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Magnet Shuffling for the RHIC

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DISCLAIMER

RHIC-AP-23

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Magnet Shuffling for the RHIC (?)

1. Remarks

a) Correction Systems (What type, How many Families. How to tune them. What on Day One).

b) Magnets in the insertions are special. special consideration at the colliding points.

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skew quadrupoles at Q2 or Q3 to control the coupling, $\nu_x - \nu_y = 0$.

At Q2 or Q3.

(1) $\beta^* = 3m$, two families are orthogonal.

(2) $\beta^* = 6m$, two families are NOT independent.

$$(\Psi_x - \Psi_y) - (\nu_x - \nu_y)\cdot\theta$$

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2. "Local" vs "Global"

"Closed Form" vs "Fourier Series"

Example

1. isolated resonances, resonance extraction.

2. localized source of errors (e.g. elements in insertions)

① ΔX_p by b_1

$$(\Delta\hat{X}_p) \equiv \frac{\Delta X_p}{\sqrt{\beta_x}} + i \langle \Delta X_p' + \frac{\alpha_x}{\beta_x}\cdot \Delta X_p \rangle \cdot \sqrt{\beta_x}$$

"Global" (b_1 distributed around the ring)

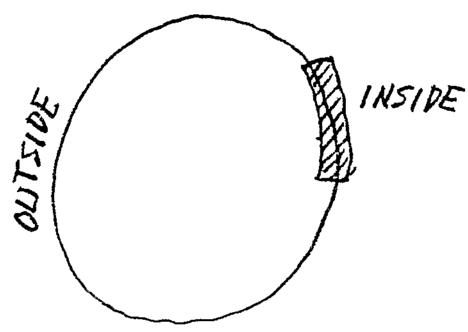
$$(\Delta\hat{X}_p)_\phi = \sqrt{\beta_x(\phi)}\cdot \nu_x^2 \cdot \sum_{-\infty}^{\infty} \frac{a_n}{\nu_x^2 - n^2}\cdot e^{in\phi_x} \quad ; \phi \equiv \psi/\nu$$

$$a_n = \frac{1}{2\pi\nu_x}\cdot \sum_{k}^{N} \left[\left(-\frac{\ell}{\rho}\right)\cdot b_1 \cdot X_p \cdot \sqrt{\beta_x}\, e^{-in\phi_x} \right]_k$$

Error b_1 at $k=1$ to N.

"Local" (b_1 confined to localized area)

OUTSIDE vs INSIDE



$$(\Delta\hat{X}_p)_0 = \frac{e^{-i\pi\nu}}{2\sin(\pi\nu)}\cdot \sum_{k}^{M} \left[\left(-\frac{\ell}{\rho}\right) b_1 \sqrt{\beta_x} X_p \cdot e^{i\psi_x} \right]_k$$

If $\underbrace{\left(-\frac{\ell}{\rho}\right)\cdot\sqrt{\beta_x}\cdot X_p}$ is the same at $k = 1 \sim M (\ll N)$

$$(\Delta\hat{X}_p)_0 = 0 \longrightarrow \boxed{\sum_{k}^{M} (b_1 \cdot e^{i\psi_x})_k = 0}$$

Confine the effect within the localized area.

② $\underline{Y_p \text{ by } a_1}$

$x \rightarrow y; \quad b_1 \rightarrow a_1$

"Local" $\left[\left(\frac{\ell}{\rho}\right) \cdot a_1 \cdot X_p \cdot \sqrt{\beta_y} \cdot e^{i\psi_y} \right]_k \longrightarrow \sum_k^M (a_1 e^{i\psi_y})_k = 0$

"Global" $\left[\left(\frac{\ell}{\rho}\right) \cdot a_1 \cdot X_p \cdot \sqrt{\beta_y}\, e^{-in\phi_y} \right]_k$

③ $\underline{(\Delta\beta/\beta)_{x+y} \text{ by } b_1}$

$$\hat{\Delta} \equiv (\Delta\beta/\beta) - i \left\langle \Delta\alpha - \frac{\Delta\beta}{\beta} \cdot \alpha \right\rangle$$

"Global" $$\hat{\Delta} = (2\nu^2) \cdot \sum_{-\infty}^{\infty} \frac{J_n}{4\nu^2 - n^2} \cdot e^{in\phi}$$

$$J_n = \frac{1}{2\pi\nu} \cdot \sum_k^N \left[\left(-\frac{\ell}{\rho}\right) \cdot b_1 \cdot \beta \cdot e^{-in\phi} \right]_k$$

"Local"

$$\hat{\Delta}\,(\text{OUTSIDE}) = \frac{e^{-i2\pi\nu}}{2\sin(2\pi\nu)} \cdot \sum_{k=1}^{M} \left[\left(-\frac{\ell}{\rho}\right) \cdot \beta \cdot b_1 \cdot e^{i2\psi} \right]_k$$

$$\hat{\Delta} = 0 \longrightarrow \boxed{\sum_k^M (b_1 \cdot e^{i2\psi})_k = 0.}$$

Two ways of looking at the same problem.

(1) "Local".

Confine the effect such that no effect OUTSIDE.

a) Given N, what M?

b) Combination of two or more blocks?

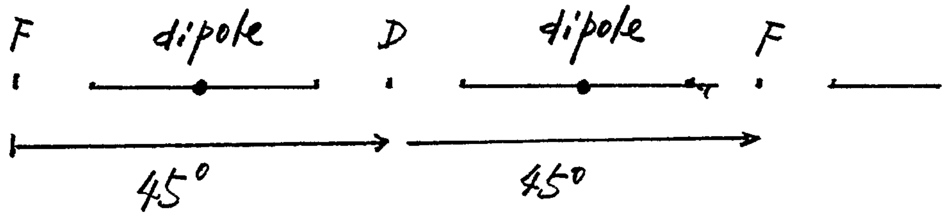
(2) "Global"

Reduce the "important" harmonics.

($n \simeq \nu$ or $n \simeq 2\nu$).

How many harmonics? $\longrightarrow$ Again localized area.

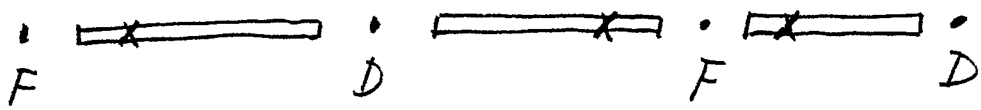
3. Thin-lens approximation



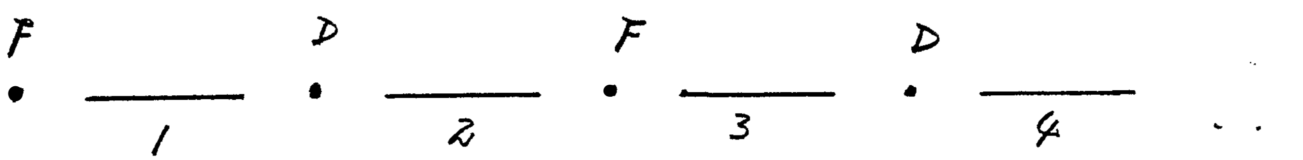
Can we take each dipole as an element or do we have to regard each dipole as several elements?

	thin-lens	integrated
$\sqrt{\beta_x}\cdot X_p\cdot e^{i\psi_x}$:	4.95 (12.5°)	5.15 (11.5°)
$\sqrt{\beta_y}\cdot X_p\cdot e^{i\psi_y}$:	4.95 (33.0°)	4.89 (31.9°)
$\beta_x\cdot e^{i2\psi_x}$:	22.4 (25.0°)	22.8 (22.5°)
$\beta_y\cdot e^{i2\psi_y}$:	22.4 (65.9°)	22.8 (68.4°)
distortion by b_2		
$\beta_x^{3/2} e^{i3\psi_x}$	106.0 (37.5°)	112.6 (30.3°)

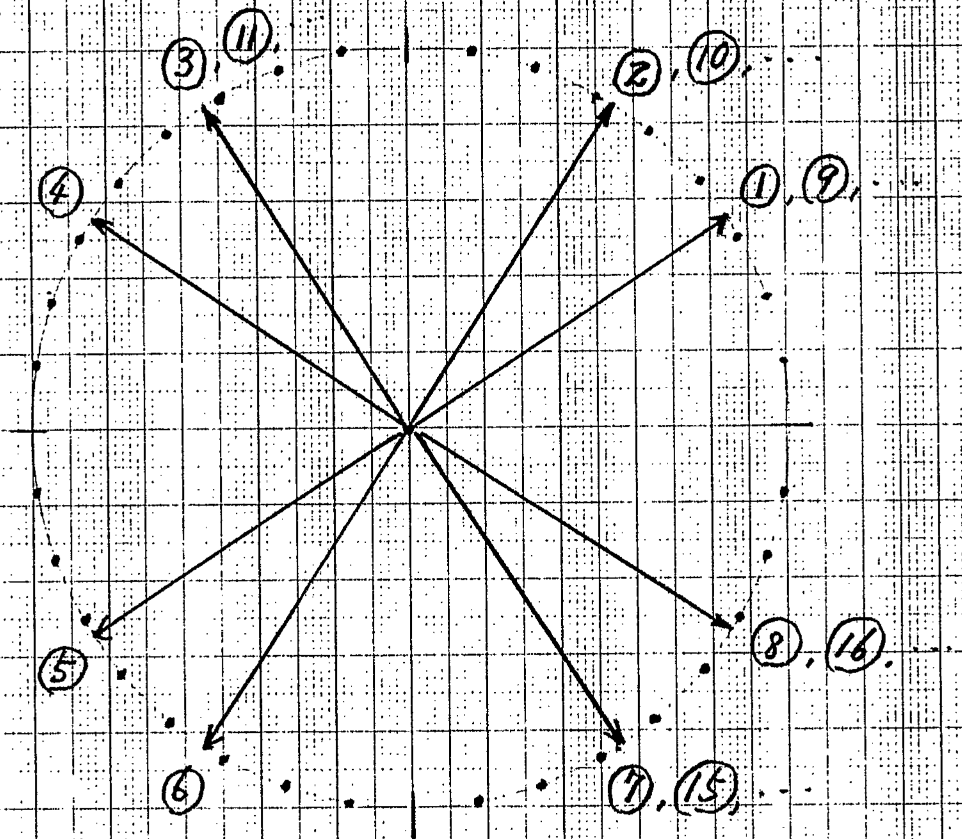
should be OK for (b_1, a_1) but may have to shift the angle for (b_2, a_2).



4. Example of "Vector Diagrams" for RHIC.

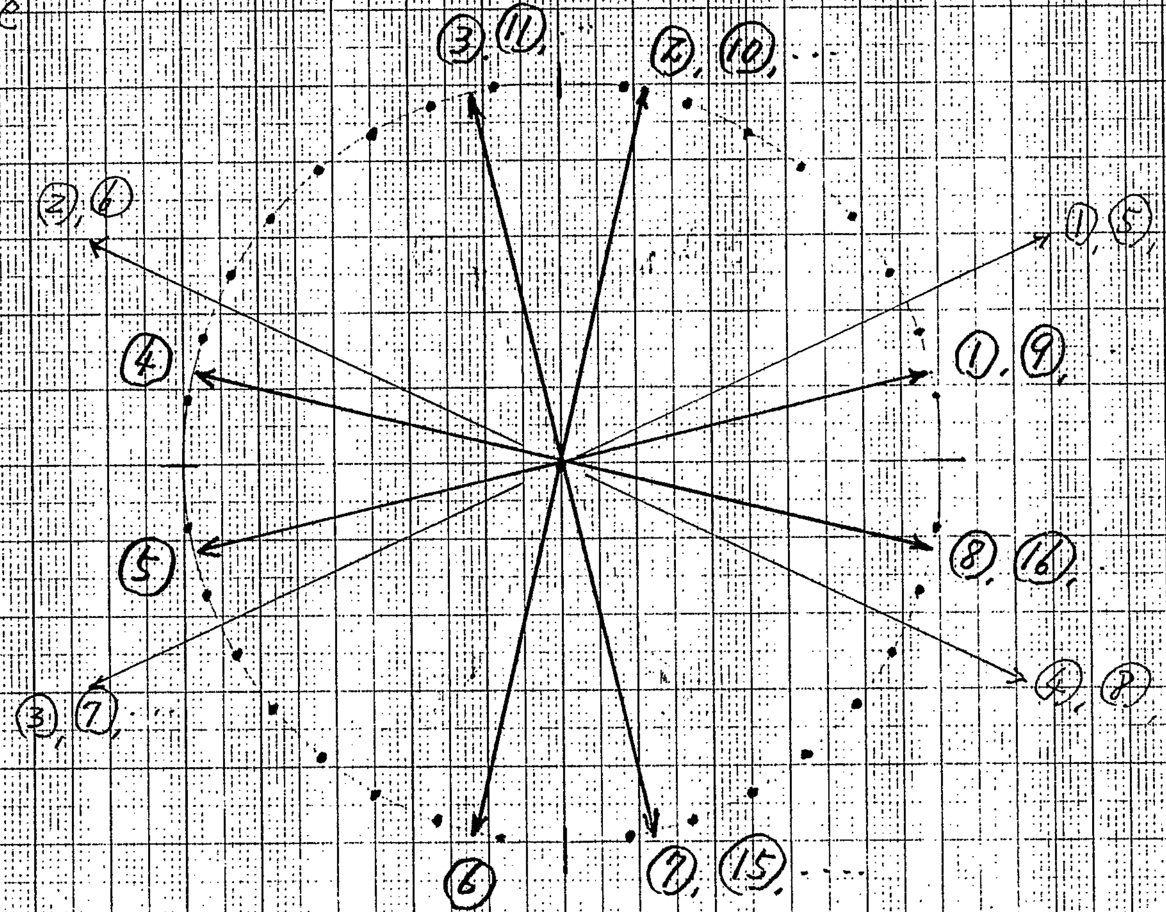


$a_1 \sqrt{\beta_y}\, X_p\, e^{i\psi_y}$



$$b_1 \sqrt{\beta_x}\, X_p\, e^{i\psi_x}$$

$$b_1\, \beta_x\, e^{i2\psi_x}$$



Important differences from the Tevatron

(1) Tevatron : b_2, a_2, a_3

(2) RHIC : b_1. a_1. b_2, a_2(?)

Phase advance / cell. RHIC : 90°
Tevatron : 68°

For RHIC, various effects coming from one multipole (for example, b_1) are correlated.

5. What I should do

Given $\langle b_1 \rangle$, $\langle a_1 \rangle$, $\langle b_2 \rangle$ & $\langle a_2 \rangle$.

(1) max. allowed values (if Gaussian)

(2) M = 8 (four cells) or 16 (eight cells)

(3) "manual" and "automated" shuffling processes combined.

(4) performance estimates.

Compare with random cases.

$(\Delta X_p)_{max}$. $(Y_p)_{max}$. $(\Delta\beta/\beta)_{max}$,

$\langle \Delta X_p \rangle_{RMS}$. " "

Distortion functions - - -