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The ?-dependence on Momentum and Betaton Amplitude in RHIC Due to Random Error Field Multipoles

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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, $A \leq 18$ mm $\cong \Delta p/p \leq .005$, 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.

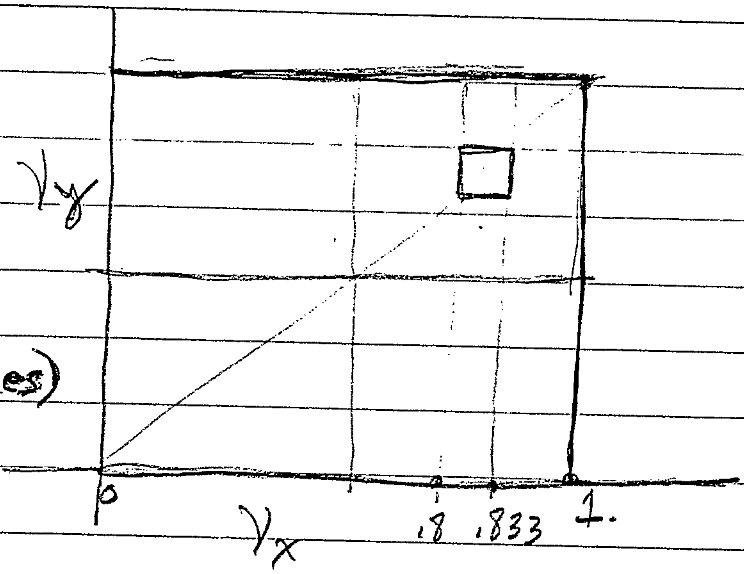
At large $\Delta p/p$, $\Delta p/p \cong .01$, large ν-shifts are observed, which are primarily due to $\Delta p/p$. This was observed by F. Dell. This occurs at larger $\Delta p/p$ which are outside the basic operating region for colliding beams. Also this effect is probably correctable with b_2, b_3, 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 $\varepsilon_x \neq \varepsilon_y$.

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

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

Motions are coupled and x and y motions have same ν_1 ν_2 ν_3, ...
Largest x component is ν_1, largest y component is ν_2.
ν_1, ν_2 are <u>primary</u> ν-values
ν_3, ν_4 ~~etc~~ are <u>secondary</u> ν-values.

Comments

In operating Region, $A_\beta \leq 17$ mm,
$\Delta P/p \leq \pm .005$, primary ν-values are all in square,
Secondary ν-values go out of square.
Worst case is* $\nu(A,p) = .852$, $\Delta\nu(A,p) = .026$
and is entirely due to amplitude, A.

In the operating region, $\nu(A)$ dominates
and $\nu(p)$ is small. $\nu(A) \leq .026$,
$\nu(p) \lesssim .007$

At large $\Delta P/p$, $\Delta P/p \simeq \pm .01$, $\nu(p)$ dominates.
Worst case is $\nu(A,p) = .862$; $\Delta\nu(p) \leq .028$,
$\nu(A) \lesssim .01$ (smaller A allowed at large $\Delta P/p$)
Primary ν-values go out of square
primarily due to $\Delta\nu(p)$.

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* Note, the linear ν-values for $\Delta P/p = 0$ are $\nu_x = 28.826$,
$\nu_y = 28.821$
and only the fractional part of ν is usually listed.

Comments (continued)

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

If the required A, when $\varepsilon_x = \varepsilon_y$, is only 13 mm, then the $\Delta\nu$ due to betatron amplitude will be much reduced in this study.

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

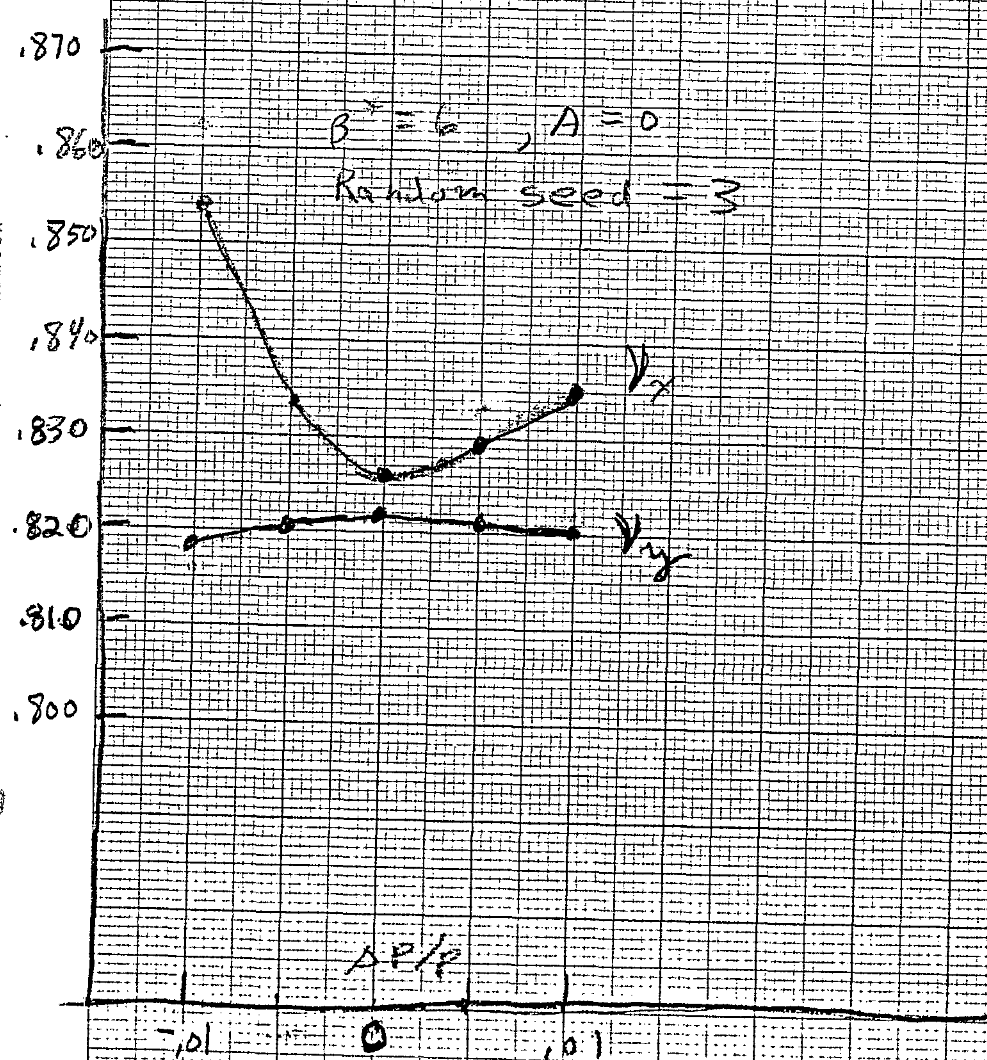
ν-dependence on A and $\Delta p/p$ due to Random error Field multipoles

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

ν(p) due to random field errors

A = 0

Worst Case Random Seed



ν Dependence on $\Delta p/p$

Sextupoles only (no random field errors)

$\beta^* = 6$, $\Delta p/p = \pm .005$, $\Delta\nu = .0025$

~~$\Delta p/p = \pm .01$ $\Delta\nu = .008$~~

$\beta^* = 3$ $\Delta p/p = \pm .0025$, $\Delta\nu = .0025$

The chromatic variations in the ν-values for the accelerator with no random multipole errors is not large in the region of planned operation.