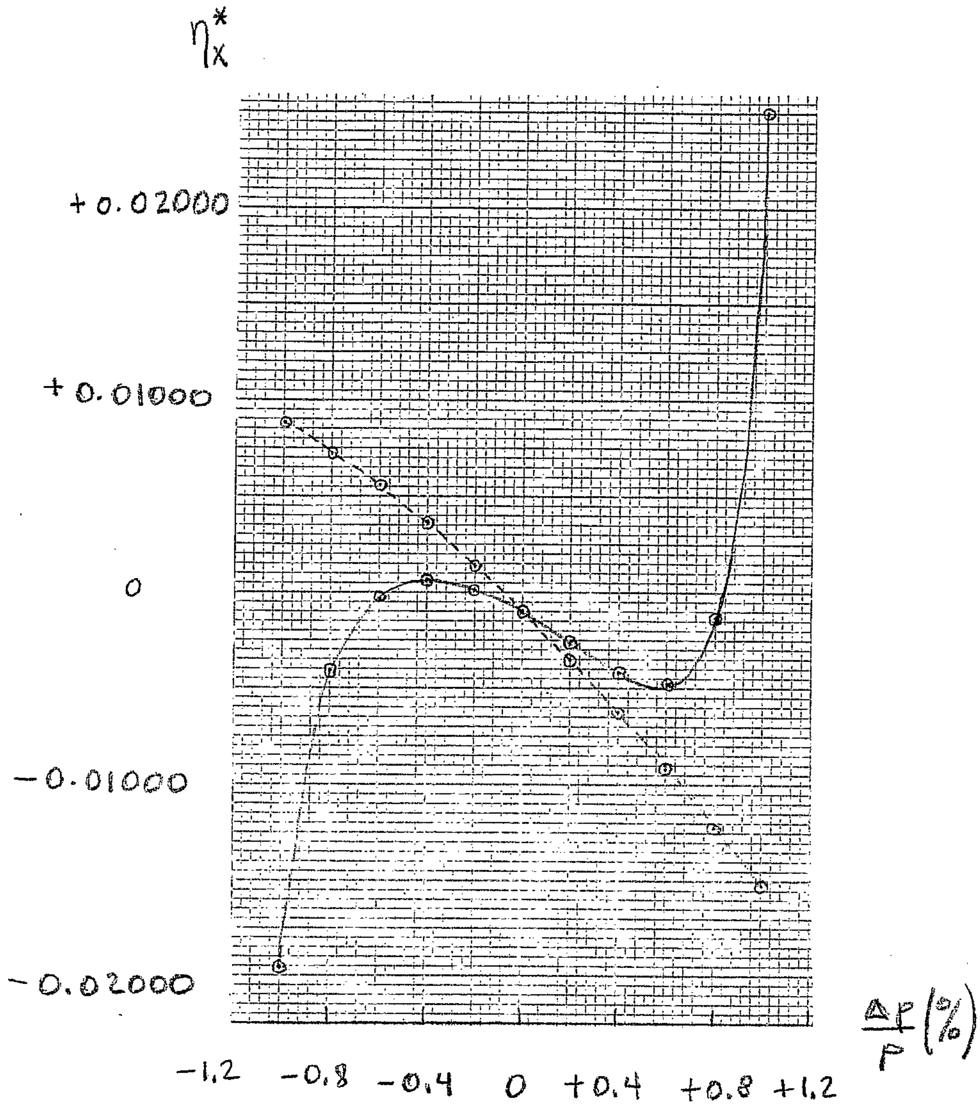

Δβx/βx max
+0.2
+0.1
0.0
−0.1
−0.2
βxmax = 303.52901
−1.2
−0.8
−0.4
0
+0.4
+0.8
+1.2
Δp/p (%)
Δβy/βy max
βymax = 312.24069
−1.2
−0.8
−0.4
0
+0.4
+0.8
+1.2
Δp/p (%)

Fig. IIb



$\frac{\Delta\beta_x^*}{\beta_x^*}$
+0.3
+0.2
+0.1
0.0
-0.1
-0.2
βx* = 0.88276
$\frac{\Delta p}{p}$(%)
-1.2 -0.8 -0.4 0 +0.4 +0.8 +1.2
$\frac{\Delta\beta_y^*}{\beta_y^*}$
βy* = 6.35198
$\frac{\Delta p}{p}$(%)
-1.2 -0.8 -0.4 0 +0.4 +0.8 +1.2

Fig. IIc



η_x^*
+0.02000
+0.01000
0
-0.01000
-0.02000
-1.2
-0.8
-0.4
0
+0.4
+0.8
+1.2
$\frac{\Delta P}{P}(\%)$

Fig. IId

Summary

We have introduced a simple sextupole scheme for the correction of chromatic effects in RHIC which give good improvement even for nonoptimized special sextupoles. However, the nature and simplicity of the method make us to have the conjecture that it can be extended to other symmetric machines with symmetric sextupole distribution, and to antisymmetric machines with antisymmetric sextupole distribution.

References

1. J. Claus, private communication.

2. RHIC Proposal, BNL 51801.

3. A. Antillon, RHIC-AP-1, BNL.

4. E.D. Courant and S. Snyder, Ann. Phys. 3, 1, (1958).