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Abstract. The ion desorption has a long history of intensive studies by many physical societies. Recently, it has been found responsible to the intensity limitation of several low energy heavy ion accelerators, and it is also of concern for high energy hadron accelerators, such as RHIC, LHC, and GSI FAIR. This article reviews the relevant observations at RHIC.

INTRODUCTION

Swift ion induced desorption has been under study by many physical societies, such as radiation, surface, material, plasma, semiconductor, etc. General reviews can be found in [1-3]. Main issues are summarized as follows.

1. Nuclear and electronic stoppings are the basic mechanism in the desorption.
2. Desorption yield usually implies neutral particles, but it could include ions, electrons, and clusters. In this article, we focus on the production of neutral particles and ions, which are mostly positive.
3. Desorption rate of neutral particles per projectile ion is cited as 0.1 to 1E6, depending on velocity, mass, charge state, incident angle of the ions and also depending on the target. Usual desorption rate for the metal target is in a range of 1 to 10 for normal incident.
4. Peak desorption energy with respect to the velocity of incident ions is around 1 MeV/u, i.e. $\beta = v/c = 0.04$ [2]. Compared with the peak production energy for secondary electron yield, which is also at $\beta = 0.04$, the uncertainty for ion desorption is larger. For normal incident, beyond the peak production energy the ion desorption rate is reduced, because that less energy is deposited on the surface.
5. A $1/\cos\theta$ factor in desorption rate is in general observed, where θ is the incident angle. See [1-5].
6. Many reported that in the ions production, there is a q^3 effect, where q is the charge state, see [6-8].

Most studies are performed for normal incident, which is sufficient to address the concerns in these societies, and it is also relatively easy in study set-ups.

In recent years, ion desorption has been found responsible for the intensity limitation of heavy ion accelerators, such as the AGS Booster [9,10], CERN LEIR [11], and GSI SIS18 [12,13]. Comments are as follows.

1. A noticeable difference from the previous studies is that for these accelerator the shallow angle incident is of concern, rather than the normal incident.
2. The energy range is from 1 MeV/u to 1 GeV/u in these machines, rather than that most previously studied in 1 keV/u to 1 MeV/u.
3. Due to the shallow incident angle, large desorption rates of 1E5 to 1E6 have been observed on steel target.

Since 2002, the high intensity hadron beam operations at the RHIC have shown that large ion desorption might be related to the beam induced vacuum pressure rise, which is now a limit of the beam intensity and hence the machine luminosity [14-16]. The RHIC situation is different from previous ones by,

1. The energy range is from 10 GeV/u to 100 GeV/u.
2. Shallow angle incident is more pronounced. For example, the intensity threshold of pressure rises at 34 meter long straight sections is clearly lower than that of the 17 meter ones.
3. Largest ion desorption rate of these shallow incidents is 1E7 or higher.

The concerns of the RHIC ion desorption issue are,

1. The large neutral particle production in beam scraping may produce high pressure rise.
2. The large positive ion production may be responsible to the electron multipacting in warm sections. The RHIC warm section electron multipacting may happen with long bunch spacings, from 106 ns to 432 ns, which is different from other machines with the normal electron cloud [17].

A better understanding of the ion desorption is of interest not only for the RHIC upgrade, but may also for the LHC heavy ion program, GSI upgrade, and perhaps Heavy Ion Fusion [18,19].

In this article, the observations in RHIC Run 2002, Run 2003, and Run 2004 are summarized.

RHIC OBSERVATIONS

RHIC observation of ion desorption is reviewed for run-away type pressure rise, the beam loss related pressure rise, the transition pressure rise, and the collimator scraper caused pressure rises of both rings (Blue and Yellow) at injection and store. To identify the ion desorption, possible contributions of electron cloud, non-beam ions pushed to wall by the beam, and malfunctions of vacuum gauge and ion pumps will be discussed for each case.

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Run-away type pressure rise in 2002

There were numerous run-away type pressure rise at the interaction region of section 12 in RHIC Run 2002. In Figure 1, 3 cases were shown.

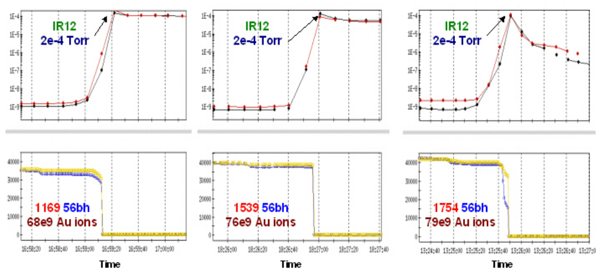

FIGURE 1. Run-away type pressure rise in RHIC Run 2002 at interaction region of section 12. All cases were associated with beam loss. Vacuum valve closed for protection, and beam was dumped.

The beam pipe at section 12 was 17 meter long stainless steel with radius of 6 cm, unbaked. The run-away pressure rise was always accompanied by beam loss. If the beam loss is responsible for the pressure rise, then the desorption rate of larger than 1E7 can be derived. The contribution of possible electron multipacting and the non-beam ions pushed to wall by the beam cannot, however, be clearly identified.

In RHIC Run 2003 and Run 2004, the run-away type pressure rise was of much less concern, probably due to extensive vacuum bake out.

Beam loss related pressure rise

In Figure 2, the pressure rises tightly related to the beam loss are shown for Fill 2818 in RHIC Run 2003. The gold beam loss at two Yellow Q3-Q4 straight sections, i.e. Yi10 and Yi2, caused significant pressure rise. These are 34 meter long stainless steel pipe with radius of 6 cm.

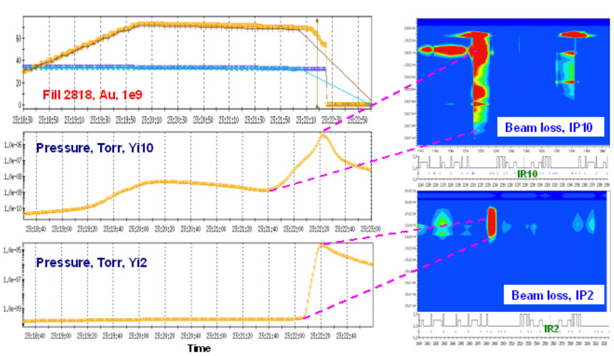

FIGURE 2. Beam loss related pressure rise in RHIC Run 2003 at Q3-Q4 straight sections Yi10 and Yi2. The first pressure rise of Yi10 at the gold beam injection was caused by electron cloud. The second pressure rise and the one at Yi2 are clearly caused by beam loss.

Electrons and non-beam ions may have contributed, however, the dominant contribution is likely the beam loss. The ion desorption rate is larger than 1E7 for gold ions at the RHIC injection energy of 9 GeV/u.

Transition pressure rise

Large ion desorption was also observed in the beam transition pressure rise, as shown in Figure 3. Transition pressure rise of about two orders of magnitude was observed at the Blue Q3-Q4 straight section Bi8. If the beam loss during the period, 5E10 deuteron ions, is responsible to the pressure rise, the deuteron ion desorption rate is 4E5. From the pin-diodes at Bi8 and the beam loss monitor, it can be seen that most beam loss was actually not at Bi8, but in elsewhere. The ion desorption rate is, therefore, much higher than 4E5.

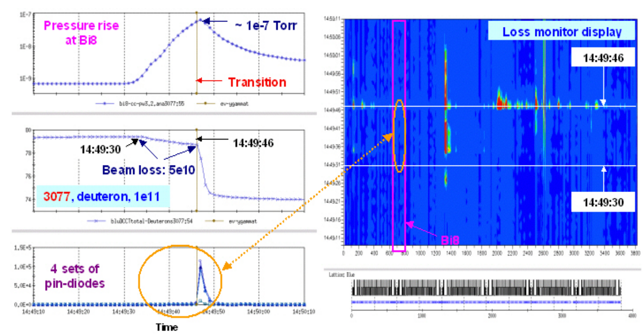

FIGURE 3. Transition pressure rise, in RHIC Run 2003 at Q3-Q4 straight sections Bi8, for deuteron beam acceleration. The beam loss was not at Bi8, indicated by pin-diodes, and mainly at other locations, indicated by beam loss monitor.

The transition pressure rise was believed not due to electron multipacting [16]. Since the ionization cross section of deuteron is much smaller than gold ions, the non-beam ions' contribution can also be ruled out.

Collimator scraper - Yellow ring

In Figure 4, the beam loss caused pressure rises, due to the Yellow collimator scraping, are shown. The collimator scraper is located at the Q3-Q4 straight section Yi7. The left side of Figure 4 shows the gold beam scraping at the RHIC injection energy of 9 GeV/u. On the right side, it is at store of 100 GeV/u. The gold ion desorption rates of the 3 incidents at the scraping at injection are 1.1E7, 1.4E7, and 0.9E7, respectively. The ion desorption rates of the 2 incidents at the store are 0.6E6 and 1.4E6, respectively. For the second incident in the right side of Figure 4, the pin-diodes indicated that the loss was not at Yi7, therefore, the real ion desorption rate should be higher.

The beam intensities were only 6E9 and 15E9 gold ions, showing that there were no contributions of either electron multipacting or non-beam ions.

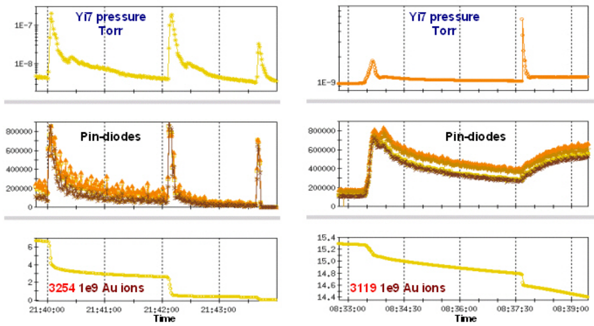

FIGURE 4. Collimator scraping caused pressure rise. The location is at Yi7. The left side is the gold beam scraping at injection, and the right side is at store.

Collimator scraper - Blue ring

In Figure 5, a collimator scraping of deuteron beam at store is shown. The location is at the Q3-Q4 straight section Bi8. It can be identified clearly that the scraper vertical movement had caused beam loss, indicated by the pin-diodes and beam loss monitor. The pressure rise of more than one order of magnitude almost exactly followed the scraper, indicating that it is the beam loss that caused the pressure rise. The total beam loss during the period is 1.1E9 deuteron ions. If all contributed to the pressure rise, then the ion desorption rate is 5.3E6. Nevertheless, very small part of that beam loss is responsible to the Bi8 pressure rise, shown by the beam loss monitor. It can be concluded that the deuteron ion desorption in this case is much higher than 1E7.

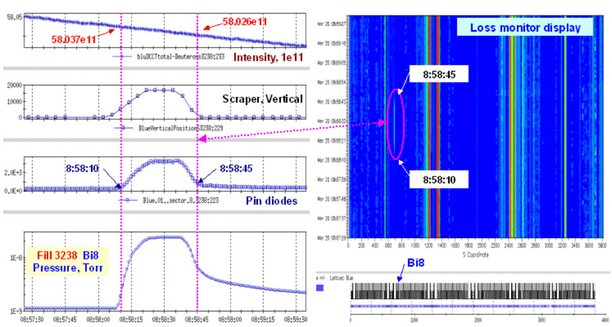

FIGURE 5. Blue collimator scraping of deuteron beam at store. The scraper vertical movement caused beam loss, indicated by both pin-diodes and beam loss monitor. The exact pattern of the pressure rise indicates that the pressure rise is caused by the beam loss. Since very small amount of beam loss is at Bi8, the ion desorption rate is very large.

DISCUSSION

RHIC observation has shown very large ion desorption at both injection and store, for both gold and deuteron ions. The key factor is probably the incident angle. If the high energy ions dump energy at relevant surface, very high desorption yield is possible. In RHIC Run 2004, beam studies had been carried out in several different ways, the results were mixed. In the normal case, the incident angle at about 1 mrad did not give rise to the desorption rate of 1E7, but only at around 2E4. In the irregular cases, for instance, the steered beam may have touched chamber, or some beam loss occurred at upstream, ion desorption rates up to 1E7 have been observed at different locations with different beam conditions. It is suspected that for these cases some real halo scraping may have occurred. The situation cannot yet be exactly described.

For RHIC luminosity improvement, the main concern of the large ion desorption rate is not the neutral particle production, but the associated ion production. Given the charged high energy particle, if the neutral particle production is large, then the ions' production may also be large. If this is confirmed, then many RHIC pressure rise at the warm sections can be explained. More importantly, this may offer other means, in addition to the remedies for normal electron cloud, for the mitigation of the beam induced pressure rise at the RHIC warm sections.

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