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Effects of Random Quadrupole Field Errors in RHIC and Their Correction

G. Parzen

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Collider Accelerator Department
Brookhaven National Laboratory

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EFFECTS OF RANDOM QUADRUPOLE FIELD ERRORS IN RHIC
AND
THEIR CORRECTION

George Parzen
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Effects of Random Quad errors, a_i, b_i

Small aperture in RHIC gives large a_i, b_i .

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

Random a_i 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 $\Delta\beta_x/\beta_x \approx 50\%$
were predicted. These were reduced
by a factor of 3 by
2 events

History (continued)

(1) Herrera projection reduced b_1 by factor 2

(2) V_x, V_y was 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

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

Random b_1 effects ($a_1 = 0$)

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

Linear effects.

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

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

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

$\Delta X_p(\text{crossing point}) = .15 \text{ m}$

Important for Beam-Beam Interaction \rightarrow $\left\{ \begin{array}{l} 20\% \text{ change in beam size} \\ \frac{\Delta B_x}{B_x} \rightarrow 7\% \text{ change in beam size} \end{array} \right.$

Results depend on b_1 error and V_x, V_y might get larger.

Above Results Agree with theory.

(1.a)

Linear effects, b_1

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

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

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

(2)

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

$\Delta P/P = 0$, 10 runs \rightarrow $A_{SL} = 19 \text{ mm}$
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)
-0.01	9
-0.005	15
0	19
0.005	19
0.01	11

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

Random Q_1 effects ($b_1 = 0$)
 $Q_1 = 16.3 \times 10^{-5}$ (rms) cm^{-1}

Linear effects

Coupling stopband
 Within stopband, coupling is 100%

10 runs, 10 different sets of random errors.

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

$\Delta y_p = .48 \text{ mm}$, at QD.
 Vertical dispersion

34% change in beam size
 at crossing point.
 affects beam-beam
 in interaction

Random q_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

$A_{SL} = 19 \text{ mm}$

same result as
for $q_1 = 0$ 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, correctors for coupling
correction in insertion region

2) a, correctors for correction
of vertical dispersion at crossing
point

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

③ Shuffling of magnets to reduce
a, and b, (Can we commit ourselves
to reducing linear effects by factor 3?)