

?-Splitting Due to Random Skew Quadrupole Fields

G. Parzen

November 1988

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.

ν -Splitting Due to Random Skew Quadrupole Fields

G. Parzen

BNL

November 28, 1988

①

Random a_1 and ν -splitting

Random a_1 in magnets causes coupling and ν -splitting. ν -splitting is important because ν -values are required to lie between .8000 and .8333 (the box between the $4/5$ and $5/6$ resonances which is 33×10^{-3} wide) (see Fig 1B)

The coupling introduces 2 ~~coupled~~ modes of oscillation with the ν -values ν_1 and ν_2 . Both ν -values are present in the x and y oscillations.

~~ν_1~~ ν_1 and ν_2 are given by

$$\nu_1 = \nu_x + |\Delta\nu|$$

$$\nu_2 = \nu_y - |\Delta\nu|$$

$$\Delta\nu = \frac{1}{4\pi} \int ds (\beta_x \beta_y)^{1/2} \frac{a_1}{\rho} e^{i(\psi_x - \psi_y)}$$

provided $\nu_x \approx \nu_y$, and correct to first order in a_1 , and $|\Delta\nu| \gg |\nu_x - \nu_y|$.

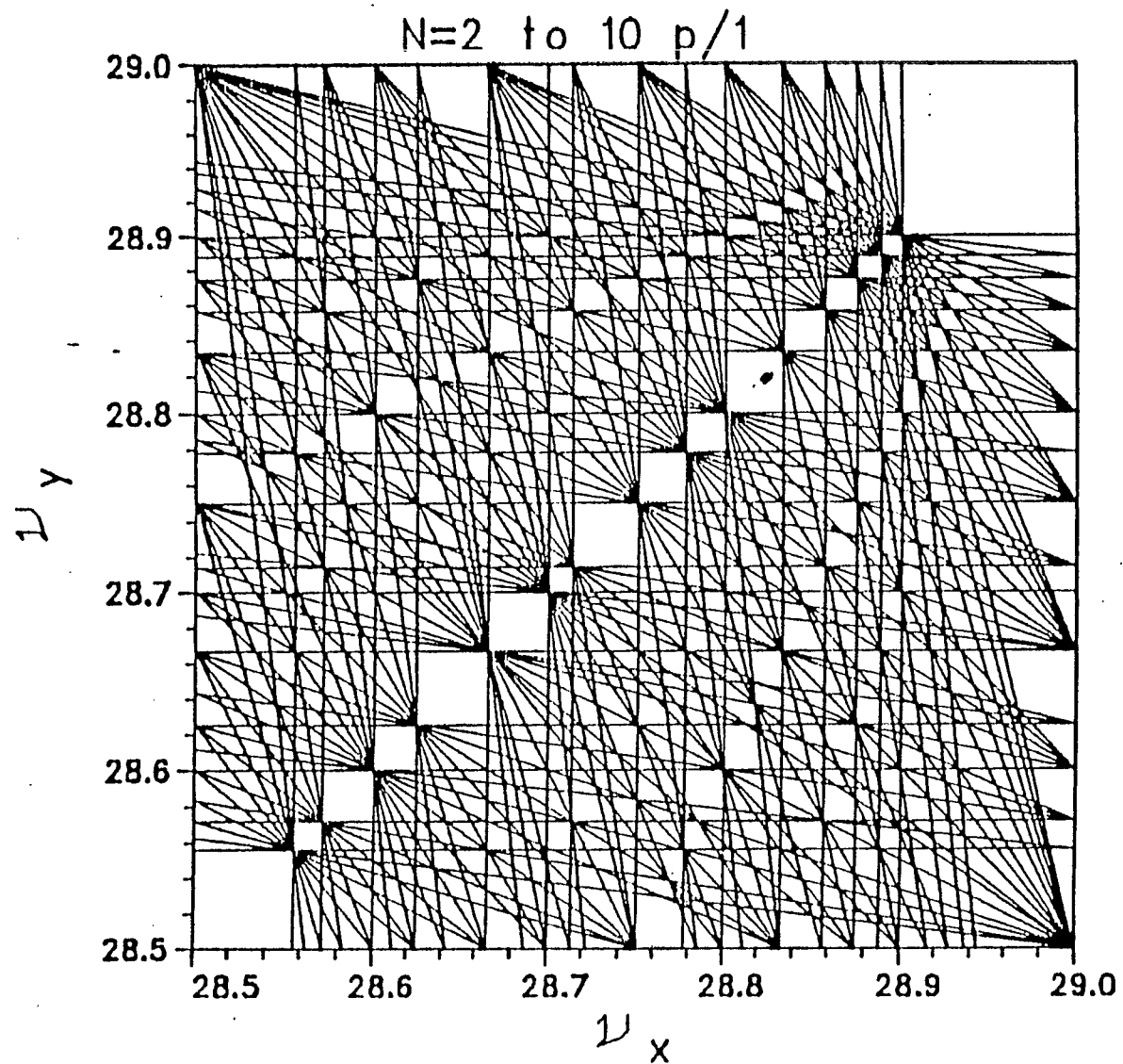
For $a_1 = 17 \times 10^{-5}$ /cm in dipoles rms

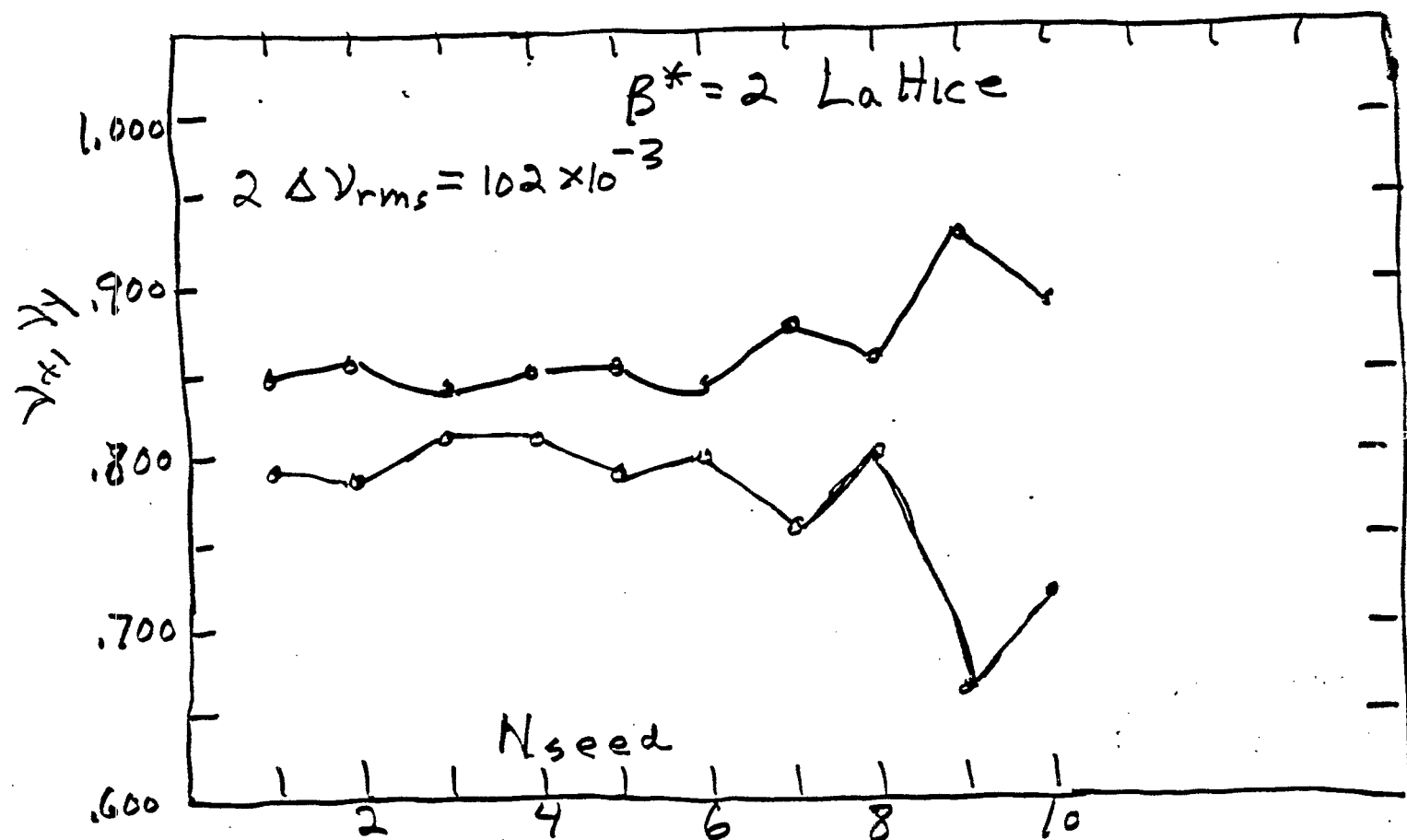
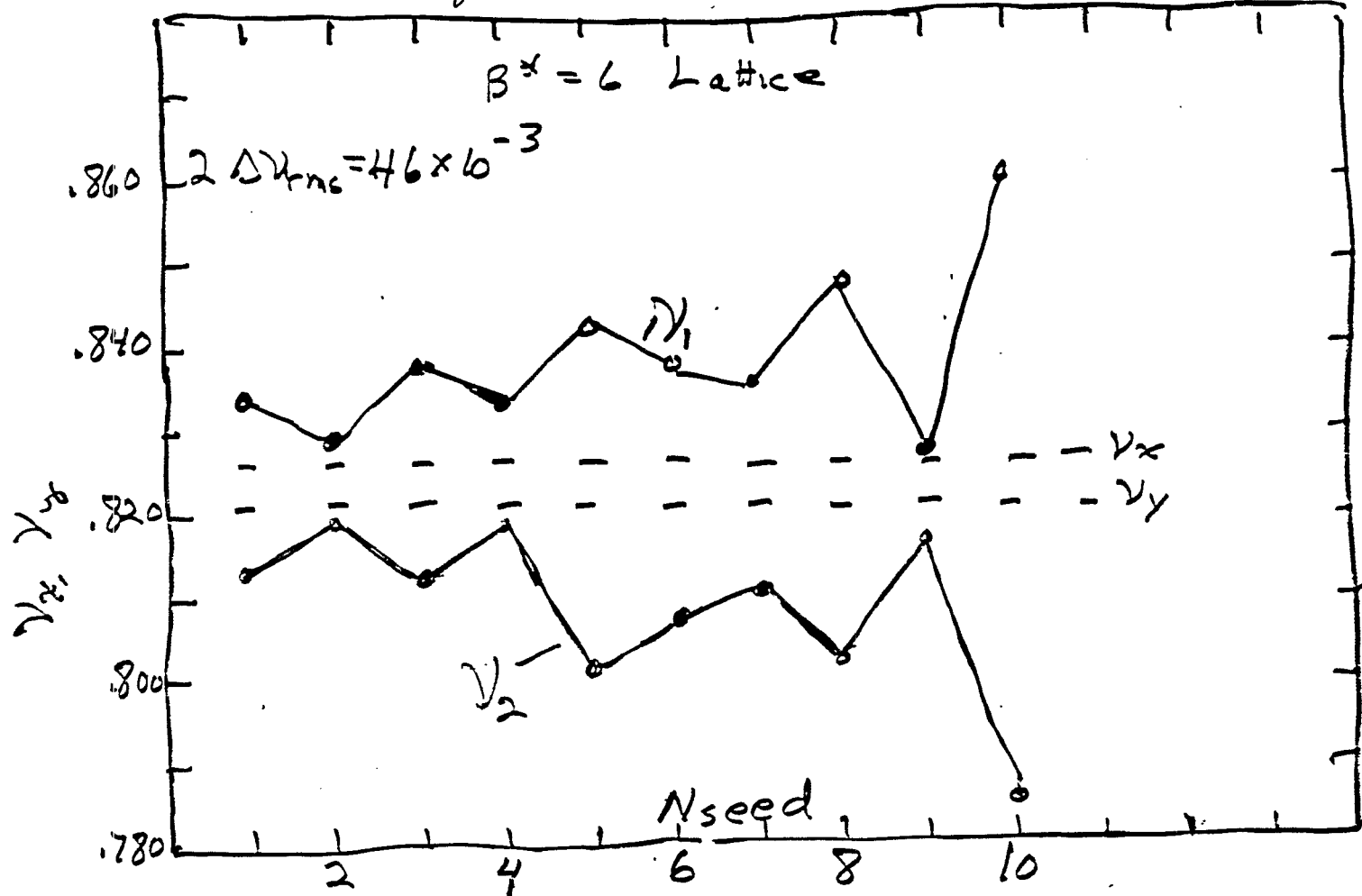
$a_1 = 40 \times 10^{-5}$ /cm in quadrupoles rms ($\Delta\theta = 1$ mrad rotation error)

tracking runs for 10 different set of random errors gives

$$(\Delta\nu_{\text{splitting}})_{\text{max}} = (\nu_1 - \nu_2)_{\text{max}} = 97 \times 10^{-3} \quad \beta^* = 6$$

$$= 260 \times 10^{-3} \quad \beta^* = 2$$





Magnet sources of V-splitting

$$2 \cdot \Delta V_{rms}$$

	$\beta^* = 6$	$\beta^* = 2$
B	.028	.028
QF	.006	.006
QD	.006	.006
Q3I	.008	.025
Q2I	.018	.052
Q1I	.009	.025
Q10	.009	.025
Q20	.018	.052
Q30	.008	.025
Total $2 \Delta V_{rms}$	.046	.102
$\Delta V_{splitting max}$	97×10^{-3}	260×10^{-3}

aligning Q2I, Q20 more accurately
than $\Delta \theta = 1 \text{ mr rms}$ would help.

Correction of γ -splitting

γ -splitting determined by $\Delta\gamma$

$$\Delta\gamma = \frac{1}{4\pi} \int ds (\beta_x \beta_y)^{1/2} \frac{Q_1}{\rho} e^{i(\psi_x - \psi_y)}$$

At the quads, QD and QF in the arcs,

$$\psi_x - \psi_y \approx \text{constant} \quad \text{or} \quad \psi_x - \psi_y \approx 0$$

$$\Delta(\psi_x - \psi_y) = \int ds \left(\frac{1}{\beta_x} - \frac{1}{\beta_y} \right) \approx 0 \quad \text{between quads.}$$

If the quadrupoles were the only source of Q_1 , then $\Delta\gamma$ is real, and a 1-power supply correction system to make $\langle Q_1 \rangle = 0$ would be sufficient.

For the dipoles in the arcs

$$\psi_x - \psi_y \approx \pm 0.3(2\pi) \approx \pm 1.2 \text{ rad.}$$

For Q2 when $\beta^* = 2$

$$\psi_x - \psi_y \approx \pm 1.8(2\pi) \approx \pm 1 \text{ rad}$$

$\Delta\gamma$ is Complex with an appreciable imaginary part.
2 family power supply correction system is required.

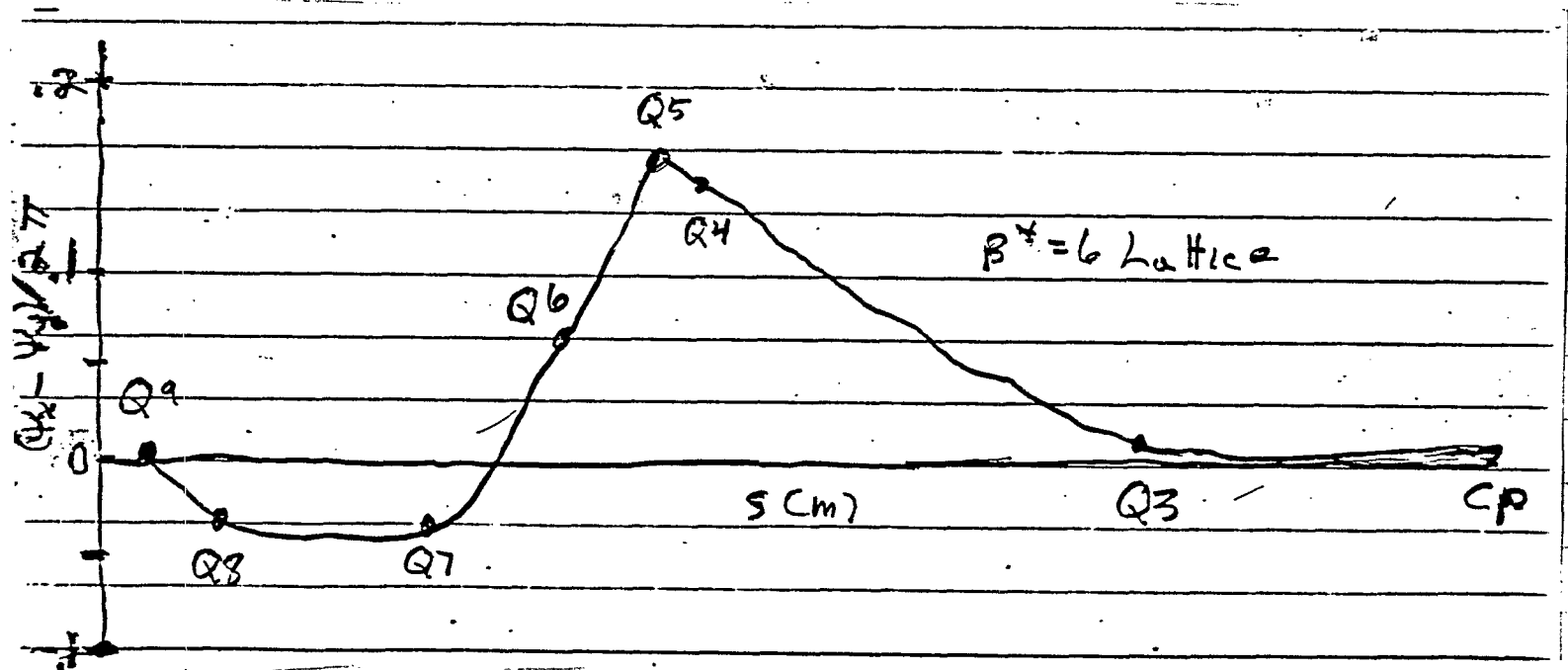
Where to put Q_i Correctors

At Q_2, Q_3 where β_x, β_y are large

But, two Q_i families need to have different values of $\psi_x - \psi_y$.

$\beta^* = 6$ Lattice

Near Q_2, Q_3 , $\psi_x - \psi_y \approx 5 \times 10^{-4} (2\pi) \approx .003$
only 1 family can be near Q_2, Q_3



Near Q_5 , $\psi_x - \psi_y \approx \pm .16 (2\pi)$

Second family can be near Q_5 .

Q₁ Correctors Location (Continued)

$\beta^* = 2$ Lattice

$\psi_x - \psi_y \approx \pm .18 (2\pi)$ near Q_2
alternates between Crossing points

1 family near Q_2 at inner arc to
outer arc crossing points.

Second family near Q_2 at outer arc to
inner arc crossing points.

Coupling Correction - $\beta^* = 6$ lattice

(7)

N_{seed}	Un Corrected					Corrected				
	$\Delta V/10^{-2}$	V_1	V_2	$ V_1 - V_2 /10^3$		$A1L(1)$	$A1L(2)$	V_1	V_2	$ V_1 - V_2 /10^3$
1	-1.1	-.03	.834	.813	16	.004	.085	.826	.821	5
2	-.58	.04	.829	.819	5	-.028	.047	.826	.821	5
3	1.50	.41	.838	.813	20	-.213	-.10	.829	.821	8
4	-.51	-.26	.833	.819	9	.144	.029	.829	.822	7
5	-2.22	.41	.843	.801	37	-.262	.192	.822	.817	5
6	1.24	-.24	.838	.808	25	.152	-.108	.825	.819	6
7	1.39	-.15	.836	.811	20	.104	-.116	.826	.820	6
8	-2.6	-.21	.848	.802	41	.083	.194	.828	.819	9
9	.45	.35	.827	.817	5	-.193	-.021	.824	.819	5
10	3.91	-.33	.861	.815	70	.242	-.321	.821	.814	7

$$a1L = \int ds a_1 = A1L/B_0, \quad A1L = \int ds B_0 a_1$$

$$\text{Maximum Correction, } A1L = .32 \times (97/70) \times 34.5 \text{ KG} \\ = 15 \text{ KG}$$

$$V\text{-splitting, } |V_1 - V_2| \leq 70 \times 10^{-3}$$

$$\text{Corrected to } |V_1 - V_2| \leq 9 \times 10^{-3}$$

$$\text{Loss of } 4 \times 10^3 \text{ of box width} = 33 \times 10^{-3}$$

$$V\text{-values } (q_1 = 0) \quad .826, .821 \quad |V_1 - V_2| = 5 \times 10^{-3}$$

Correctors at $\phi 2I, \phi 5I$ of

inner arc to outer arc in sections

Coupling Correction

 $\beta^* = 2$ lattice

(8)

Uncorrected						Corrected				
N_{seed}	$\Delta y/10^{-2}$	y_1	y_2	$ y_1 - y_2 /10^{-3}$		$q_{1L}(1)$	$q_{1L}(2)$	y_1	y_2	$ y_1 - y_2 /10^{-3}$
1	-1.29, 2.21	.850	.796	49		.071	.006	.828	.820	8
2	-1.19, 3.25	.860	.789	66		.053	-.043	.828	.821	7
3	1.19, .59	.840	.819	16		-.027	-.046	.833	.827	6
4	-1.16, .73	.851	.818	28		.046	.025	.842	.828	14
5	-2.52, 2.19	.856	.791	60		.108	.045	.826	.819	7
6	1.72, .56	.842	.802	35		-.044	-.062	.825	.816	9
7	1.46, -5.16	.878	.759	114		-.120	.033	.825	.819	6
8	-2.78, -.48	.857	.805	47		.076	.033	.836	.827	9
9	.71, -11.3	.930	.666	259		-.187	.149	.827	.820	7
10	1.09, -5.14	.890	.770	115		-.108	.044	.839	.828	11

Maximum Correction, $A1L = (.19)(34.5) = 6.6 \text{ KG}$

V-splitting, $|y_1 - y_2| \leq 259 \times 10^{-3}$

Corrected to $|y_1 - y_2| \leq 14 \times 10^{-3}$

Loss of 9×10^{-3} of the box width 33×10^{-3}

V-values ($q_i = 0$), .826, .821 $|y_1 - y_2| = 5 \times 10^{-3}$

Correctors at Q2I of inner arc to outer arc insertion
Q2O of outer arc to inner arc insertion

Using Q2, Q5 correctors increases A1L
required by factor 12.

Suggested Conclusions

1) 3 families of Q_1 correctors
with 3 separate power supplies.

2) family one, before Q_{2I} in inner arc
to outer arc insertions

3) family two before Q_{20} in outer arc
to inner arc insertions

4) family three before Q_{50} in ^{outer} arc
to ^{inner} arc insertions (to avoid
 Q_{5I} at 6 o'clock (J. Claus))

5) Required strength $A_{1L} = 15 \text{ KG}$
 $A_{1L} = \int ds B_0 a_1$