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Linear Random Quadrupole Effects and Their Correction

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Random a_1, b_1 Linear Effects

Random $b_1 \longrightarrow \dfrac{\Delta\beta_x}{\beta_x}, \dfrac{\Delta\beta_y}{\beta_y}, \Delta X_p$

Random $a_1 \longrightarrow \Delta Y_p$, Coupling – νsplitting

a_1, b_1 sources

Random Coil errors, $a_1 = 16.8\times10^{-5}/cm$, $b_1 = 8.4\times10^{-5}/cm$ in Dipoles

$a_1 = b_1 = 15\times10^{-5}/cm$ Quads

Quad effective length, $\Delta L/L = 2\times10^{-3}$, $b_1 = 40\times10^{-5}/cm$ in Quads

Quad rotation error, $\Delta\theta = 1\times10^{-3}$ r, $a_1 = 40\times10^{-5}/cm$ 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.

$\Delta\beta_x/\beta_x$ and $\Delta\beta_y/\beta_y$

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 fn the rms $\Delta\beta/\beta$.

	$\beta^* = 6$	$\beta^* = 2$	
	$(\Delta\beta_x/\beta_x)_{rms}$		
B	.036	.035	
QF	.036	.036	$\left(\frac{\Delta\beta}{\beta}\right)_{max} = 3.0 \left(\frac{\Delta\beta}{\beta}\right)_{rms}$
QD	.007	.007	
Q3I	.032	.108	
Q2I	.026	.079	
Q1I	.023	.063	
Q1O	.024	.067	
Q2O	.080	.227	
Q3O	.014	.039	
Total $\frac{\Delta\beta}{\beta}$ rms	.116	.29	
$\frac{\Delta\beta}{\beta}$ max	.36	.90	All magnets
$\frac{\Delta\beta}{\beta}$ max	.15	.15	B+QD+QF magnets

$\Delta\beta/\beta$ (Continued)

The high β Quads, Q1, Q2, Q3 contribute most of $\Delta\beta/\beta$. These quads should be correctected 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 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

	$\beta^* = 6$ mm at CP $\Delta p/p = .01$	$\beta^* = 2$ 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
Q1O	.031	.026
Q2O	.104	.088
Q3O	.019	.014
Total rms	.511	.303
$\Delta X_{p,rms}$ at QF	.15 m	.15 m
$\Delta X_{p,max}$ at QF	.40 m, 25% of $\hat{X}_p$	.40 m, 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
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
$Y_{p,rms}$ at QD	.21 m	.21 m
$Y_{p,max}$ at QD	.46 m, 31% of $\hat{X}_p$	.46 m

Quads → $Y_{p\,max}$ = .16 m = 11% of $\hat{X}_p$

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

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

27% effect on beamsize at crossing point.

a_1 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_1 in insertion quads locally.

② Shuffle Dipoles, QF, and QD in arcs to reduce $\Delta\beta_x/\beta_x$, $\Delta\beta_y/\beta_y$, ΔX_p and ΔY_p

3) a_1 correction system in arcs to correct remaining ΔY_p.