MEASUREMENTS OF THE BETATRON FUNCTIONS IN RHIC

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Abstract

The Relativistic Heavy Ion Collider (RHIC) provides collisions of the fully stripped gold ions for four experiments. This report shows results from measurements of the betatron functions within the Interaction Regions (IR) as well as in the arcs in both "blue" and "yellow" rings. A single quadrupole excitation or the beam position monitors' RMS. values at injection are used to obtain the betatron amplitude function.

1 INTRODUCTION

RHIC consists of two identical three fold symmetric rings which provided collisions during the run in the summer of 2000 of the fully stripped gold ions. During this commissioning run the maximum energy was 70 GeV/nucleon. At two interaction regions (IRs), one at 8 o'clock where is the large detector "PHENIX" located, and at 2 o'clock where the smaller experiment "BRAMS" resides collisions were established at points with $\beta^* \sim 3m$. At the 6 and 10 o'clock the minimum of the beta function was $\beta^* \sim 8m$. The RHIC lattice is made of six arcs with twelve standard $\sim 90^o$ FODO cells between the IRs. The IRs are made of almost the same FODO cells with missing dipoles, to allow for zero dispersion at collision points. The IR tunable FODO cells also allow matching of the betatron functions between the high focusing triplets and the arc FODO cells. The expected values of the lattice functions in RHIC are presented in Table 1.

Table 1: Maximum Twiss Functions in RHIC at the IR

Region	β_x	β_y	β_{min}	$D_x atIP$
IR 8 and 2	424.94	413.76	8.50	-0.0001
IR 6 and 10	154.47	171.08	3.19	0.0048
Arcs	47	48	10.92	1.89

The maximum values of the betatron functions are within the strong focusing triplet quadrupoles around the two low β IRs while the other values are presented within the arc FODO cells. The beam positions around the ring were measured with a total of 334 beam position monitors (BPMs) per one ring. Almost half of the BPMs (total of 160) are dual plane monitors. Each BPM is capable of measuring and recording the turn by turn positions of the center of the beams. In this report a measurement of the β_x, β_y, and D_x will be presented and compared with the design.

* Work performed under auspices of the U.S. Department of Energy

2 AMPLITUDE FUNCTIONS β_X, β_Y MEASUREMENTS

The amplitude betatron function measurements during the RHIC commissioning were obtained first from the injection oscillations taking the rms value. A measurement in the horizontal plane is presented in Fig. 1 together with the predicted values, while the vertical plane measurements is presented in Fig. 2.

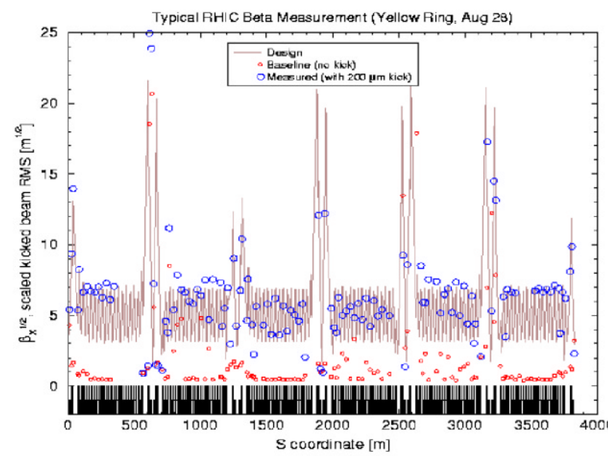


Figure 1: Measured -o- and predicted β_x betatron function in the horizontal plane.

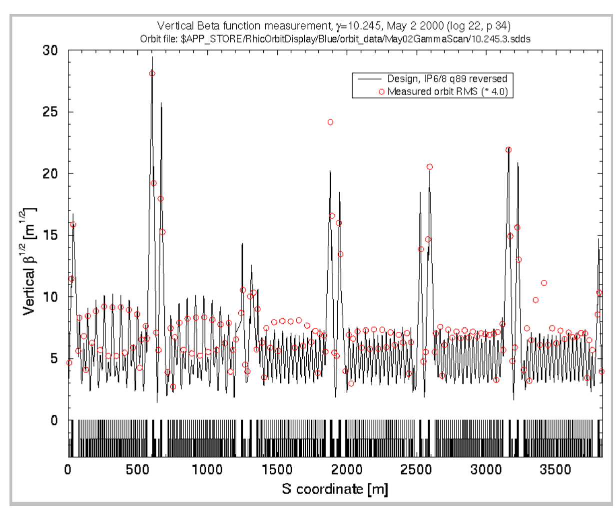


Figure 2: Measured -o- and predicted β_y betatron function in the vertical plane.

3 DISPERSIONFUNCTION MEASUREMENTS

At the beginning of the RHIC commissioning there was a clear disagreement between the measured and predicted horizontal dispersion measurements. With a help of the ON-LINE model a wrong polarity quadrupole power supply was detected. Three measurements of the dispersion function are presented in Fig. 3. The first measurement shown in Fig. 3 was done before a polarity of the quadrupole power supply was properly corrected. At the same plot design values are shown by the full line.

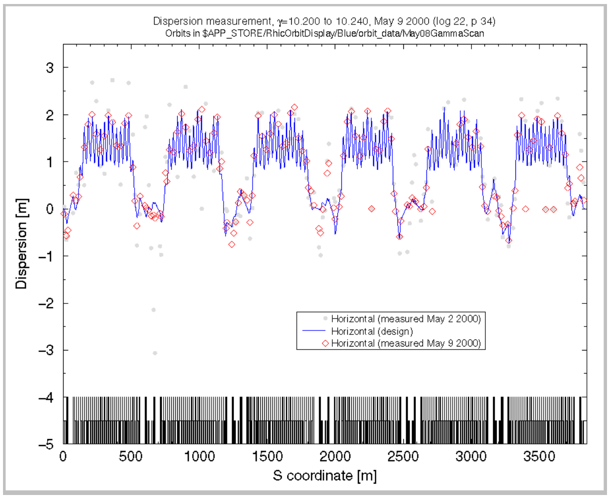


Figure 3: Dispersion function measurements before power supply correction -◇-, after the correction -o- and predicted horizontal and vertical dispersion functions.

4 BETATRON FUNCTION MEASUREMENTSBY THE TRIM QUADRUPOLES

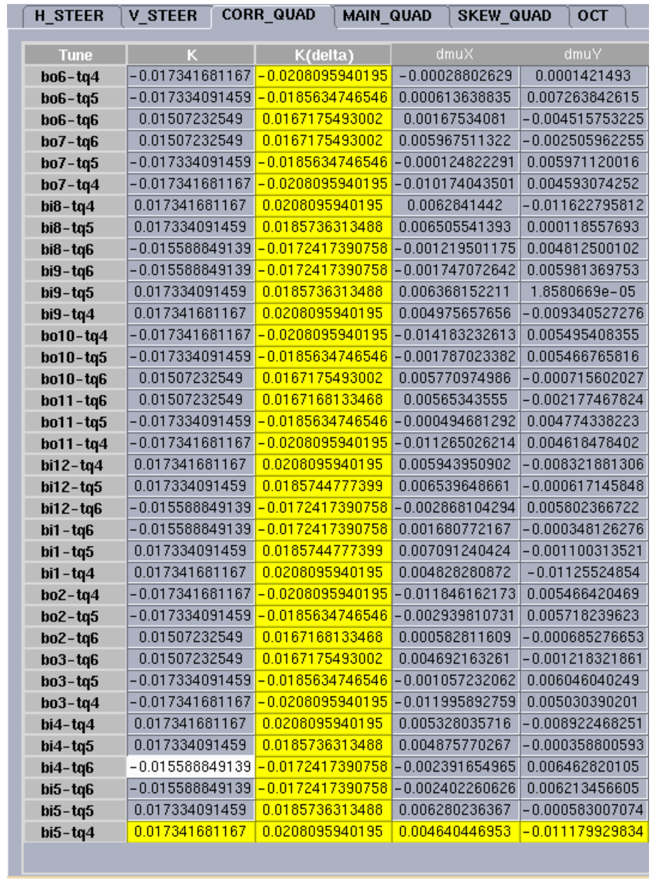
Although a special program was developed for a purpose of the different element polarity check it was used also for the betatron amplitude measurements. The betatron functions at each adjustable quadrupole are determined by measuring the tune shift [1] due to a change of strength k l as shown in Eq. 1

$$\Delta\nu \simeq \frac{1}{4\pi}\int_l \beta(s)\Delta k\, ds, \qquad (1)$$

$$\beta_Q \simeq \frac{4\pi\Delta\nu}{l\Delta k}, \qquad (2)$$

where β_Q is the average function of the beta function at the quadrupole. The tune shift is measured by a betatron tune measurement system described above. A part of the application program control and results from the measurements are shown in Fig. 4.

The betatron functions at the trim quadrupole locations were measured at the trim quad locations around the ring as presented for the horizontal betatron function in Table 2


H_STEER | V_STEER | CORR_QUAD | MAIN_QUAD | SKEW_QUAD | OCT

Tune	K	K(delta)	dmuX	dmuY
bo6-tq4	-0.017341681167	-0.0208095940195	-0.00028802629	0.0001421493
bo6-tq5	-0.017334091459	-0.0185634746546	0.000613638835	0.007263842615
bo6-tq6	0.01507232549	0.0167175493002	0.00167534081	-0.004515753225
bo7-tq6	0.01507232549	0.0167175493002	0.005967511322	-0.002505962255
bo7-tq5	-0.017334091459	-0.0185634746546	-0.000124822291	0.005971120016
bo7-tq4	-0.017341681167	-0.0208095940195	-0.010174043501	0.004593074252
bi8-tq4	0.017341681167	0.0208095940195	0.0062841442	-0.011622795812
bi8-tq5	0.017334091459	0.0185736313488	0.006505541393	0.000118557693
bi8-tq6	-0.015588849139	-0.0172417390758	-0.001219501175	0.004812500102
bi9-tq6	-0.015588849139	-0.0172417390758	-0.001747072642	0.005981369753
bi9-tq5	0.017334091459	0.0185736313488	0.006368152211	1.8580669e-05
bi9-tq4	0.017341681167	0.0208095940195	0.004975657656	-0.009340527276
bo10-tq4	-0.017341681167	-0.0208095940195	-0.014183232613	0.005495408355
bo10-tq5	-0.017334091459	-0.0185634746546	-0.001787023382	0.005466765816
bo10-tq6	0.01507232549	0.0167175493002	0.005770974986	-0.000715602027
bo11-tq6	0.01507232549	0.0167168133468	0.00565343555	-0.002177467824
bo11-tq5	-0.017334091459	-0.0185634746546	-0.000494681292	0.004774338223
bo11-tq4	-0.017341681167	-0.0208095940195	-0.011265026214	0.004618478402
bi12-tq4	0.017341681167	0.0208095940195	0.005943950902	-0.008321881306
bi12-tq5	0.017334091459	0.0185744777399	0.006539648661	-0.000617145848
bi12-tq6	-0.015588849139	-0.0172417390758	-0.002868104294	0.005802366722
bi1-tq6	-0.015588849139	-0.0172417390758	0.001680772167	-0.000348126276
bi1-tq5	0.017334091459	0.0185744777399	0.007091240424	-0.001100313521
bi1-tq4	0.017341681167	0.0208095940195	0.004828280872	-0.01125524854
bo2-tq4	-0.017341681167	-0.0208095940195	-0.011846162173	0.005466420469
bo2-tq5	-0.017334091459	-0.0185634746546	-0.002939810731	0.005718239623
bo2-tq6	0.01507232549	0.0167168133468	0.000582811609	-0.000685276653
bo3-tq6	0.01507232549	0.0167175493002	0.004692163261	-0.001218321861
bo3-tq5	-0.017334091459	-0.0185634746546	-0.001057232062	0.006046040249
bo3-tq4	-0.017341681167	-0.0208095940195	-0.011995892759	0.005030390201
bi4-tq4	0.017341681167	0.0208095940195	0.005328035716	-0.008922468251
bi4-tq5	0.017334091459	0.0185736313488	0.004875770267	-0.000358800593
bi4-tq6	-0.015588849139	-0.0172417390758	-0.002391654965	0.006462820105
bi5-tq6	-0.015588849139	-0.0172417390758	-0.002402260626	0.006213456605
bi5-tq5	0.017334091459	0.0185736313488	0.006280236367	-0.000583007074
bi5-tq4	0.017341681167	0.0208095940195	0.004640446953	-0.011179929834

Figure 4: A part of a control page of the application program for the multi-element polarity check.

and for the vertical betatron function in Table 3. This is a part of the available data. The application had been built for finding elements with the wrong polarity during the commissioning and it is very easy to use. At the same time any discrepancies between the expected and measured values leads towards better understanding of the role of each element in RHIC.

Table 2: Horizontal Betatron function measurement

Tr. quad	Δ k	$\Delta\nu_x$	β_x	β_x mod.
bo2-tq4	-0.00347	-0.01185	42.93	39.28
bo3-tq4	0.00347	-0.01200	43.47	36.373
bo3-tq5	-0.00123	-0.00106	10.80	7.68
bo3-tq6	-0.00165	0.00469	35.84	39.280
bi9-tq4	0.00347	0.00498	18.03	18.9823

4.1 Difference Orbit Measurements

One of the fastest methods of finding the correspondence between the measured beam position orbit positions and expected lattice functions is a single corrector dipole kick with recording the orbit differences. Results obtained by this method, shown in the other publications at this con-

Table 3: Vertical Betatron function measurements

Tr. quad	**Δ k**	$\Delta\nu_y$	β_y	β_y **mod.**
bo2-tq4	-0.00347	0.00547	19.8	18.87
bo3-tq4	0.00347	0.00501	18.23	19.9
bo3-tq5	-0.00123	0.00605	61.77	64.50
bo3-tq6	-0.00165	-0.00122	9.31	13.07
bi9-tq4	0.00347	-0.00934	33.85	36.46

ference [2], were also used to find sources of the local decoupling.

5 SUMMARY

This report had shown betatron function measurement results during the commissioning run. These measurements had shown to be very useful during this period especially the dispersion function measurements which allowed fast error analysis using the on-line model. It is expected to commission in RHIC soon a new AC dipole system with possibility of a very fast betatron function measurements in the whole ring by looking the beam position monitor response in the turn by turn mode.

6 REFERENCES

[1] E.D. Courant and H.S. Snyder, “Theory of Alternating Gradient Synchrotron”, Annals of Physics, Vol. 3, (1958), pp. 1-48.

[2] V. Ptitsyn, J. Cardona, F. Pilat,J. P. Koutchouk, “Measurement and Correction of Linear Effects in the RHIC Interaction Regions”, at this conference, RPAH122.