BNL-101736-2014-TECH

RHIC/AP/81;BNL-101736-2013-IR

The Residual ?-Shift Due to Random Skew Quadrupole Errors

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April 1989

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AD/RHIC-AP-81

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April 16, 1989

The ν-shift due to the random a_1

The random a_1 introduces two coupled modes with ν-values ν_1 and ν_2. The x-motion and the y-motion now have both ν-values ν_1 and ν_2.

$$x = (\ )e^{i\nu_1\theta} + (\ )e^{i\nu_2\theta}$$
$$y = (\ )e^{i\nu_1\theta} + (\ )e^{i\nu_2\theta}$$

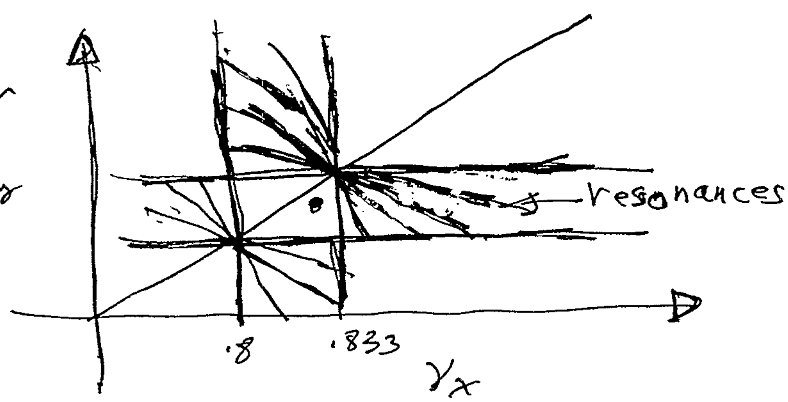
The ν_1, ν_2 can differ appreciably from the original ν_x, ν_y.

Is this ν-shift due to a_1 dangerous?

Review of the ν-shift due to random b_1

The b_1 ν-shift is easier to understand.

The resonance lines $n_x\nu_x + n_y\nu_y = \text{integer } n$ are considered dangerous if a time modulation of the ν-values is present. A ν-shift due to b_1 which shifts ν_x, ν_y out of the resonance free box is considered dangerous.



ν-shifts due to a_1

In this case the ν_x, ν_y diagram is not as useful, I think ~~(it is still true one)~~ that, just as in the ν-shifts due to b_1 case, one needs to avoid the resonance lines $n_1 \nu_1 + n_2 \nu_2 = \text{integer}$. This become difficult when the shift in ν_1 and ν_2 becomes comparable to 33×10^{-3}.

The expected ν-shifts in RHIC are

$$|\nu_1 - \nu_2|_{max} \simeq 100 \times 10^{-3} \quad \text{for } \beta^* = 6$$
$$|\nu_1 - \nu_2|_{max} \simeq 250 \times 10^{-3} \quad \text{for } \beta^* = 2$$

The ν-shifts due to a_1 cannot be corrected with b_1 correctors such as QF and QD.

The ν-shifts due a_1 and b_1 are given by

$$|\nu_1 - \nu_2| = 2 \left\{ \left(\frac{\nu_x - \nu_y}{2}\right)^2 + |\Delta\nu_{11}|^2 \right\}^{1/2}$$

$$\Delta\nu_{11} = \frac{1}{4\pi\rho} \int ds \, (\beta_x \beta_y)^{1/2} a_1 \exp i(\psi_x - \psi_y)$$

$$\nu_{av} = (\nu_1 + \nu_2)/2 = (\nu_x + \nu_y)/2$$

where ν_x, ν_y are ν-values when $a_1 = 0$.
Above correct to first order in a_1

b_1 correctors can be used to move ν_x, ν_y
The best one can do is make $\nu_x = \nu_y$ and
then $|\nu_1 - \nu_2| = |\Delta\nu_{11}|$
$\nu_{av.}$ ca be controlled using the b_1 correctors.

Global Correction System

Two families of skew quads
can be adjusted to make $\Delta\nu_{11} = 0$
This should correct the ν-splitting to

$$|\nu_1 - \nu_2| = |\nu_x - \nu_y|$$

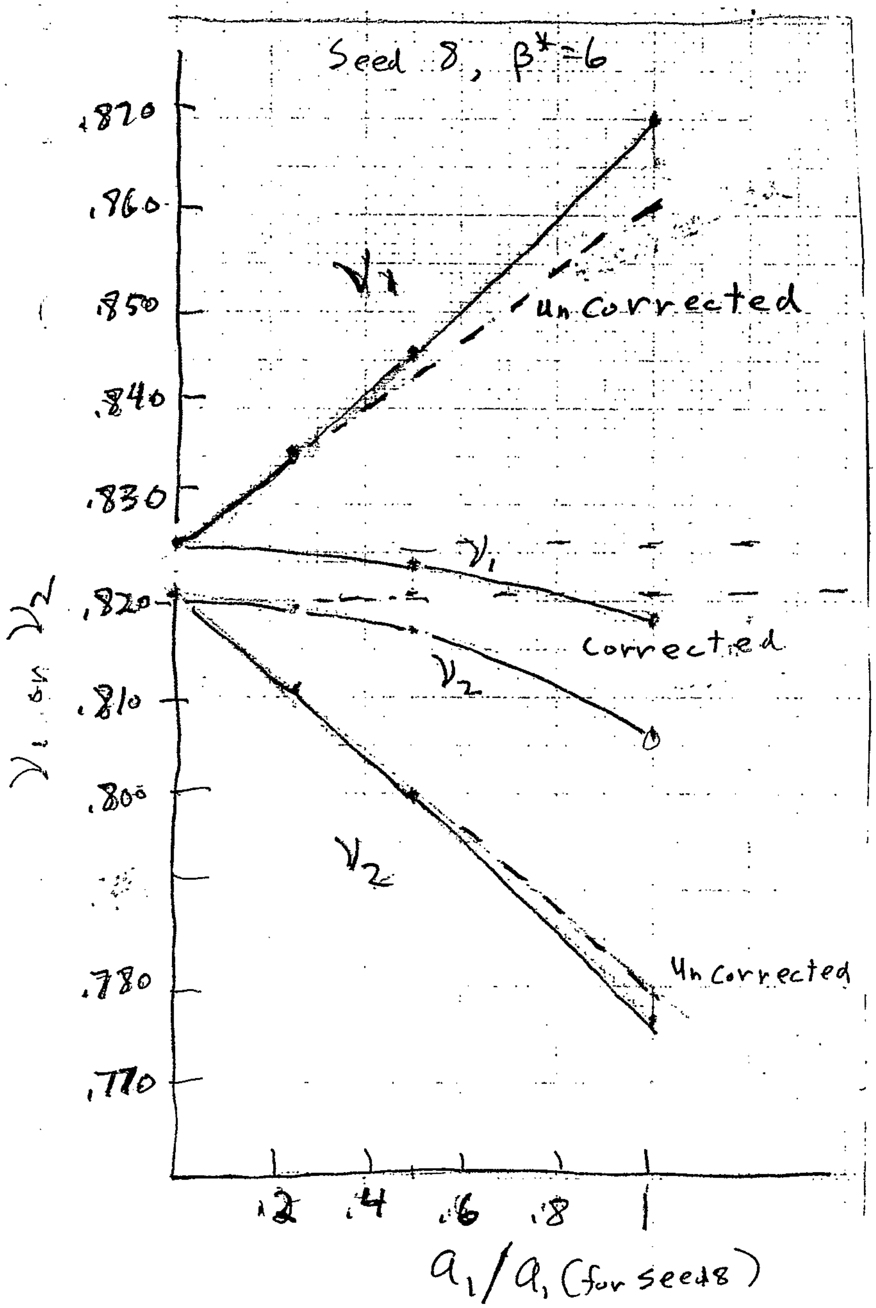
Results for the Global Correction System

	$\beta^* = 6$						$\beta^* = 2$					
	Un Corrected			Corrected			Uncorrected			Corrected		
N_{seed}	ν_1	ν_2	$\lvert\nu_1-\nu_2\rvert/10^{-3}$	ν_1	ν_2	$\lvert\nu_1-\nu_2\rvert/10^{-3}$	ν_1	ν_2	$\lvert\nu_1-\nu_2\rvert/10^{-3}$	ν_1	ν_2	$\lvert\nu_1-\nu_2\rvert/10^{-3}$
1	.844	.801	43	.825	.819	6	.854	.796	58	.828	.822	6
2	.868	.789	79	.822	.811	11	.935	.707	228	.838	.819	19
3	.855	.795	60	.826	.820	6	.869	.783	86	.829	.825	4
4	.864	.783	81	.824	.815	9	.883	.772	111	.830	.823	7
5	.841	.820	21	.832	.818	14	.872	.778	94	.836	.820	16
6	.824	.815	9	.828	.820	8	.848	.805	43	.832	.821	11
7	.836	.818	18	.830	.822	8	.847	.840	7	.852	.834	18
8	.872	.772	100	.820	.805	15	.895	.741	154	.838	.818	20
9	.845	.805	40	.826	.821	5	.866	.785	81	.828	.822	6
10	.854	.811	43	.827	.821	6	.891	.749	142	.827	.822	5

In a fair number of machines, there is a large residual $|\nu_1 - \nu_2|$. In 3 cases for $\beta^* = 6$ and for 5 cases for $\beta^* = 2$, the residual $|\nu_1 - \nu_2|$ is about 11×10^{-3} to 20×10^{-3}.

This appears to be due to terms in $|\nu_1 - \nu_2|$ which go like a_1^2 or higher powers of a_1.

ν_1, ν_2 versus a_1



Local Correction System

It appears that the correction of the residual $|\nu_1 - \nu_2|$ requires a more local correction system

A possible local correction is the a_1 Correctors near QD in the arcs.

Using these correctors, assuming each a_1 corrector can be individually powered, the following $|\nu_1 - \nu_2|$ was achieved

	$\beta^{x} = 6$	
N_{seed}	Global Correction $\|\nu_1 - \nu_2\|/10^{-3}$	Local Correction $\|\nu_1 - \nu_2\|/10^{-3}$
8	15	6.4
5	13	6.6
2	10	5.0
	$\beta^{*} = 2$	
8	20	7.2
7	18	7.5
6	11	6.8
5	16	4.0
2	19	7.5

Further correction could be achieved by making $\nu_x = \nu_y$ using b_1 Correctors.

Some Unsolved Problems

1) How well can 4-families of a_1 correctors per sextant do?

2) What measurements can one do to help set the local a_1 correctors?

3) Can one correct the residual $|\nu_1 - \nu_2|$ and the reduction in A_{SL} due a_1 simultaneously with the same a_1 correctors.