

The β -dependence on Momentum and Betatron Amplitude in RHIC Due to Random Error Field Multipoles

G. Parzen

February 1986

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.

The ν -dependence on Momentum and Betatron Amplitude
in RHIC Due to Random Error Field Multipoles

G. Parzen

BNL

December 9, 1986

Introduction:

Studies of the dependence of the ν -values on particle momentum $\Delta p/p$, and in the betatron amplitude, A show that the random error field multipoles can produce large changes in the ν -values at the larger values of A and $\Delta p/p$, that may cause the particle to cross resonances of lower order than the tenth. According to the experience at the SPS, the crossing of such resonances may cause beam losses.

In the basic operating region for RHIC, $A \leq 18 \text{ mm} \approx \Delta p/p \leq .005$, some particles have ν -shifts which move the particle out of the basic operating square, and the particle crosses resonances of lower order than the tenth. This appears to happen only for some particles with large betatron amplitudes, A , and the effect does not seem likely to affect the performance by much. The ν -shifts in the operating region for colliding beams is primarily due to betatron amplitude, A .

At large $\Delta p/p$, $\Delta p/p \approx .01$, large ν -shifts are observed, which are primarily due to $\Delta p/p$. This was observed by F. Dell. This occurs at larger $\Delta p/p$ which are outside the basic operating region for colliding beams. Also this effect is probably correctable with b_2 , b_3 , b_4 correction coils. ν -shifts due to A are more difficult to correct, as this shift depends on the size of the horizontal and vertical betatron amplitudes, and is different in different directions in betatron amplitude space.

The studies reported on in this note were done for particles with equal initial horizontal and vertical emittances, ϵ_x and ϵ_y . More studies are needed for the case when $\epsilon_x \neq \epsilon_y$.

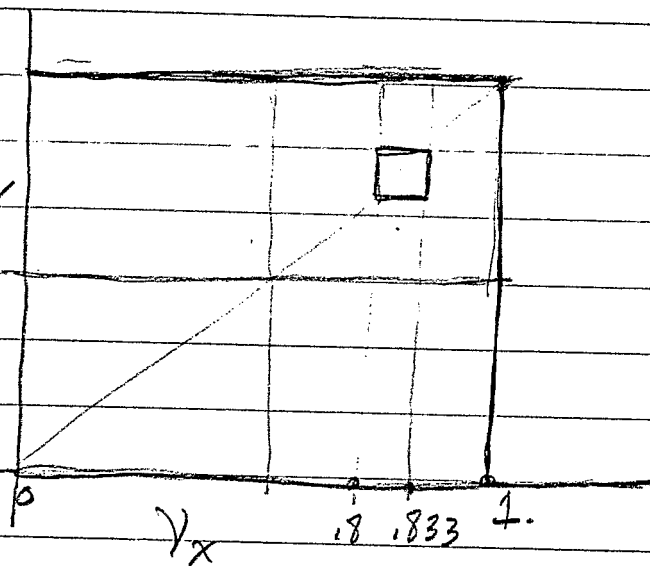
①

Allowed ν -limits

$$\nu = 28.826, 28.821$$

in box,
boundaries are
.80, .833

(4/5 and 5/6 resonances)



Generalized ν -Values

Fourier analyze x and y motion; find frequencies in each motion

$$x \rightarrow \underline{\nu_1}, \nu_2, \nu_3, \nu_4, \dots$$

$$y \rightarrow \nu_1, \underline{\nu_2}, \nu_3, \nu_4, \dots$$

Motions are coupled and x and y motions have same $\nu_1, \nu_2, \nu_3, \dots$

Largest x component is ν_1 , largest y component is ν_2 .

ν_1, ν_2 are primary ν -values

ν_3, ν_4 etc are secondary ν -values.

Comments

In operating Region, $A_\beta \leq 17 \text{ mm}_z$
 $\Delta P/P \leq \pm 0.05$, primary V -values are all in square.
 Secondary V -values go out of square.
 Worst case is* $V(A, P) = .852$, $\Delta V(A, P) = .026$
 and is entirely due to amplitude, A .

In the operating region, $V(A)$ dominates
 and $V(P)$ is small. $V(A) \leq .026$,
 $V(P) \leq \overset{.007}{\cancel{.026}}$

At large $\Delta P/P$, $\Delta P/P \approx \pm 0.1$, $V(P)$ dominates.

Worst case is $V(A, P) = .862$; $\Delta V(P) \leq .028$,

$V(A) \leq .01$ (smaller A allowed at large $\Delta P/P$)

Primary V -values go out of square
 primarily due to $\Delta V(P)$.

linear

(*) Note, the V -values for $\Delta P/P = 0$ are $V_x = 28.826$,
 $V_y = 28.821$

and only the fractional part of V is usually listed.

Comments (continued)

In the computer runs done to find $\nu(A, \rho)$, $E_x = E_y$ for the initial conditions, and amplitudes up to $A = 17$ mm were included in the study.

If the required A , when $E_x = E_y$, is only 13 mm, then the ν due to betatron amplitude will be much reduced in this study.

Other directions in the initial E_x, E_y have not been studied very much. When $E_x \neq E_y$, the ν dependence on A is quite different from that ~~is~~ found in the $E_x = E_y$ case.

V-dependence on A and OP/P due to

4

Random error Field multiples

B*	6	6	6	3
OP/P	0	$\pm .005$	$\pm .01$	0
Primary V	all stay in square	All stay in square		all stay in square
	$V(A,P) \approx .820$	$V(A,P) \approx .830$	$V(A,P) \approx .862$	$\Delta V(A,P) \approx .832$
	$\Delta V(A,P) \approx .017$	$\Delta V(A,P) \approx .019$	$\Delta V(A,P) \approx .036$	$\Delta V(A,P) \approx .01$
	$\Delta V(A) \approx .017$	$\Delta V(A) \approx .026$	$\Delta V(A) \approx .011$	$\Delta V(A) \approx .01$
	$\Delta V(P) = 0$	$\Delta V(P) \approx .007$	$\Delta V(P) \approx .028$	$\Delta V(P) = 0$
Secondary V	$V(A,P) \approx .852$	$V(A,P) \approx .847$	Secondary V less important than primary V.	$V(A,P) \approx .837$
	$\Delta V(A,P) \approx .026$	$\Delta V(A,P) \approx .021$		$\Delta V(A,P) \approx .01$
	$\Delta V(A) \approx .026$	$\Delta V(A) \approx .018$		$\Delta V(A) \approx .01$
Linear OP/P = 0 V-values	28.826, 28.821			28.827, 28.821

$V(p)$ due to random field errors

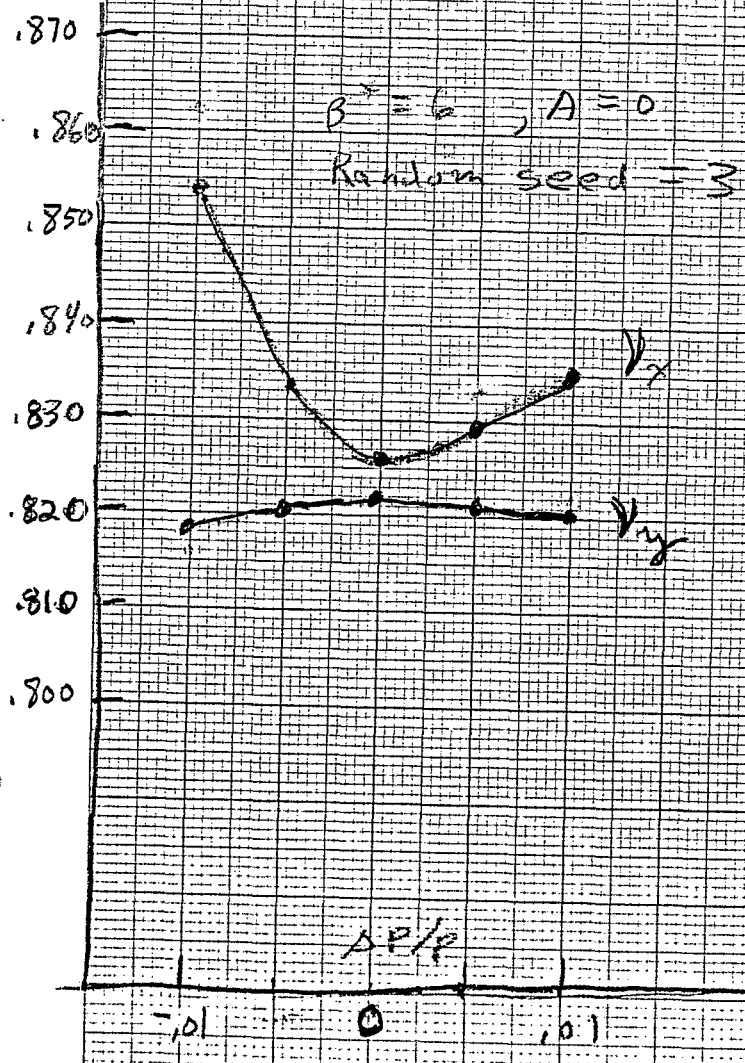
$A = 0$

Worst Case Random Seed

SQUARE 10 X 10 TO THE HALF INCH AS 1613 - 60

GRAPHIC CONTROLS CORPORATION
Buffalo, New York Printed in U.S.A.

GRAPH PAPER



V Dependence on P/P

Sextupoles only (no random field errors)

$$\beta^* = 6, \quad \Delta \frac{p}{p} = \pm 0.005, \quad \Delta V = 0.0025$$

$$\Delta \frac{p}{p} = \pm 0.01 \quad \Delta V = 0.008$$

$$\beta^* = 3 \quad \Delta \frac{p}{p} = \pm 0.0025, \quad \Delta V = 0.0025$$

The chromatic variations in the γ -values for the accelerator with ^{random} no multiple errors is not large in the region of planned operation.