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Abort Gap Cleaning in RHIC*

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Abstract

During the RHIC Au-run in 2001 the 200 MHz storage cavity system was used for the first time. The rebucketing procedure caused significant beam debunching in addition to amplifying debunching due to other mechanisms. At the end of a four hour store, debunched beam could account for approximately 30%-40% of the total beam intensity. Some of it will be in the abort gap. In order to minimize the risk of magnet quenching due to uncontrolled beam losses at the time of a beam dump, a combination of a fast transverse kicker and copper collimators were used to clean the abort gap. This report gives an overview of the gap cleaning procedure and the achieved performance.

1 INTRODUCTION

Although it is planned to install momentum collimators for later runs, for now RHIC lacks any such device. While a 28 MHz cavity is used for injection and acceleration in RHIC, a 200 MHz storage system for Au-particles was used for the first time in 2001. The amount of debunched beam due to a combination of rebucketing and IBS [1] with heavy ion operation is significant and can account for as much as 50% of the circulating beam. So far, RHIC was operated in a 60 bunch mode where 55 bunches in one ring collide with 55 bunches in the other, leaving a 5 bunch abort gap. The two rings, named blue and yellow respectively, and the six interaction regions (IR) of RHIC with the four experiments are sketched in figure 1. The abort gap is

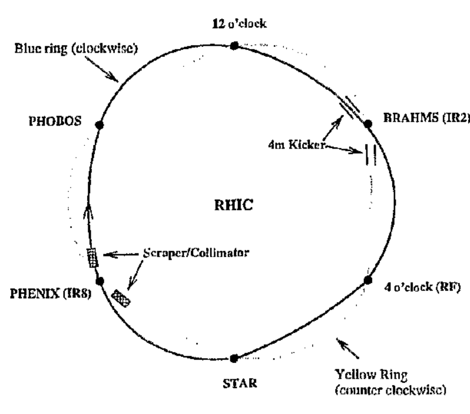

Figure 1: Location of the kicker and collimators in the RHIC rings.

needed to make sure that the circulating beam is cleanly removed by the abort system [2]. Any significant beam in this abort gap will not be dumped properly and can therefore cause magnet quenches and background peaks for the experiments. To attack these problems, the existing hardware of the transverse collimators [5] and the transverse kickers used for the tune measurement system [3] are combined. Any beam in the abort gap is excited transversely by the kickers while the collimators are positioned such that they are the limiting aperture in the rings. Figure 1 shows the geometry.

2 HARDWARE

2.1 *Kicker*

Each ring has two kicker modules with two 2m-long stainless steel striplines allowing both, horizontal and vertical kicks. The two kickers are connected in series to provide 4m of stripline kickers. Each of the four planes can be powered independently. So far only pulsed power combined with fast (FET) switches have been used. All striplines in both rings are charged by one power supply producing an approximately 140 ns long pulse. For this application, the kicker is tuned to excite beam between nominal bunches and especially within the abort gap.

2.2 *Trigger*

The FET switches are triggered by a Numerically Controlled Oscillator (NCO) board. The NCO outputs pulses with a programmable phase and a programmable frequency of up to 20 MHz. By selecting a NCO frequency close to the horizontal and vertical betatron frequency the beam is kicked resonantly enhancing the effect on the beam significantly if compared with a single kick. Finding the resonant frequency is crucial for the gap cleaning application and a set point equal to or very close to the betatron frequency was shown to kick bunched beam at storage out of the ring after a few dozens of turns. The NCO is triggered synchronously with the beam allowing more than 10,000 turns of kicking. In order to reduce the duty cycle and save the lifetime of the switches, no more than 300 turns per trigger event were used in any application. The horizontal kickers are about 4 times as efficient as the vertical ones due to the different β-functions [4]. By moving the kicker to a large β-function location, as planned for the next run, we will enhance the resulting amplitude.

2.3 *Collimator*

The RHIC collimators [5] consist of 45 cm long L-shaped copper scrapers placed downstream of the PHENIX detector in each ring. Each collimator is moved by three stepper motors, which control the horizontal and vertical

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positions and rotate the collimator about the vertical axis. The stepper motors allow a positioning resolution of 0.5 μm horizontally and vertically. Four dedicated PIN diode loss monitors and four ion chamber beam loss monitors downstream of each scraper monitor beam losses.

3 EXPERIENCE

3.1 The Method

The abort gap cleaning procedure contained two steps: **(1)** excite the debunched beam transversely and **(2)** collimate the excited beam with the scrapers.

(1) In order to excite the debunched beam, the tune meter kickers (section 2.1) are used. The kicker timing was changed such, that in place of an occupied bucket beam in the abort gap area was excited. The kicker pulsed for a 300 turns with this event repeated every 4 seconds. To enhance the efficiency, the frequency had to be as close a possible to the betatron tune of the debunched beam. The frequency would be manually scanned starting with the tune of the bunched beam in an approximate $\pm$ 0.01 range. Figure 2 shows such a scan. Depending on the amount of debunched beam, one could either measure the tunes of the debunched beam by using the tune meter [3] or monitor the beam loss at the scrapers once they were moved in. The difference between the yellow and blue beam is not understood. Naively one would expect a loss distribution for the debunched beam more or less as seen in the yellow beam. Often, the loss distribution relative to resonant tunes could not be reproduced. Typically, a resonant frequency could be found in the horizontal plane only due to the favorable horizontal β-function at the location of the kicker. Once a resonant frequency was found, it was kept constant while the kickers continued to excite with 0.25 Hz. Sometimes, debunched beam appeared not to refill the cleaning window within the given 4 sec and a timing sweep thru the abort gap was needed to get a decent cleaning efficiency.

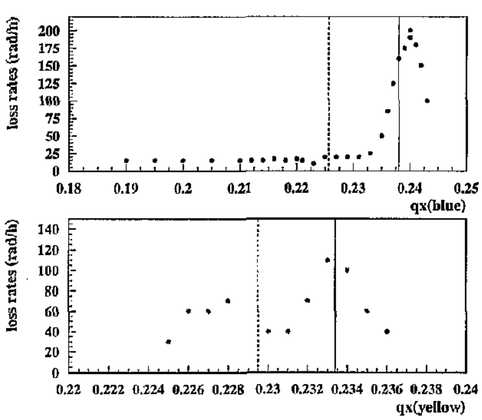

Figure 2: *Loss monitor readings as a function of horizontal tunes in the blue (top) and yellow (bottom) ring during a tune scan in the abort gap. The solid and dashed line corresponds to the tune of the bunched beam at the beginning of the same fill and the next fill respectively.*

(2) At the beginning of the procedure, the scrapers were moved to a predefined position by using a script. A certain readback from the PIN diodes, sensitive to scattered particles from the scraper jaw, was used to determine the exact location. The losses down stream of the scrapers, as shown in 2, were measured by ion chamber loss monitors and used to find the resonant frequency. Typically, the scraper position had to be adjusted a few times during the procedure which lasted approximately 1-2 hours.

3.2 Data

Figure 3 shows the RHIC beam currents as a function of time during with the gap cleaning in the blue ring towards the end. Just before the gap cleaning procedure is started the blue debunched beam accounts for about 0.8 10^{10} ions (30% of the total beam). The amount of debunched beam is derived from the difference of beam currents as measured by the DCCT [6] and the WCM [7]. After about 40 minutes the debunched beam is decreased to about 0.3 10^{10} ions. No bunched beam gets lost during the procedure.

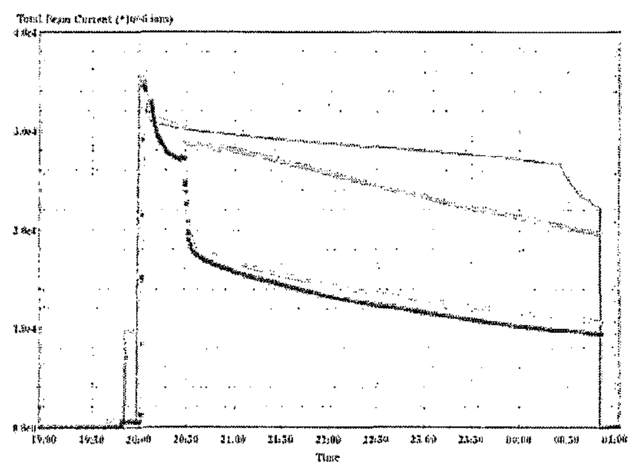

Figure 3: *Beam current as a function of time during fill 1837. The shown graphs, from top to bottom, correspond to: Blue DCCT, Blue WCM, Yellow DCCT, Yellow WCM. Gap Cleaning is done during the last 30 minutes in the blue ring.*

During a successful cleaning typically about 0.4 10^{10} ions debunched beam were removed in less than 45 minutes. Usually only the beam with the higher total beam current needed cleaning. It turned out that experimental background due to "dirty dumps" (i.e. beam in the presence of a lot of debunched beam is dumped causing uncontrolled beam losses around the ring) was not a problem. In fact, background was found to be high (increased by a factor of up to 2 or 3 in IR8) during the cleaning procedure itself (see figure 4). It stayed below an acceptable limit though. However, several magnet quenches due to "dirty dumps"

Table 1: *RHIC magnet quenches between Oct 15 and Nov 24 01, caused by either beam dump or aborts involving significant debunched beam.*

fill	Ring	$I_{deb.}[10^{10}$ ions] Blue	Yellow	cause
1323	B	n.a.	0.2	beam dump
1325	B	n.a.	0.6	beam dump
1329	B	n.a.	n.a.	beam dump
1337	B	n.a.	1.0	beam dump
1345	B	n.a.	n.a.	beam dump
1512	B	2.3	0.6	abort due to losses
1526	B	1.2	-	abort due to losses
1564	B	n.a.	-	beam dump
1641	B	0.6	0.4	abort due losses
1652	B	1.7	1.3	beam dump
1715	B	0.9	-	beam dump
1789	B/Y	0.6	0.3	abort due to losses
1831	B	0.6	0.1	beam dump

were reported. "Dump" refers to the deliberate procedure of initiating a beam dump while "abort" refers to beam dumps initiated by a fault condition such as high losses or power supply failure. Magnet quench data is available for the period Oct 15 01 - Nov 24 01 with a total of 82 fills ($\geq$ 0.5 h). 29 quenches were recorded in that period. Table 1 lists two types of quenches which were initiated by a beam dump or had significant debunched beam currents at the time of the abort respectively. In some cases a quench caused by losses is indistinguishable from a quench caused by the following "dirty dump/abort". However, considering both types we are left with about 11%-16% of the fills ending with a magnet quench due to debunched beam in that period. The upper limit from this data sample for a tolerable amount of debunched beam is between 0.3 and 0.5 10^{10} ions. While we had no chance to try gap cleaning in fills ended by an abort, the procedure probably failed on the others. Unfortunately there is no WCM data available for 6 of them. Figure 4 shows a failed attempt. Gap cleaning is active for the last 50 minutes of the fill resulting in an increased background signal at IR8. However, there is no significant decrease of the debunched current visible. When the fill is finally dumped it causes a magnet quench in the blue ring. It is not yet understood why the procedure failed in this case. So far the analyzed data is inconclusive due to the limited data sample and the missing WCM data in many cases.

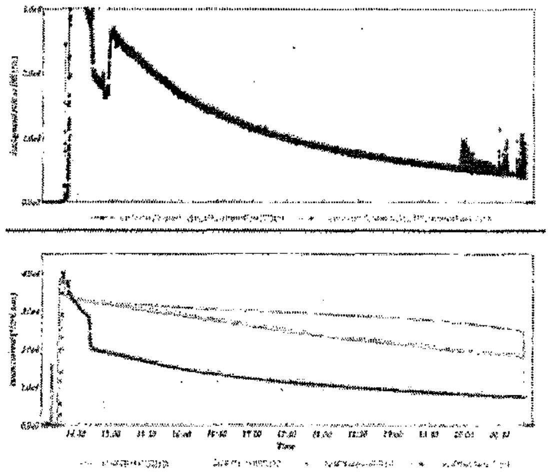

Figure 4: *Experimental background at IR8 (top) and beam current (bottom) as a function of time during fill 1831. The shown graphs in the bottom plot, from top to bottom, correspond to: Blue DCCT, Blue WCM, Yellow DCCT, Yellow WCM. Gap Cleaning is done during the last 50 minutes in the blue ring.*

4 CONCLUSION

A gap cleaning procedure using the transverse tune meter kicker and the collimators has been established and routinely used at RHIC during the Au-operation to minimize the built-up of debunched beam in the abort gap. Typically the gap could be cleaned prior to beam dump within less than 1 hour. While it is proven to be successful in many cases, the procedure failed in approximately 10% of the fills causing magnet quenches. The tolerable limit of debunched beam is between 0.3 and 0.5 10^{10} ions. Those numbers are derived from a limited data sample and have to be confirmed after analysis of the full data set. A momentum collimator is planned for the FY04 run involving substantial civil engineering in the RHIC tunnel since there is no available warm space with significant dispersion. Improvements such as a dedicated gap cleaning application and moving the kickers to a more favorable location are planned for the short term future. The application will allow automated frequency scans as well as timing sweeps throughout the abort gap.

5 REFERENCES

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