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TOLERANCE REQUIREMENTS FOR ENERGY DOUBLER QUADRUPOLE

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I.

Tolerance requirements for the energy-doubler dipole, Mark II, have been discussed in the previous report.[1] After the report was issued, S.C. Snowdon pointed out that there is a design for 7-ft. long superconducting quadrupoles to be used for the doubler.[2] This note summarizes tolerance requirements for this quadrupole. The shape of the vacuum pipe is circular and the distance from the center to the innermost wire is 1.25 in. With an iron shield (inner radius = 3.0625 in.), the design value of the integrated field gradient is 1,262 kG for the conductor current of 2,815 A. This corresponds to $\nu_x = \nu_y \cong 19.4$ at 980 GeV. There are three blocks of conductors in each octant and the results presented here are based on the assumption that all twenty-four blocks have the same rms error Δ_r in their radial positions and the same rms error Δ_{az} in their azimuthal positions.

A perfectly constructed quadrupole has the median plane field of the form

$$B_y = B_o'x + B_o^{(5)}x^5/5! + B_o^{(9)}x^9/9! + \cdots\cdots$$

where x is the radial distance from the axis. For $\nu_x = \nu_y \cong 19.4$,

$$B_o'/B_o = 0.3421/\text{in},$$

$$B_o^{(5)}/B_o = 0.0240/\text{in}^5,$$

$$B_o^{(9)}/B_o = -\ 99.3/\text{in.}^9.$$

Since resonances driven by $B_o^{(5)}$ and $B_o^{(9)}$ are of the sixth order ($6\nu_x = n$, $4\nu_x + 2\nu_y = n$, etc.) and of the tenth order ($10\nu_x = n$, $8\nu_x + 2\nu_y = n$, etc.), respectively, their effects on the beam should be negligible unless the doubler is used as a storage device.

II.

The procedure used for obtaining coil misalignment effects is identical to what is given in the previous report.[1] Results are simply listed below together with results from ref. 1 for dipoles.

(a) <u>closed-orbit distortion</u>

	dipole	quadrupole
$(\Delta x)_{rms}$ in mm	$0.152\sqrt{\beta_x(m)}\ \Delta_{az}(\text{mil})$	$0.0055\sqrt{\beta_x}\ \Delta_{az}$
$(\Delta y)_{rms}$ in mm	$0.219\sqrt{\beta_y(m)}\ \Delta_{az}(\text{mil})$	$0.0180\sqrt{\beta_y}\ \Delta_{az}$

(b) <u>half-integer stopbands</u>

total width

	dipole	quadrupole
$(\delta\nu_x)_{rms}$	$0.0082\ \Delta_r(\text{mil})$	$0.00127\ \Delta_r$
	$0.0299\ \Delta_{az}(\text{mil})$	$0.00163\ \Delta_{az}$
$(\delta\nu_y)_{rms}$	$0.0083\ \Delta_r(\text{mil})$	$0.00127\ \Delta_r$
	$0.0303\ \Delta_{az}(\text{mil})$	$0.00163\ \Delta_{az}$

(c) <u>third-integer resonances</u>

ε_x, ε_y = horizontal and vertical emittance/π in mm-mrad.

total width

	dipole	quadrupole
$(\delta\nu_x)_{rms}$	$0.00205\sqrt{\varepsilon_x}\ \Delta_r$(mil)	$0.00027\sqrt{\varepsilon_x}\ \Delta_r$
	$0.00938\sqrt{\varepsilon_x}\ \Delta_{az}$(mil)	$0.00046\sqrt{\varepsilon_x}\ \Delta_{az}$
$(\delta\nu_y)_{rms}$	$0.00638\sqrt{\varepsilon_y}\ \Delta_r$(mil)	$0.00031\sqrt{\varepsilon_y}\ \Delta_r$
	$0.0313\sqrt{\varepsilon_y}\ \Delta_{az}$(mil)	$0.00040\sqrt{\varepsilon_y}\ \Delta_{az}$

(d) <u>tune spread due to octupole field</u>

ε_x, ε_y = horizontal and vertical emittance/π in mm-mrad.

	dipole	quadrupole
$(\delta\nu_x)_{rms}$	$1.28\times10^{-4}\ \varepsilon_x\ \Delta_r$(mil)	$5.3\times10^{-5}\ \varepsilon_x\ \Delta_r$
	$9.31\times10^{-4}\ \varepsilon_x\ \Delta_{az}$(mil)	$1.47\times10^{-4}\ \varepsilon_x\ \Delta_{az}$

In all cases listed above, the coil misalignments in quadrupoles produce effects which are ~ 10% or less of the similar effects arising from dipoles. This is reasonable since the total length of all dipoles is ten times of the quadrupole total length in the doubler.

I am grateful to S. Snowdon for supplying data on the quadrupole design.

References

1. S. Ohnuma, TM-502, June 14, 1974.
2. S.C. Snowdon, private communication. There is no written report on the design.