

QUADRUPOLE CORRECTORS FOR THE HALF-INTEGER STOPBANDS IN THE BOOSTER

A. G. Ruggiero

January 1989

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

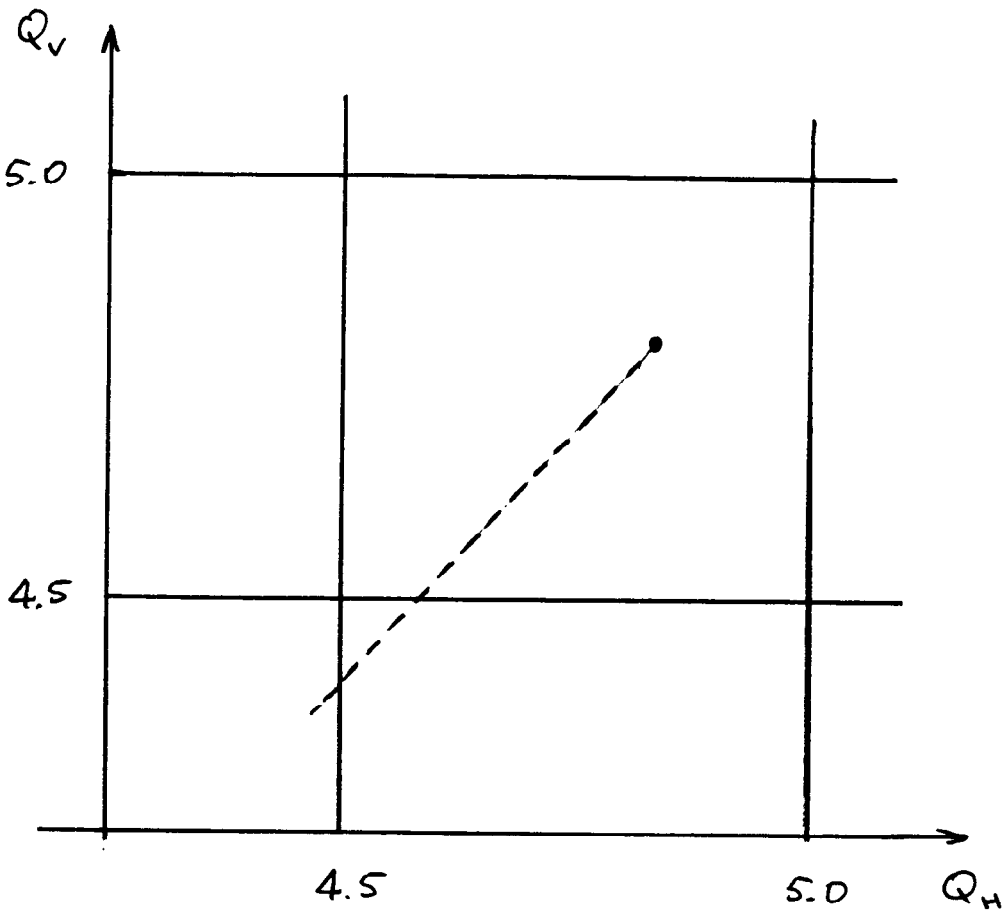
**QUADRUPOLE CORRECTORS FOR THE
HALF-INTEGER STOPBANDS IN THE BOOSTER**

**AD
BOOSTER TECHNICAL NOTE
NO. 135**

A. G. RUGGIERO

JANUARY 12, 1989

**ACCELERATOR DEVELOPMENT DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973**



Half-Integer Stopbands

$$\begin{cases} 2Q_H = 9 \\ 2Q_H = 10 \end{cases} \quad \text{and} \quad \begin{cases} 2Q_V = 9 \\ 2Q_V = 10 \end{cases}$$

Driving Terms ($\kappa = B'/B_P$)

$$J = \frac{1}{2\pi} \oint \beta(s) \kappa(s) e^{i\rho \phi(s)} ds$$

H and V $\rho = 9$ and 10

Expectation Values of the Stopbands

* Booster TN # 112 (Feb. 1988)

Assume $(\Delta k/k)_{rms} = 10^{-3}$ then the rms values of the stopband widths are

$$\delta v_H = 0.0035$$

$$\delta v_V = 0.0038$$

* Similar contribution is expected from the product

sextupoles \times uncorrected closed orbit

Booster TN # 107

* Once the closed orbit is corrected, the corresponding contribution is about 10 times smaller.

* It is not possible to know in advance the errors and the stopbands they cause.

The correction scheme should be capable to generate a set of driving terms with selected amplitudes and phases

There are 8 conditions:

$$\sum_s \beta_{H_s} K_s \cos \theta \phi_{H_s} = \frac{2\pi}{L} |J_{H\theta}| \cos \psi_{H\theta}$$

$$\sum_s \beta_{H_s} K_s \sin \theta \phi_{H_s} = \frac{2\pi}{L} |J_{H\theta}| \sin \psi_{H\theta}$$

$$\sum_s \beta_{H_s} K_s \cos 10 \phi_{H_s} = \frac{2\pi}{L} |J_{H10}| \cos \psi_{H10}$$

$$\sum_s \beta_{H_s} K_s \sin 10 \phi_{H_s} = \frac{2\pi}{L} |J_{H10}| \sin \psi_{H10}$$

$$\sum_s \beta_{V_s} K_s \cos \theta \phi_{V_s} = -\frac{2\pi}{L} |J_{V\theta}| \cos \psi_{V\theta}$$

$$\sum_s \beta_{V_s} K_s \sin \theta \phi_{V_s} = -\frac{2\pi}{L} |J_{V\theta}| \sin \psi_{V\theta}$$

$$\sum_s \beta_{V_s} K_s \cos 10 \phi_{V_s} = -\frac{2\pi}{L} |J_{V10}| \cos \psi_{V10}$$

$$\sum_s \beta_{V_s} K_s \sin 10 \phi_{V_s} = -\frac{2\pi}{L} |J_{V10}| \sin \psi_{V10}$$

Moreover, we require that the betatron tunes do not change, that is

$$\sum_s \beta_{H_s} K_s = 0$$

$$\sum_s \beta_{V_s} K_s = 0$$

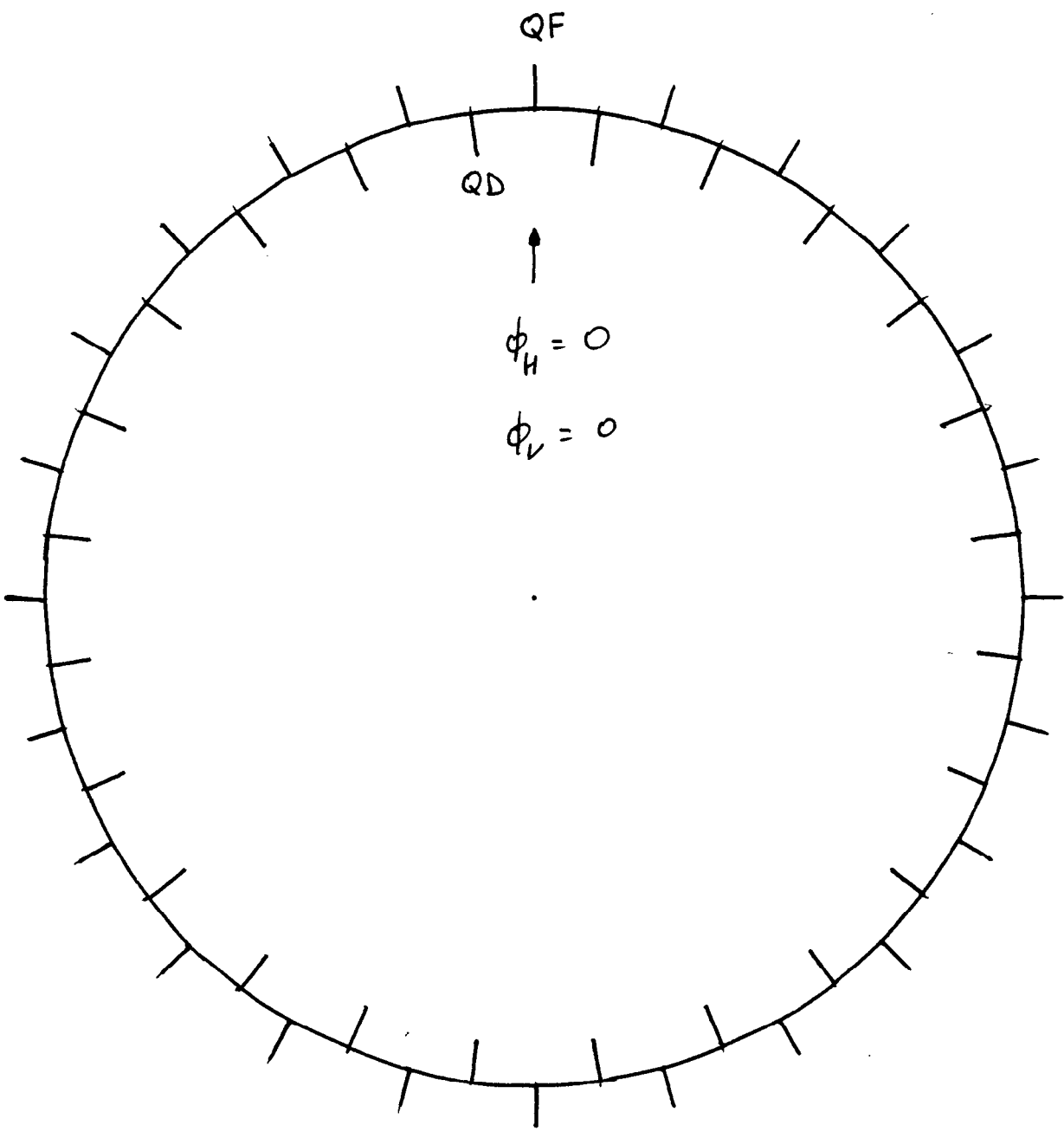
QF, focussing horizontally	$\beta_H = 13.5 \text{ m}$	$\beta_V = 3.5 \text{ m}$
QD, focussing vertically	$\beta_H = 3.5 \text{ m}$	$\beta_V = 13.5 \text{ m}$

Define the origin of ϕ_H and ϕ_V at the location of any QF.

Because of the symmetry build-up in the lattice

$$\phi_{H_s} = \phi_{V_s} = \frac{2\pi}{48} (s-1)$$

$$s = 1, 2, \dots, 48$$



Corrector K_{je}

$$\vec{K}_e = L \left(\underset{QF_1}{K_{1e}}, \underset{QD_1}{K_{2e}}, \underset{QF_2}{K_{3e}}, \underset{QD_2}{K_{4e}}, \dots, \underset{QD_4}{K_{8e}} \right)$$

$$l = 1, 2, \dots, 6$$

$$\vec{K}_e = \vec{K}_1 \cos \frac{\pi}{5} (l-1)$$

This will make $\Delta Q_H = \Delta Q_V = 0$

Thus we are concerned only with the calculation of the components of the vector \vec{K}_1

$$M \vec{K}_1 = \vec{J}$$

$$\vec{K}_1 = M^{-1} \vec{J}$$

$$M^{-1}$$

-0.3533	-0.0000	0.4217	-0.0175	0.0916	0.0000	-0.1093	0.0045
0.0351	0.0846	-0.0327	-0.1044	-0.1352	-0.3264	0.1260	0.4028
-0.8619	-0.2499	0.9703	0.1710	0.2234	0.0648	-0.2515	-0.0443
0.0257	0.2312	-0.0223	-0.2544	-0.0990	-0.8919	0.0860	0.9814
-0.7861	-0.4328	0.9505	0.2593	0.2038	0.1122	-0.2464	-0.0672
-0.0257	0.2312	0.0012	-0.2554	0.0990	-0.8919	-0.0044	0.9852
-0.2499	-0.2499	0.3739	0.1957	0.0648	0.0648	-0.0969	-0.0507
-0.0351	0.0846	0.0239	-0.1068	0.1352	-0.3264	-0.0923	0.4118

$$\vec{J} = \begin{bmatrix} J_{H9} \cos \psi_{H9} \\ J_{H9} \sin \psi_{H9} \\ J_{H10} \cos \psi_{H10} \\ J_{H10} \sin \psi_{H10} \\ - J_{v9} \cos \psi_{v9} \\ - J_{v9} \sin \psi_{v9} \\ - J_{v10} \cos \psi_{v10} \\ - J_{v10} \sin \psi_{v10} \end{bmatrix}$$

$$|J| = 0.01$$

ψ

	0°	30°	60°	90°	120°	150°
	-0.02220	-0.01923	-0.01110	-0.00000	0.01110	0.01923
	0.00220	0.00457	0.00571	0.00532	0.00350	0.00075
	-0.05415	-0.05475	-0.04067	-0.01570	0.01348	0.03905
	0.00161	0.00866	0.01339	0.01453	0.01178	0.00587
	-0.04939	-0.05637	-0.04824	-0.02719	0.00115	0.02918
	-0.00161	0.00587	0.01178	0.01453	0.01339	0.00866
	-0.01570	-0.02144	-0.02144	-0.01570	-0.00575	0.00575
	-0.00220	0.00075	0.00350	0.00532	0.00571	0.00457

$$2Q_H = 9$$

	0°	30°	60°	90°	120°	150°
	0.02649	0.02240	0.01230	-0.00110	-0.01420	-0.02349
	-0.00205	-0.00506	-0.00671	-0.00656	-0.00466	-0.00150
	0.06096	0.05817	0.03979	0.01074	-0.02118	-0.04742
	-0.00140	-0.00921	-0.01455	-0.01599	-0.01315	-0.00678
	0.05972	0.05986	0.04397	0.01629	-0.01575	-0.04357
	0.00007	-0.00796	-0.01386	-0.01605	-0.01393	-0.00809
	0.02349	0.02649	0.02240	0.01230	-0.00110	-0.01420
	0.00150	-0.00205	-0.00506	-0.00671	-0.00656	-0.00466

$$2Q_H = 10$$

	0°	30°	60°	90°	120°	150°
	0.00576	0.00498	0.00288	0.00000	-0.00288	-0.00498
	-0.00850	-0.01761	-0.02201	-0.02051	-0.01352	-0.00290
	0.01404	0.01419	0.01054	0.00407	-0.00349	-0.01012
	-0.00622	-0.03341	-0.05164	-0.05604	-0.04542	-0.02263
	0.01281	0.01461	0.01251	0.00705	-0.00030	-0.00756
	0.00622	-0.02263	-0.04542	-0.05604	-0.05164	-0.03341
	0.00407	0.00556	0.00556	0.00407	0.00149	-0.00149
	0.00850	-0.00290	-0.01352	-0.02051	-0.02201	-0.01761

$$2Q_V = 9$$

	0°	30°	60°	90°	120°	150°
	-0.00687	-0.00581	-0.00319	0.00028	0.00368	0.00609
	0.00792	0.01951	0.02588	0.02531	0.01796	0.00580
	-0.01581	-0.01508	-0.01031	-0.00279	0.00549	0.01230
	0.00540	0.03551	0.05611	0.06167	0.05070	0.02616
	-0.01548	-0.01552	-0.01140	-0.00422	0.00408	0.01130
	-0.00028	0.03071	0.05347	0.06190	0.05375	0.03119
	-0.00609	-0.00687	-0.00581	-0.00319	0.00028	0.00368
	-0.00580	0.00792	0.01951	0.02588	0.02531	0.01796

$$2Q_V = 10$$

At Injection

$$B_p = 2.15 \text{ T}\cdot\text{m}$$

$$\frac{B'L}{B_p} < 0.1 \text{ m}^{-1}$$

$$L = 0.5 \text{ m}$$

$$B' < 43 \text{ G/cm}$$

$$\text{Pole Tip Radius} = 8.255 \text{ cm}$$

$$(a) \text{ Pole Tip Field} < 355 \text{ Gauss}$$

$$(b) \text{ Maximum Pole Tip Field} = 8.3 \text{ KG}$$

$$(a)/(b) < \frac{0.355}{8.3} = 4.3\%$$

*) Eliminate the zero-tune-drift conditions

still require δ conditions for a total of 4 stopbands

$$\vec{k}_l = \vec{k}_1 \cos \frac{\pi}{2} (l-1)$$

$$l = 1, 2, \dots, 6$$

$$\frac{k}{k_{max}} \sim 1.8\%$$

Small tune-drift ~ 0.02

(*) Only Four conditions for

• $2Q_H = 9$
 $2Q_V = 9$ stop bands

$$\vec{K}_l = \vec{K}_1 \cos \pi(l-1) \quad l = 1, 2, \dots, 6$$

$$\frac{K}{K_{max}} \sim 0.3 \%$$

No tune - shift

(*) Only Four conditions for

$$2 Q_H = 10$$

$$2 Q_V = 10$$

stop bands

$$\vec{K}_l = \vec{K}_1 \cos \frac{\pi}{3} (l-1)$$

$$l = 1, 2, \dots, 6$$

$$\frac{K}{K_{max}} \sim 0.45 \%$$

No tune-drift