

Closed Orbit Analysis For RHIC

A. G. Ruggiero

April 1984

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.

CLOSED ORBIT ANALYSIS

FOR

RHIC

A. G. Ruggiero

(BNL, April 13, 1984)

Closed Orbit Analysis for RHIC

Value $\hat{y}_P(s)$ not exceeded with a probability P

$$\hat{y}_P(s) = \kappa(P) \left[1 + \frac{\sin \pi \nu}{3} \right] \sqrt{\frac{\beta(s)}{\bar{\beta}}} \sqrt{2} \langle y \rangle$$

where for circular vacuum chamber

P	50%	75%	90%	98%
$\kappa(P)$	1.28	1.63	1.95	2.40

The rms value $\langle y \rangle$ of the expected closed orbit deviation

$$\langle y \rangle = \frac{1}{2\sqrt{2} |\sin \pi \nu|} \sqrt{\sum_i m_i \beta_i \bar{\beta} \psi_i^2}$$

Combining

$$\hat{y}_p(s) = K(P) \frac{1 + \frac{\sin \pi v}{3}}{2 \cdot |\sin \pi v|} \sqrt{\sum_i m_i \beta_i \beta(s) \psi_i^2}$$

Take $v = 34.4$ and $P = 90\%$

then

$$\hat{y}_p(s) = 1.35 \sqrt{\sum_i m_i \beta_i \beta(s) \psi_i^2}$$

The results are shown in the next table -

It seems that surveying of the quadrupoles is considerably more important than the dipole errors -

	Horizontal		Vertical	
	Quad	Dipole	Quad	Dipole
Source	Displacem.	Field Error	Displacem.	Tilt
ψ_i	$l_i, \kappa_i, \Delta y_i$	$\Delta B/B_i, \theta_{B_i}$	$l_i, \kappa_i, \Delta y_i$	θ_i, θ_{B_i}
θ_{B_i}		0.03885		0.03885
$\Delta B/B_i$		$1/4 \times 10^{-3}$		
θ_i				$1/4$ mrad
m_i		150		150
β_i		26.4 m		26.4 m
$\sqrt{\sum_i m_i \beta_i \psi_i^2}$		0.000647 m ^{1/2}		0.000647 m ^{1/2}
l_i	1.9 m		1.9 m	
κ_i	0.05 m^{-2}		0.05 m^{-2}	
Δy_i	$1/4$ mm		$1/4$ mm	
m_i	123		123	
β_i	(51.6 + 7.5) m		(51.6 + 7.5) m	
$\sqrt{\sum_i m_i \beta_i \psi_i^2}$	0.0020 m ^{1/2}		0.0020 m ^{1/2}	
$y_p / \sqrt{\beta(s)}$	2.84 mm		2.84 mm	
$\beta(s)$ in m				
For $\beta(s) = 51.4 \text{ m}$	<u>2.0 cm</u>		<u>2.0 cm</u>	

Half-Integer Stop Band Width
induced by closed orbit and sextupole

The equation is

$$x'' + k(s)x = gx^2$$

neglecting coupling with y-plane

let

$$x = x_c + z$$

= closed orbit + free oscillation

then one derives

$$z'' + k(s)z = 2gx_c z$$

The expectation value of the half-integer stop band width is then

$$\Delta\nu = \frac{1}{\pi} \sqrt{\sum_i m_i (\beta_i l_i g_i k_i)^2}$$

We have two families of sextupoles

	SF	SD
n_i	72	72
β_i	51.5 m	7.5 m
$\langle \delta_i \rangle_{rms}$	15. mm	5.8 mm
$l_i g_i =$ $= \frac{1}{2} \left(\frac{B''}{B\rho} \right)_i l_i$	0.05 m ⁻²	0.10 m ⁻²
$\langle \Delta v_i \rangle_{rms}$	0.10	0.012
$\langle \Delta v \rangle_{rms}$	0.105	

This is too large

Day 1 Operation Mode

1. Closed Orbit Deviations expected to be large (centimeter range)
2. With full sextupoles on the Half-Integer Stopband width is expected to be quite large (~ 0.1)

(a) Choose β -tunes ~ 34.25
half-way between $\frac{1}{2}$ integer values

(b) Turn Sextupoles completely off!
Natural chromaticity ~ 50

(c) Use small pencil beams:
proton beams, bunched, moderate intensity
 10^{11} particles/bunch
few bunches are enough
maybe one AGS pulse

$$\Delta p/p = \pm 0.4 \times 10^{-3} \Rightarrow \Delta v = \pm 0.02 \quad \text{O.K. P.}$$

$$\text{emittance} = 0.7 \pi \text{ mm}^2 \text{ mrad} \quad (95\% \text{ of beam})$$

$$(\equiv \pm 6 \text{ mm at } \beta = 51.4 \text{ m}) \quad \text{O.K. V.}$$

28 GeV

(d) The beam should be able to go around

Confidence level $\approx 90\%$

(e) Establish one turn circulation
Read beam position at B.M.

(f) Establish second turn circulation
Read beam position at B.M.

(g) Compare B.M. position between first and second turn
Minimize difference by adjusting Angle and steering at Injection

(h) When first, second, ..., nth turn identical closed orbit has been established

(i) Move quadrupoles to reduce closed orbit down to $\pm 2\text{mm}$ peak-to-peak level - Work out strategy!

(j) Fine adjustment with local steering elements - work out strategy and requirements - - - !