BEAM INJECTION INTO RHIC

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Abstract

During the RHIC sextant test in January 1997 beam was injected into a sixth of one of the rings for the first time. We describe the injection zone and its bottlenecks. We report on the commissioning of the injection system, on beam based measurements of the kickers and the application program to steer the beam.

1 INTRODUCTION

The beam for the Relativistic Ion Collider (RHIC) is extracted from the Alternating Gradient Synchrotron (AGS), transported through the AGS-to-RHIC transfer line (AtR) and then injected into either the Yellow or Blue ring of RHIC. The AtR comprises the u- and w-line (shared for both rings) and one 90 degree arc for each of the RHIC rings (named x-line for the Blue and y-line for the Yellow ring) [1]. At the end of 1995 u- and w-line were tested with beam [2, 3]. In January 1997, bunches of gold ions were guided through the y-line, injected into a sextant of the Yellow ring and transported to the end of the sextant [4, 5, 6].

At the beginning of the sextant test a vertical corrector magnet(yo5-tv9, next to quadrupole yo5-qf8, see Fig. 1) was powered with 30 A and replaced the injection kickers. It made the initial injection of beam into the sextant easier. Later, when good injection conditions were established, the injection kickers [7] were commissioned. Kicker strength and rise time were measured with beam to ensure that design criteria are met. An injection application program, designed to assist the operator in bringing the incoming beam onto the design orbit, was partially tested.

2 THE INJECTION REGION

There are 6 quadrupoles at the end of the y-line (yq1, ..., yq6, see Fig. 1) providing enough degrees of freedom to match the optical functions of the AtR with those in the ring. After passing the last quadruple triplet (yq4, ..., yq6) the beam is injected into the sextant. The incoming beam lies in a plane about 52 mm above the ring level. A pitching magnet (yp1) provides a 3 mrad downward deflection upstream of the septum magnet ylamb. The beam then passes through the quadrupoles yo5-qf8 and yo5-qd9 and crosses the RHIC reference orbit in the center of the injection kickers yki1-yki4. The four kickers deflect the beam vertically by 1.86 mrad onto the RHIC design orbit.

The iron Lambertson septum magnet ylamb bends the incoming beam by 38 mrad and brings the beam axis into horizontal coincidence with the reference orbit in the sextant. The iron septum magnet will separate the incoming beam from the circulating one. The stray field in the region of the circulating beam is kept below 10^{-4} T by means of a soft iron beam pipe, acting as a magnetic shield. The Corrector-Quadrupole-Sextupole assemblies (CQS) for yo5-qf8 and yo5-qd9 are shortened by leaving out the sextupole corrector. In addition, the beam pipe in yo5-qf8 is slightly bent upwards to give more clearance for the injected beam.

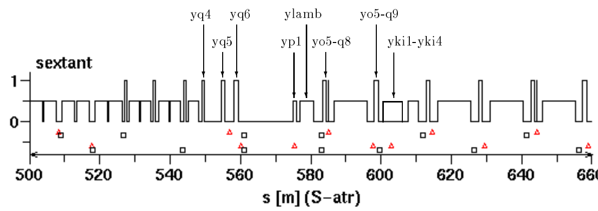

Figure 1: The optical elements in the injection region of the RHIC Yellow ring. Dipole are of height 0.5, quadrupoles are of height 1. The upper (lower) squares show the locations of horizontal (vertical) beam position monitors, the triangles denote orbit correctors. The longitudinal s-position is taken from the beginning of the transfer line.

Tab. 1 lists some optical functions in the injection region. The relatively large vertical beta function in the injection kicker (the maximum in the arcs is 45 m) combined with the small inner beam pipe diameter (41.2 mm compared to 80 mm in the arcs) is a bottleneck for injection.

Table 1: Optical functions in the injection region for the horizontal and vertical plane.

element	pos. [m]	β_x [m]	β_y [m]	D_x [m]	D_y [m]
yq4	549.81	27.98	25.67	1.69	-0.00
yq5	555.70	35.68	43.68	1.84	-0.00
yq6	559.30	12.20	103.12	1.00	-0.00
yp1	575.93	22.86	25.32	-0.55	0.00
ylamb	580.83	38.22	14.50	-0.94	0.02
yo5-qf8	584.35	47.82	11.20	-1.08	0.03
yo5-qd9	599.18	11.18	47.82	-0.83	0.11
yki1	601.68	14.61	37.91	-1.00	0.10
yki2	603.13	17.28	32.79	-1.10	0.10
yki3	604.59	20.44	28.17	-1.20	0.09
yki4	606.04	24.08	24.04	-1.30	0.09

3 INJECTION KICKER MEASUREMENTS

The injection kickers are described in detail in Ref. [7]. There are four injection kickers per ring. The kickers for the Yellow ring were commissioned during the sextant test.

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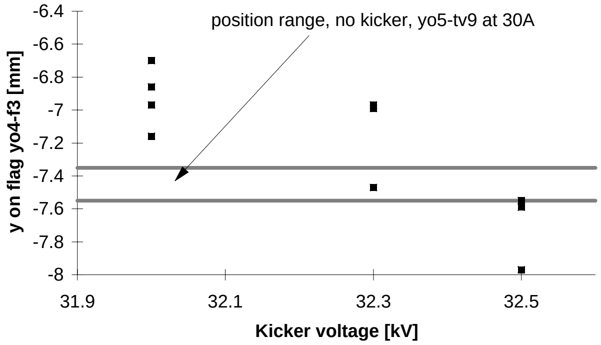

Figure 2: Measurement of the injection kicker strength. The beam was observed on a flag at the end of the sextant. The position on this flag for 3 different kicker strengths is compared with the position when the kicker was replaced by a nearby vertical corrector.

The commissioning consisted of four parts: first, finding the correct timing, second, determining the correct kicker strength, third, measuring the rise time and fourth, recording the shot-to shot stability for multi-bunch extraction. In this case four bunches, 100 ms apart, were injected.

For the first task the kicker current signal was compared with the signal from a beam position monitor close to the injection kickers. The main vertical deflection for the injection still came from the vertical corrector yo5-tv9. The kickers were operated with about 30% of their design voltage to find the delay time with the maximum vertical deflection. The beam response to the kicker was observed on a flag (yo4-f3) some 500 m downstream at the end of the sextant.

Second, the kicker voltage was varied while the beam position was observed on the flag at the end of the sextant. At 32.3 kV (close to the design value of 32 kV) the beam position on this flag was the same as with the vertical corrector next to yo5-tv9.

The rise time limits the number of bunches that can be injected into a RHIC ring. Since the electromagnetic field in the kicker is rather complicated (about 94% of the magnetic and about 6% of the electric field contribute to the kick) only a measurement with beam can give reliable results for the rise time. The following procedure was used to measure the rise time: In a first step the vertical corrector was switched on with the kicker timing far off. Then the kicker timing was changed until a change of the beam position on the last flag was visible. In a second step, the kicker was used fully timed in and the corrector yo5-tv9 switched off. The kicker delay time was varied so long as to see a drop in the maximum beam deviation on the flag. In Fig. 3 this measurement is shown, when all four kickers were used.

However, in kicker current measurements one of the four kickers showed a longer rise time and a reduced flat top value. Therefore, another measurement without this weaker kicker was taken too. The kicker was switched off and the missing strength was again provided by the vertical corrector magnet. Applying a similar procedure as for the first measurement, the measured rise time was clearly below the design value of 95 ns (see Fig. 4). It was found out later, that the different behavior of one of the kickers could be explained by a temperature regulation problem of a thyratron in the pulser circuit for this kicker.

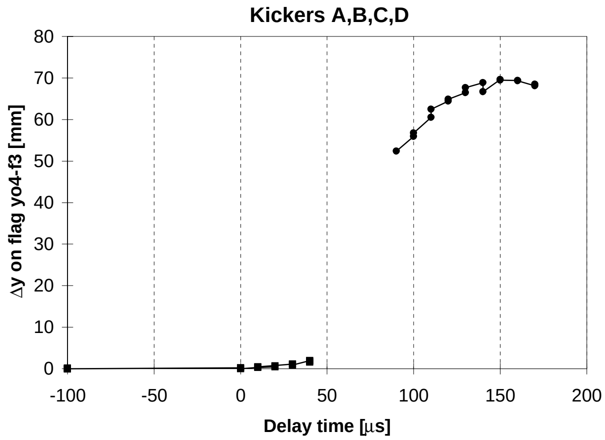

Figure 3: Rise time measurement using all four injection kickers. The beam position was observed on a flag at the end of the sextant. The left part of the curve was measured while the vertical corrector yo5-tv9 was powered at nominal strength; the right part of the curve was measured without it.

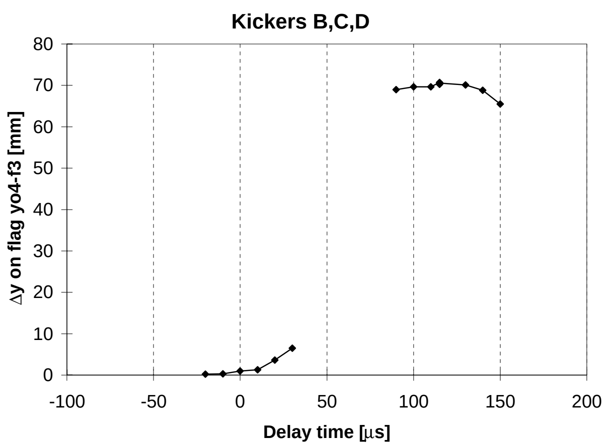

Figure 4: Rise time measurement using only three injection kickers, excluding the "abnormal" one (cf. Fig. 3). The left part of the curve was measured while the corrector yo5-tv9 was powered at its nominal strength; the right part of the curve was measured with 0.25 of its nominal strength.

Fourth, the stability for multibunch injection was measured. In Fig. 5 the horizontal and vertical trajectories in the sextant are shown for 4 injected bunches separated by

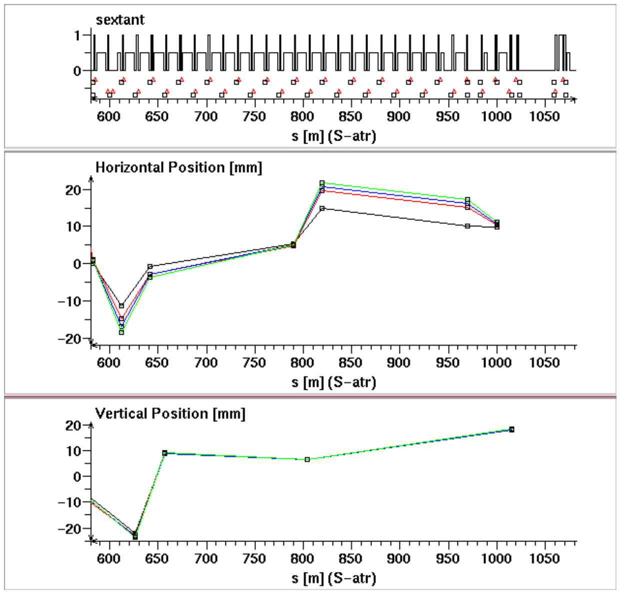

Figure 5: Injection of multiple bunches into the Sextant. Bunches are separated by 100 ms.

100 ms. There is an excellent agreement for the vertical orbits, indicating that there is no performance degradation of the kickers in this mode. The disagreement in the horizontal plane can be attributed to changing horizontal ejection conditions of the AGS.

4 THE INJECTION PROGRAM

The injection tuning program guides the beam from the pitching magnet yp1 through the kicker magnets yki1 through yki4 (see Fig. 1). The horizontal and vertical phase space coordinates at yp1 are constructed from two position measurements in each plane upstream of yp1. The horizontal and vertical phase space coordinates at the kickers are obtained from a pair of beam position monitors in each plane downstream of yki4. From the measured phase space coordinates at the kickers a pair of horizontal and vertical correctors in each plan is set to correct for the deviations. Correctors between yp1 and yk1 can be set manually. The graphical user interface of the program is shown in Fig. 6.

However, the initial steering in the injection region was done with beam loss monitors since the beam position monitors were not available at this time. Later the injection tuning program could be tested only for the horizontal plane and without the injection kickers. A test result is shown in Fig. 7.

5 CONCLUSION

Although there is no ample space for the the beam injection into RHIC, the injection process during the sextant went very well. In addition, the kickers performed as expected, even exceeding the rise time requirements.

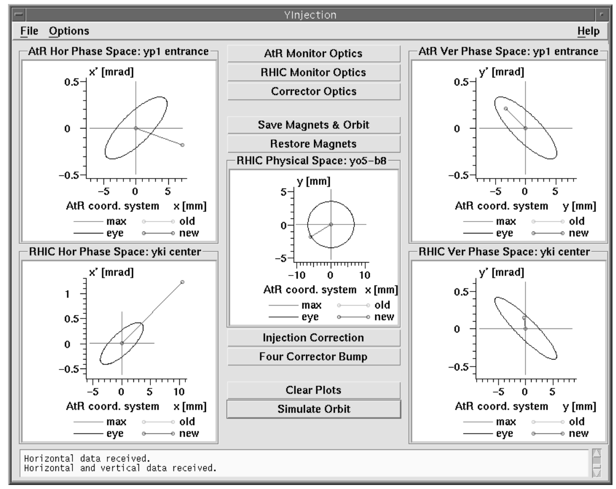

Figure 6: Graphical user interface for the injection tuning program.

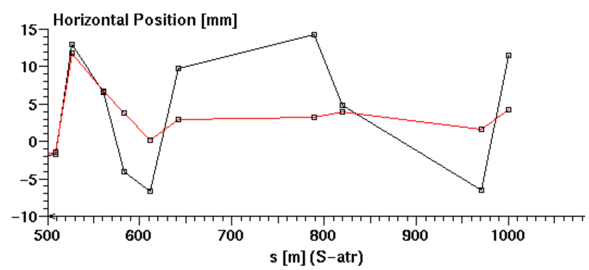

Figure 7: Correction of the horizontal orbit at injection.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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