RHIC Pressure Rise and Electron Cloud

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1 Introduction

In the RHIC 2001-2002 run, unexpected vacuum pressure rise was observed in both gold and proton operations. For gold beam with bunch length 20 ns, the beam intensity was limited at 9×10^8 and 5×10^8 fully stripped ions per bunch for bunch spacing of 216 ns and 108 ns, respectively. The pressure rise from $< 10^{-9}$ $Torr$ to $> 10^{-5}$ $Torr$ was observed. For proton beam with comparable bunch length, bunch spacing and bunch charge intensity, the pressure may rise to $> 10^{-7}$ $Torr$. All pressure rises took place, very unevenly, in warm sections, mainly the 6 interaction regions (IR) and 24 single beam long straight sections. For detailed machine parameter and pressure rise, see [1-4].

Electron desorption is now suspected to be the main cause of the pressure rise. Gold ion beam loss had clearly created violent pressure rise in quite a few cases, and this mechanism is of concern for next run. However, in the intensity limiting cases, the pressure rise pattern is different from the ones due to beam loss, and look more like 'multipacting and saturating' [4]. Calculation shows that ion desorption may contribute to pressure rise at high intensity [1,2], but observed pressure rise had shown inconsistent pattern with ion desorption. On the other hand, large upward coherent tune shift along the bunch injection was observed for high intensity beam, indicating that electron density in the RHIC is at least comparable with the one observed at the SPS [5]. Calculation using this electron density and usual electron desorption rate gives rise to a pressure rise in the order of 10^{-6} $Torr$ [1,2], similar to the SPS [6]. There are other indications in favor of electron desorption dominance, for instance, the pressure rise is very sensitive to bunch spacing, rather than total intensity [4,7].

Also in the RHIC 2001-2002 run, fast transverse beam instability had happened frequently, beam-beam collision and octupolar field were needed to stabilize the beam and to improve the machine tunability [8]. Measured transverse impedance is somewhat higher than the expected [9], which itself, however, looks not sufficient to explain these instabilities. Electron cloud is suspected to play a role in destabilizing beam [10].

Problems and questions remain.

1. It is needed to prove that electron desorption is indeed the dominant factor in pressure rise, before we make decisions to solve the pressure rise problem.

2. Secondary electrons alone are unlikely to survive near 200 ns bunch gap, even considering the low energy electron reflectivity [6]. On the other hand, the beam lost at long straight sections with glancing angle can create large amount of positive ions, which may extend the lifetime of secondary electrons [1]. Is this really happening? Are there other factors?

3. The beam intensity threshold of pressure rise at single beam straight sections (SSS) is about a half of that at IR. The length of straight pipe at IR is 16 $meters$, and at SSS it is 34 $meters$, plus cold straight sections of about 15 $meters$ on both ends of warm bore. If beam halo scraping at wall with glancing angle can help electron multipacting, then the situation at SSS would be worse than that at IR.

4. As soon as the beam was accelerated, the pressure rise decreased. It is suspected that the reduced transverse beam size, and hence the halo scraping, is taking effect here. Other factors?

5. The pressure rise in gold run is much worse than proton beam, and also the usual electron density of $10^{12}/m^3$ is not sufficient to explain the very high pressure rise observed at the RHIC gold run. Better understanding of the mechanism in gold beam pressure rise is needed.

2 Set-up for pressure rise and electron cloud study

By the next run, starting December, 2002, two stations for the electron cloud and pressure rise study will be ready at the RHIC. One is at the interaction region IR12, and another is at the blue beam long straight section of sector 1, i.e., Bi1. Each station is equipped with,

1. A horizontal and a vertical electron detectors, with grounded screen of 23% transparency, a retarding grid with ± 1 kV bias adjustable, and

the collector of ± 100 V adjustable. By change the grid and collector bias, both electrons and positive ions can be detected.

2. Three vacuum gauges located near center and near both ends of straight section.

3. Solenoid with at least 8 meters coverage around detectors. Field is adjustable, and highest field is about 70 *Gauss*.

4. Eight pin-diodes around the chamber, near detectors, which will be used to detect the beam loss in vicinity, with very high sensitivity.

5. A residual gas analyzer, RGA.

6. An electron multiplier with the amplification gain of 4000.

7. A BPM type pick-up at Bi1, which can be used to collect electrons, for comparison.

In addition, the entire straight section at Bi12 will be covered by 4 independent segments of solenoid, with the maximum field strength of 70 *Gauss*, which will be used for the solenoid study.

One collimator in Blue ring will be modified to detect secondary electron yield at the shallow angle beam scraping.

The AGS to RHIC transfer line (ATR) will be prepared for the study of beam loss induced vacuum pressure rise.

3 Study outline

The studies are mainly aimed at answering key questions, looking for solutions of pressure rise and beam instability, and also for some physics study at the RHIC high energy.

The study outline is shown as follows. Brief comments are in parentheses, and detailed study plan is under developing.

1. Is electron desorption the dominant factor in pressure rise?

   - Electron cloud time structure vs. pressure rise. (One of the main purpose in building e-detectors)
   - Electron density and saturation. (Mostly at Bi1, electron density and desorption rate may explain the pressure rise)

2. Why RHIC allows electron multipacting with 216 ns bunch spacing?

   - Electron cloud decay time. (Look at different bunch gap settings, and also by dumping the beam)
   - Ions detection. (It is suspected positive ions may help electrons to survive long bunch gap)

3. Why beam intensity threshold of pressure rise at single beam straight section is lower than at IR?

   - Steering the beam, observe electron cloud and pressure rise. (Beam halo scraping along the wall is suspected to help e-multipacting)
   - Beam loss effect. (This effect is especially important for gold beam)

4. The RHIC electron cloud and vacuum pressure rise characteristics.

   - Energy distribution of secondary electrons. (Change e-detector retarding voltage)
   - Gas composition and its evolution along with the pressure rise. (Help understanding the pressure rise mechanism)

5. Looking for solutions of pressure rise.

   - Solenoid effect. (If electron cloud is to blame for pressure rise, this might be the solution. A complete solenoid study at Bi12, by powering independently the 4 segments of solenoid with different field strength)
   - Electron cloud vs. beam injection pattern. (Change the beam injection pattern and intensity, observe electron cloud and pressure rise)
   - Beam scrubbing. (Perhaps in proton run)

6. Electron cloud effect on the beam instabilities.

   - Coherent tune shift along the bunch injection. (Continue)
   - Incoherent tune spread vs. beam-beam collision, octupole setting, and chromaticity. (Using Schottky?)

7. Other studies

- ATR transfer line vacuum study by steering the beam. (To help understanding of subjects 2 and 3)
- Secondary electron production study using collimator, and possible at the ATR. (An unprecedented study at the RHIC high energy)
- Ionization cross section study. (Another unprecedented study at the RHIC high energy)

4 References

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