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Effects of Random Quadrupole Field Errors in RHIC and Their Correction

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RHIC-AP-26

EFFECTS OF RANDOM QUADRUPOLE FIELD ERRORS IN RHIC

AND

THEIR CORRECTION

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Effects of Random Quad errors, a_1, b_1

Small aperture in RHIC gives large a_1, b_1.

Random b_1 causes random $\Delta\beta_x/\beta_x$, $\Delta\beta_y/\beta_y$ and ΔX_p

Random a_1 causes coupling and random ΔY_p, vertical dispersion.

These effects can cause loss of aperture and can worsen the beam-beam interaction.
They might also worsen non-linear orbit instabilities.

History

Large effects like $\Delta\beta_x/\beta_x \simeq 50\%$ were predicted. These were reduced by about a factor of 3 by 2 events

History (Continued)

(1) Herrera projection reduced b_1 by factor 2

2) ν_x, ν_y were moved away from .6 to near .82 (away from 1/2 integer resonance)

Nevertheless, effects remained substantial — and there was concern over effects on tracking results. So present correction system was proposed having 36 independent a_1 and b_1 correction coils per ring, 6 per sector — with the b_1 and a_1 correction coils positioned in a complicated way to maximize their effect.

Results of Studies

$a_1 = 16.8\ E{-5}$, $b_1 = 8.4 \times 10^{-5}\ cm^{-1}$ (rms) in dipoles.

Random b_1 effects ($a_1 = 0$)

10 runs, 10 different set of random errors, b_1.

Linear effects

$\left(\frac{\Delta\beta}{\beta}\right)_{max} \simeq 15\%$ $\Delta(6\sigma_x) = 1.4$ mm in QF at $\gamma = 30$

$\Delta X_p(QF)_{max} = .34$ m, 20% of X_p
$\Delta X = 1.7$ mm at $\Delta p/p = 5 \times 10^{-3}$ in QF.

$X_p \frac{\Delta p}{p} + 6\sigma_x \rightarrow 3$ mm loss, more in insertions at $\gamma = 30$

Δx_p (crossing point) $= .1$ m

Important for Beam-Beam Interaction →
- 20% change in beam size
- $\frac{\Delta\beta_x}{\beta_x} \rightarrow 7\%$ change in beam size

Results depend on b_1 error and ν_x, ν_y — might get larger.

Above Results Agree with Theory.

Linear effects, b_1

$\frac{1}{2}$ integer stop-band,

$$(\Delta\nu)_{max} = .023$$

($\frac{1}{2}$ stop-band width)

Non-linear effects (random b_1, $a_1 = 0$)

$\Delta p/p = 0$, 10 runs → $A_{SL} = 19$ mm
same result as for $b_1 = 0$

spread in A_{SL} is smaller in 10 runs; better chance to get larger A_{SL} when $b_1 = 0$.

momentum study
10 runs for each $\Delta p/p$

$\Delta p/p$	A_{SL} (mm)
-.01	9
-.005	15
0	19
.005	19
.01	11

Results about the same as for $b_1 = 0$ case

Random a_1 effects ($b_1 = 0$)

$a_1 = 16.3 \times 10^{-5}$ (rms) cm^{-1}

Linear effects

Coupling stopband

Within stopband, coupling is 100%

10 runs, 10 different sets of random errors.

$(\Delta\nu)_{max} = .033$, coupling stopband (half-width)

$\Delta y_p = .48$ mm, at QD.

Vertical dispersion

34% change in beam size at crossing point.

affects beam-beam interaction

Random a_1 (Non-Linear effects) $b_1 = 0$

Tracking study should be done after correction of linear coupling.

Without - Correcting Coupling

$\frac{\Delta p}{p} = 0$, 10 runs $\quad A_{SL} = 19$ mm

same result as for $a_1 = 0$ case.

Momentum study not yet done. Waiting for coupling correction procedure.

Possible Conclusions

Presently proposed complicated $a, b,$ correction system may not be needed except for the following corrections

1) a_1 correctors for coupling correction in insertion region

2) a_1 correctors ~~f~~or correction of vertical dispersion at crossing point

Correction of $\frac{\Delta\beta_x}{\beta_x}$, $\frac{\Delta\beta_y}{\beta_y}$, X_p at crossing point may be done with insertion quad trims. Required ~~[illegible]~~ strength of trims needs to be computed.

(3) Shuffling of magnets to reduce a_1 and b_1 (Can we commit ourselves to reducing linear effects by factor 3?)