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Comments on the a1, b1 Correction System

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AD/RHIC/AP-89

RHIC PROJECT
Brookhaven National Laboratory

Comments on the a_1, b_1 Correction System

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COMMENTS ON THE a_1, b_1 CORRECTION SYSTEM

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1. a_1 Correction System

ν -Shift Effect

Coupling introduces normal modes ν_1, ν_2 .

Before Correction

$$|\nu_1 - \nu_2|_{max} = 228 \times 10^{-3} \quad \beta^* = 2$$

$$|\nu_1 - \nu_2|_{max} = 80 \times 10^{-3} \quad \beta^* = 6$$

(G. Parzen, AD/RHIC-AP-81, 1989.)

Global Correction System

a_1 correctors in insertions at Q2 and Q5. Two families for each β^* . Q2 and Q5 for $\beta^* = 6$. Q2 for $\beta^* = 2$.

After Correction (Residual $\Delta\nu$)

$\Delta\nu_{11}$ Stopband = 0 (Correct to make stopband = 0)

$$|\nu_1 - \nu_2|_{max} = 15 \times 10^{-3} \quad \beta^* = 6$$

$$|\nu_1 - \nu_2|_{max} = 20 \times 10^{-3} \quad \beta^* = 2$$

Empirical Correction (Correct to minimize $|\nu_1 - \nu_2|$)

$$|\nu_1 - \nu_2| = 7 \times 10^{-3} \quad \beta^* = 6$$

$$|\nu_1 - \nu_2| = 12 \times 10^{-3} \quad \beta^* = 2$$

Some additional a_1 correctors needed to reduce $|\nu_1 - \nu_2|$.

Note the advantage of setting correctors empirically, rather than setting them to cancel the $\nu_x = \nu_y$ stopband.

Betatron Distortion due to Random a_1

Indicated by large $\beta_1, \beta_2 - \Delta\beta/\beta \simeq 60\%$ found.

Betatron distortion measured by coupling distribution factor, CDF

$$CDF = \frac{X_{max}(s)}{X_{max}(s)_{a_1=0}} \text{ for given } x_o, x'_o, y_o, y'_o$$

Usual assumption, $CDF \simeq 1.4$ for $\epsilon_{x,o} = \epsilon_{y,o}$. Computer study gives

$$(CDF)_{max} \simeq 2$$

Consequences of Large CDF – Aperture Loss

a) Linear Aperture Loss

Calculations of aperture required, e.g. the extraction magnet, can be off by 40%.

b) Dynamic Aperture Loss (A_{SL} loss)

At some QF, A_{SL} can be reduced by 40%. Average loss A_{SL} about 15%. (G. Parzen, AD/RHIC-AP-80, 1989.)

Residual $|\nu_1 - \nu_2|$ and CDF Correction

Proposal: Separately excited a_1 near each high β quad in the insertions. Twelve separately excited a_1 near Q2.

This was also suggested by Correction System Review Committee.

This may correct both residual $|\nu_1 - \nu_2|$ and the CDF.

a_1 correctors near QD in arc may also be helpful but may not be necessary.

The above 3 effects, (1) the residual $|\nu_1 - \nu_2|$, (2) the high CDF and (3) the loss in A_{SL} , deserve careful consideration before giving up the a_1 correctors in the arcs.

The a_1 at Q2 are excited in two families to generate the cos and sin of the $\nu_x + \nu_y$ harmonic. This gives a total of 4 knobs in the a_1 correction system to control $|\nu_1 - \nu_2|$ and the CDF.

Note that again the Q2 correctors are set empirically to reduce the CDF and the residual $|\nu_1 - \nu_2|$. They are not set to cancel out a $|\nu_x + \nu_y|$ stopband.

Are two knobs sufficient to control the CDF and the residual $|\nu_1 - \nu_2|$? Some judgment is needed as to what level of correction is sufficient.

2. The b_1 Correction System

$\Delta\beta/\beta$ Effects of Random b_1

$$\beta^* = 6 \quad (\Delta\beta/\beta)_{max} = 0.36$$

$$\beta^* = 2 \quad (\Delta\beta/\beta)_{max} = 0.90$$

$(\Delta\beta/\beta)_{max} = 0.20$ comes from the arcs. Largest effect from Q1, Q2, Q3, $\beta^* = 2$. (G. Parzen, AD/RHIC-AP-71, 1988.)

Above is a large effect and needs correction. Most of this effect can be corrected using b_1 corrections in the insertion quads.

Proposal: Use the b_1 corrections in the insertion quads to also correct the 20% effect due the arc magnets, as well as the large effect due to Q1, Q2, Q3.

Note that the a_1 effects and b_1 effects are similar and of the same order. The b_1 effects only appear smaller because of the availability of correction coils that are already there for other reasons. Both a_1 and b_1 produce a ν -shift, a betatron distortion, and a loss in dynamic aperture.

Using the b_1 coils in the insertions makes the b_1 correction system and the a_1 correction look similar.

Proposal: Use 4 knobs in the Q2, Q3 magnets to control the effects of the $2\nu_x$ and $2\nu_y$ resonances on $\Delta\beta_x/\beta_x$ and $\Delta\beta_y/\beta_y$. This will produce a certain level of correction which may be sufficient. More knobs could be added, but would be difficult to use.

Why Correct b_1 ?

b_1 effects may be larger than expected because of

- a) difficulty in correcting Q1, Q2, Q3
- b) closed orbit errors in sextupoles
- c) other various sources
- d) operating near the integer ν -value.

3. Dispersion Correction

$$\frac{\Delta X_p}{X_p} = 0.25 \quad \text{at QF}$$

$$\frac{\Delta Y_{p,max}}{Y_p} = 0.31 \quad \text{at QD}$$

Mostly from arc magnets. (G. Parzen, AD/RHIC-AP-71, 1988.)

Reasons for Correcting X_p, Y_p

- 1) Effect on beam-beam interaction
- 2) To be able to operate near integer, $\nu \simeq 29$, where effect maybe about 3 times larger.

Proposal:

- 1) Use a_1 correctors at QD in arcs to correct Y_p . Possible a_1 corrector near Q9 as a back-up correction.
- 2) Use b_1 correctors at QF in arcs and b_1 in insertion quads to correct X_p .

The only new correctors required by the proposals in this note are the a_1 correctors at each Q2 in the insertions.