Losses at AP50 During Stacking

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Introduction

Between November 22 and December 11, 2005 the Antiproton Source department undertook round-the-clock beam studies devoted to improving the acceptance of the AP2 beamline and the Debuncher. Upon resuming normal stacking operations after these studies, relatively high radiation levels on the AP50 radiation monitors were observed. The observed peak levels approach 50% of the level that would take down the pbar beam permit. The purpose of this report is to document this effect and the measurements that have been made to date to understand it.

Figure 1 shows the Antiproton Source radiation monitor display. The levels shown here are typical of what has been observed since stacking was resumed after the studies.

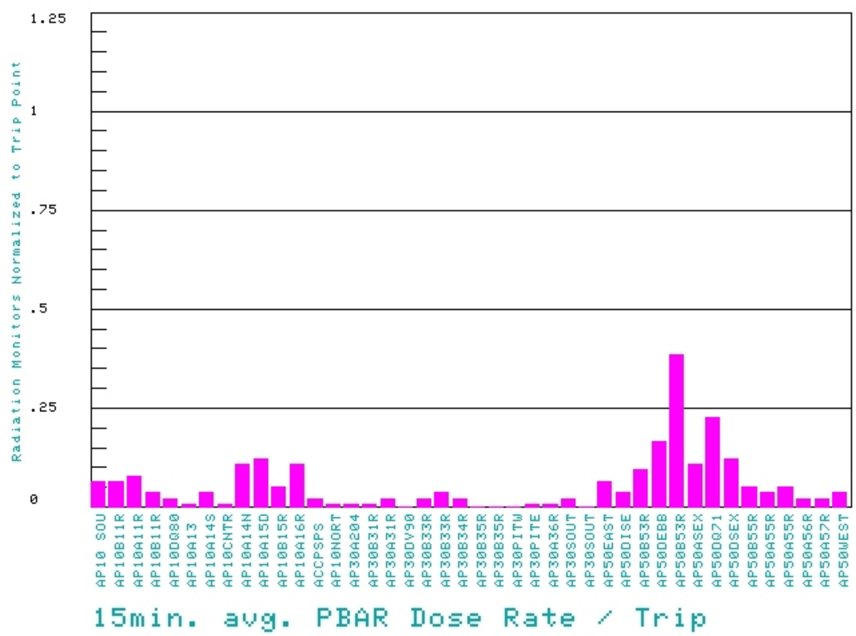

Figure 1 Antiproton Source radiation monitors during the day shift of January 6, 2006. The location of each of the radiation monitors in the AP50 service building is given in Figure 2. At this time M:TOR109 averaged 7.5E12 protons/pulse and D:IC728 averaged 5.8E09. The average stacking cycle time was 2.7 sec (A:STCKAV). The peak losses are at monitors AP50DQ719 and AP50B53R07. These monitors are located near the center of AP50 – just downstream of the Debuncher injection kicker.

Figure 2 shows the locations of the radiation monitors in the AP50 service building. The measured losses are greatest on two monitors that are located slightly to the east of the center of AP50.

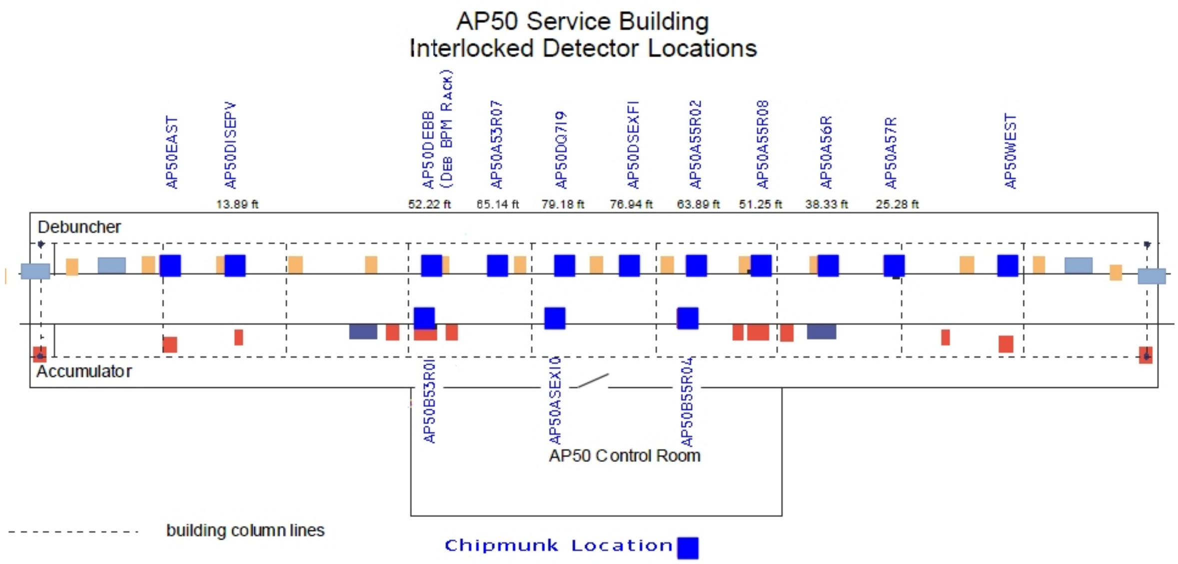

Figure 2 This drawing shows the location of the radiation monitors in AP50. The radiation monitors are the blue squares. The labels correspond to the partial labels given in Figure 1. This drawing was adapted from figure 16 in the 2000 Antiproton Source shielding assessment[1].

There are several questions that one could ask at this point to try to get to understand these new losses:

1. Are these losses a new phenomenon? Are these losses better or worse than before the studies

2. Are the losses from injected or circulating beam?

3. Is the lattice what we think it is through this region?

4. Is the beam properly steered through the downstream end of AP2 and into the injection channel of the Debuncher?

These questions are the subject of the remainder of this report.

History of AP50 Radiation Monitor Levels

Enhanced radiation levels at AP50 are not a new phenomenon. The radiation monitors at AP50 showed a 20 – 25% increase after the Fall 2004 shutdown (Figure 3). This corresponds to the time slip-stacking became operational. Figure 4 shows the radiation monitor history immediately before and after the November – December 2005 studies. This data shows that there is no apparent increase in AP50 radiation levels as a consequence of the studies.

Figure 5 compares the radiation level as a function of beam on target before the studies with the level after the studies. There is a correlation between the intensity of proton beam on the production target and the AP50 radiation levels. The AP50 radiation per proton appears to be

[1] The original figure can be found at the following URL: http://www-bdnew.fnal.gov/pbar/documents/Antiproton%20Source%202000%20Shielding%20Assessment/Shielding%20Assessment%20Files/figures/Figure%2016%20with%20overlay.pdf

slightly lower after the studies. It is very likely that the increased radiation levels at AP50 are a consequence of increased beam on target.

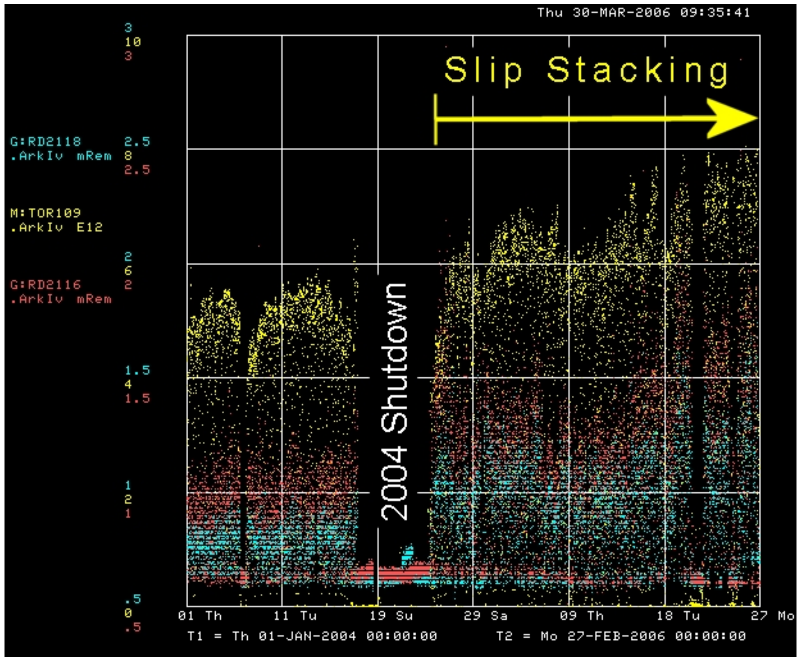

Figure 3 AP50 radiation monitors from January 1, 2004 to the present. After the 2004 shutdown these radiation monitors showed a significant increase.

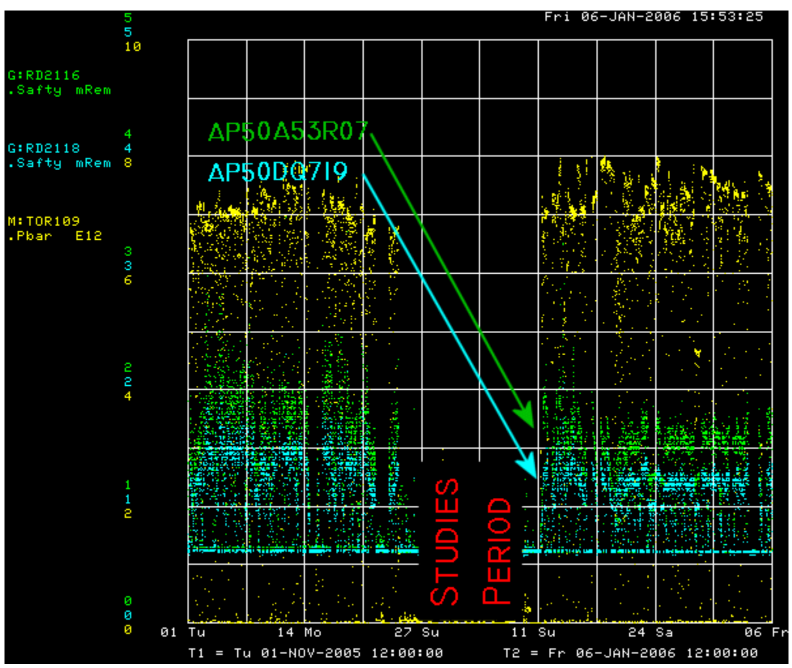

Figure 4 History of the AP50 radiation monitors showing the highest levels during stacking. Rad. Monitor AP50A53R07 is shown in green, AP50DQ719 is shown in cyan. The yellow trace shows the proton intensity

per pulse on target (M:TOR109). This graph shows three weeks prior to the studies and four weeks after the studies.

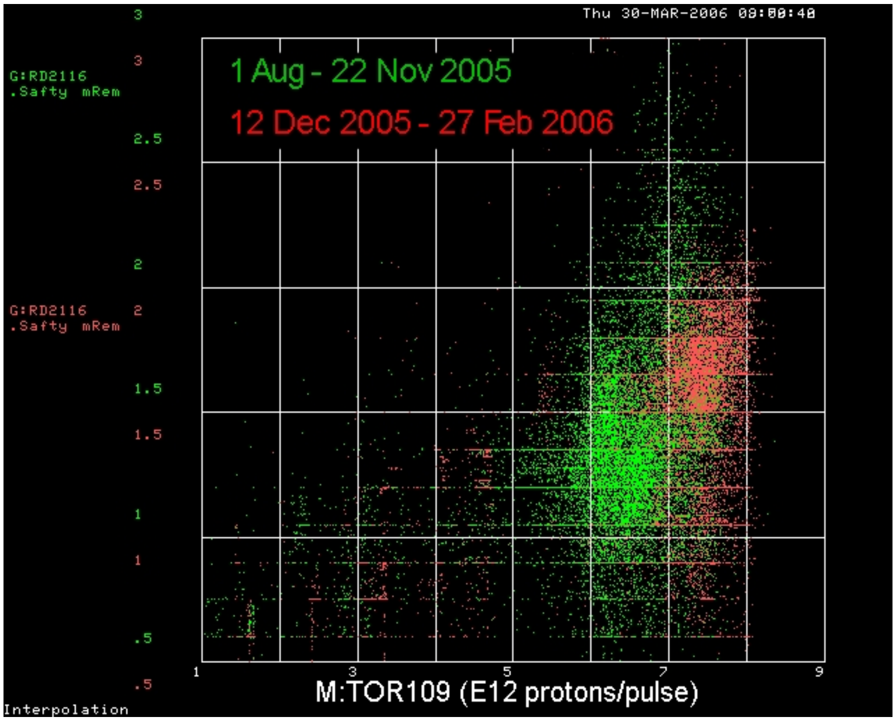

Figure 5 AP50 radiation monitor AP50A53R07 versus M:TOR109 before (green) and after (red) the November – December studies period. The radiation per unit proton flux on target is slightly lower after the studies.

Source of the radiation: Injected versus Circulating Beam losses

The AP50 radiation monitors showing the highest levels are in the vicinity of the injection region of the Debuncher. Thus, the source of the observed radiation levels could be losses from injected beam, or Debuncher circulating beam, or both. To determine the source of the radiation a scraper (D:TJ308) was inserted to kill the circulating beam[2]. The observed radiation levels were unchanged after insertion of the scraper. Therefore the increased AP50 radiation levels are due to losses from the injected beam.

Injection Channel lattice / Injected – Circulating beam separation

Among the possible causes of losses from the injected beam are lattice distortions that cause the beam to be large in the limited aperture of the injection channel, or losses on the injection septum due to inadequate separation of the injected and circulating beam. Gross errors in both of these categories can be seen by observation of the beam profile on SEM403 – located about 3.5 m downstream of the injection septum. Figure 6 shows the beam profile on SEM403 during stacking. The observed widths are consistent with the Debuncher and AP2 lattice model beta functions and the expected beam emittances. The vertical width of the injected beam is the same as that of the circulating beam, indicating that the AP2 line is not grossly mis-matched to the Debuncher. Moreover, the vertical separation between the injected and circulating beam is what

[2] This test was performed on the evening shift of December 13, 2005.

it should be, and is consistent with previous measurements[3]. Thus, it appears that lattice distortion or insufficient beam separation are not causes of the increased radiation levels at AP50.

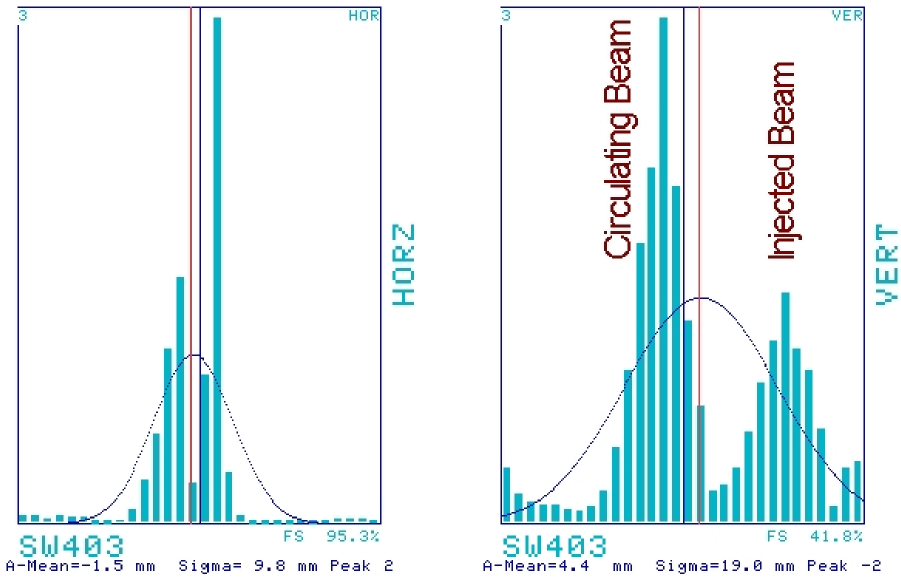

Figure 6 SEM403 profiles during stacking (12/16/2005 Day shift). The wire spacing is 3 mm. Therefore the vertical separation between the injected and circulating beam is approximately 30 mm. The ½-width of both the circulating and injected beam is between 12 and 15 mm. This width corresponds to a vertical emittance between 22 and 35 π mm•mrad (β_y = 6.51 m). The horizontal width of the circulating beam is between 12 and 15 mm. This corresponds to a horizontal emittance between 19 and 30 π mm•mrad (β_x = 7.45 m).

Steering of the beam in the Debuncher injection channel

During the November – December 2005 studies the beam trajectory in the injection region of the Debuncher was established by centering the beam vertically in the quadrupole magnets. A month later, during the January 2006 studies period, the beam was horizontally centered. These efforts are described in the following documents:

K. Gollwitzer, Debuncher Orbit/BPM-Quad center offsets

K. Gollwitzer, Debuncher Orbit Correction.

After the Debuncher orbit was established, great care was taken to properly position the injection septum and establish an injection trajectory that is centered in the downstream quadrupoles of the AP2 line. This work is described in the following document:

D. McGinnis, Setting AP2-Debuncher Injection Region.

Also, an alignment check was performed on the magnets at the downstream end of AP2 and in the Debuncher injection region. Nothing was more than 0.5 mm out of alignment.

The steering of the beam in the Debuncher injection channel is better than it has been at any time during Run II. Beam steering errors are not likely the cause of the increased radiation levels at AP50.

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[3] The SEM403 profile during stacking was previously measured on January 18, 2005.

Conclusions

The increased radiation levels measured on the radiation monitors near the center of the AP50 service building are a direct consequence of the increased beam on target since slip-stacking became operational. The observed levels are due to injected beam rather than circulating beam. Errors in the AP2/Debuncher lattice and in the beam trajectory have been ruled out as a source of the increased radiation levels.

Two of the AP50 radiation monitors routinely report values at 25 – 50% of that which would take down the pbar beam permit. Therefore, it is important that these monitors be watched frequently while stacking. Furthermore, careful attention should be given to these monitors when initiating stacking, while tuning the beamlines, and when tuning Debuncher injection.