

Linear Random Quadrupole Effects and Their Correction

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(1)

Random a_i , b_i Linear Effects

Random $b_i \rightarrow \frac{\Delta \beta_x}{\beta_x}, \frac{\Delta \beta_y}{\beta_y}, \Delta X_p$

Random $a_i \rightarrow \Delta Y_p, \text{Coupling - } \Delta \text{splitting}$

a_i, b_i Sources

Random Coil errors, $a_i = 16.8 \times 10^{-5} / \text{cm}$, $b_i = 8.4 \times 10^{-5} / \text{cm}$
in Dipoles

$a_i = b_i = 15 \times 10^{-5} / \text{cm}$ Quads

Quad effective length, $\Delta L/L = 2 \times 10^{-3}$, $b_i = 40 \times 10^{-5} / \text{cm}$
in Quads

Quad rotation error, $\Delta \theta = 1 \times 10^{-3} \text{ rad}$, $a_i = 40 \times 10^{-5} / \text{cm}$
in Quads

F. Dell found that the high β quads contributed to the linear effects.

Including $\Delta L/L$ and $\Delta \theta$ errors, the arc quads also contribute significantly.

Following slides show contributions made by the important magnets.

$$\underline{\Delta B_x/\beta_x \text{ and } \Delta B_y/\beta_y}$$

Tracking studies have been done — Results are in good agreement with analytical results for the rms effect.

To find contributions of each magnet, it is easier to use the analytical results for the rms $\Delta B/\beta$.

$$\beta^* = 6$$

$$\beta^* = 2$$

		$(\Delta B_x/\beta_x)_{rms}$		
B	.036	.035		
QF	.036	.036	$\left(\frac{\Delta B}{\beta}\right)_{max} = 3.0 \left(\frac{\Delta B}{\beta}\right)_{rms}$	
QD	.007	.007		
Q3E	.032	.108		
Q2E	.026	.079		
Q1E	.023	.063		
Q10	.024	.067		
Q20	.080	.227		
Q30	.014	.039		
Total $\frac{\Delta B}{\beta}_{rms}$	.116	.29		
$\frac{\Delta B}{\beta}_{max}$	.36	.90	All magnets	
$\frac{\Delta B}{\beta}_{max}$	.15	.15	B + QD + QF magnets	

$\Delta B/B$ (Continued)

The high β Quads, Q1, Q2, Q3 contribute most of $\Delta B/B$. These quads should be corrected individually using the Insertion quad trims. This requires a good measurement of $\Delta L/L$.

The remaining $(\Delta \beta_x/\beta_x)_{\max} = 18\%$ can be corrected by shuffling dipoles and quads ~~in~~ in the arcs

QF and QD contribute about the same as the dipole

Note $\Delta \beta_x/\beta_x$ and $\Delta \beta_y/\beta_y$ are similar except that different quads play the important role.

Horizontal Dispersion ΔX_p

 $\beta^* = 6$ $\beta^* = 2$

	mm at CP $\Delta p/p = .01$	mm at CP $\Delta p/p = .01$	
B	.338	.194	
QF	.325	.189	
QD	.069	.040	
Q3I	.044	.039	
Q2I	.033	.031	
Q1I	.026	.026	
Q10	.031	.026	
Q20	.104	.088	
Q30	.019	.014	
Total rms	.511	.303	
$\Delta X_{p,rms}$ at QF	.15m	.15m	
$\Delta X_{p,max}$ at QF	.40m, 25% of \hat{X}_p	.40m, 25% of \hat{X}_p	

$\Delta X_{p,max}$ gives 60% effect on beam size at C.P.

QF and Dipole contribute equally

Shuffle both QF and dipoles in arc to reduce ΔX_p .

Q20 is corrected locally.

Vertical Dispersion ΔY_p

	$\beta^* = 6$	$\beta^* = 2$	
	mm at CP $\Delta p/p = .01$	mm at CP $\Delta p/p = .01$	
B	.674	.389	
QF	.136	.079	Quads $\rightarrow Y_{\text{max}} = .16 \text{ m}$ $= 11\% \text{ of } \hat{X}_p$
QD	.158	.091	
Q3I	.028	.023	
Q2I	.056	.052	
Q1I	.027	.026	
Q10	.029	.025	
Q20	.058	.051	
Q30	.029	.023	
Total rms	.726	.419	
$Y_{p, \text{rms at QD}}$	.21 m	.21 m	
$Y_{p, \text{max at QD}}$	.46 m, 31% of \hat{X}_p	.46 m	

ΔY_p due to QD, QF cannot be corrected by shuffling magnets.

$$\Delta Y_p (\text{due to quads}) = .16 \text{ m max}, 11\% \text{ of } \hat{X}_p$$

27% effect on beam size at Crossing point.

Q1 Correctors in arcs intended to correct ΔY_p due to Quads, and the remaining ΔY_p due to dipoles after shuffling.

Conclusions

- 1) Correct random b_i in insertion quads locally.
- ② Shuffle Dipoles, QF, and QD in arcs to reduce $\Delta B_x/B_x$, $\Delta B_y/B_y$, ΔX_p and ΔY_p .
- 3) A correction system in arcs to correct remaining ΔY_p .