Effects of Booster Scraping in Polarized Proton Runs 2006 and 2008

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Abstract

Effects of the Booster vertical scraping on the RHIC beam polarization, the RHIC beam emittance, and on the Booster to AGS transfer efficiency and AGS transmission as well, are further studied.

In [1], the strong dependence of the RHIC beam polarization and emittance on bunch intensity in proton run 2008 (pp08) is compared with the proton run 2006 (pp06), where the dependence is much weaker. The setting in the AGS Booster, mainly the vertical scraping, is suspected to having played a role in the different patterns in the two runs.

In this note, we further study the effects of the Booster vertical scraping on the RHIC beam polarization, and on the RHIC beam emittance as well. With the improvement of the RHIC bunch intensity in mind, the Booster scraping effects on the Booster to AGS transfer (BtA) efficiency and the AGS transmission are also studied. For simplicity and to be more useful, only the RHIC fills after the one-week shutdown in pp06 and the fills using the AGS User 2 in pp08 are shown. For these fills, the machine settings in AGS are similar in pp06 and pp08 runs. Furthermore, this setting might be used for next polarized proton run, at least at the beginning of the run.

In Fig.1, the RHIC beam polarization, the RHIC beam emittance at early store, and the BtA and AGS transmissions are plotted against the Booster vertical scraping.

The Booster scraping is represented by the ratio of Binput/Blate, where Binput is the intensity measured for the beam coming from LINAC and Blate is measured at the late of the acceleration cycle in the Booster. The ratio of Binput/Blate, hereby named scraping ratio, spans from 1.1 to 3.2 in the plots. The scraping ratio below 1.5 means very little or no scraping applied in the Booster. For heavy scrapings, there are some fills in pp06 that had the scraping ratio as large as 5.4, but as shown in Fig.1, for best polarization and emittance the scraping ratio around 2.8 seems sufficient.

In Fig.1, there are total 72 RHIC fills for pp06, i.e., 7780 to 7957, and 18 fills for pp08, i.e., 9972 to 10000. The last fill in pp08, 10002, is not included, since it has a very low bunch intensity, less than 0.9×10^{11} protons.
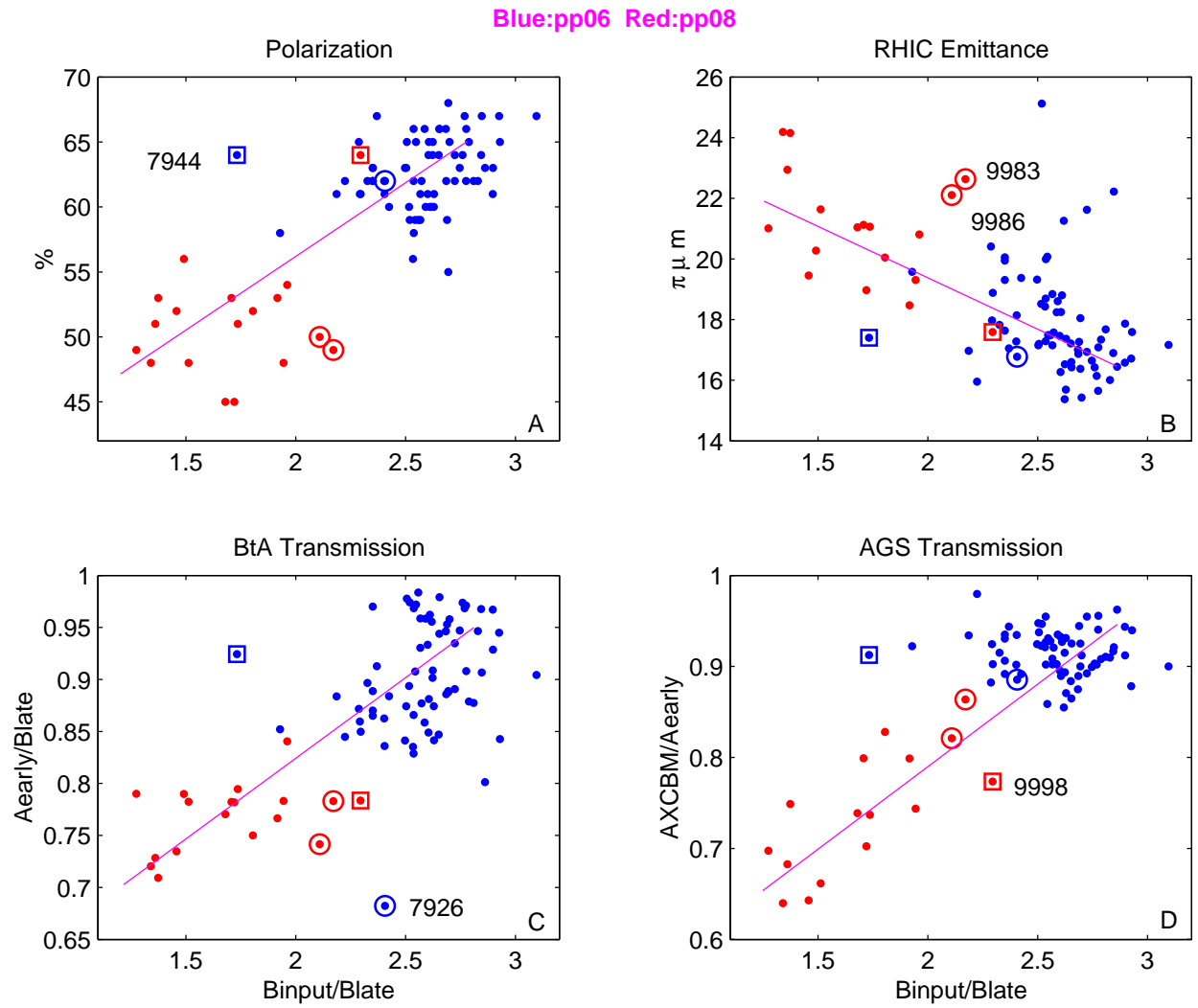
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Figure 1: Booster scraping effects on RHIC beam polarization, RHIC beam emittance, and the BtA and AGS transmissions for pp06 and pp08 runs.

The largest scraping ratio of pp08 (red) is 2.33, but most pp06 fills (blue) have the ratio larger than that, indicating the most noticeable difference between the two runs.

It can be observed from Fig.1 that the fills in the two runs, despite of different scraping ratios, have shown similar trend in the Booster scraping effect for the polarization, emittance, and the BtA and AGS transmissions as well. That says, for most fills a single line fitting can be placed for each sub-plot, allowing a study that might be useful in future polarized proton runs.

Below are some comments regarding to each subplot.

1. In Fig.1A, the RHIC beam polarization is plotted against the Booster scraping ratio. The RHIC polarization is for Blue beam measured at the early store for each fills (although the Yellow polarization in pp06 is similar to Blue, in pp08 it is systematically lower than Blue. The problem is believed not in the injectors, hence it is not included in this study). Approximately, with the Booster scraping ratio from 1.2 to 2.8, the center line of the polarization is raised from 47% to 65%. It is good to see that for polarization improvement, the Booster scraping ratio less than 3 seems sufficient. For this scraping ratio, at the Booster input intensity of 6×10^{11} protons, the exit Booster intensity would be more than 2×10^{11} protons, meeting the RHIC bunch intensity requirement.

2. In Fig.1B, the RHIC beam emittance (normalized, 95%) at the early store of each fills is plotted against the Booster scraping ratio. Approximately, with the Booster scraping ratio from 1.2 to 2.8, the center line of the emittance is reduced from 22 $\pi\mu m$ to 17 $\pi\mu m$. The impact of the emittance improvement, for the increased Booster scrapings, on the luminosity is not trivial. It is interesting to notice that from the Booster exit to the RHIC early store, entire AGS and RHIC rampings are on the path, yet the vertical size at the BtA (horizontal size is little affected by the Booster vertical scraping), affected by the scraping, is shown as an important factor in determining the RHIC beam emittance. There is no doubt that the AGS and/or RHIC rampings add on some emittance growth. Nevertheless, the Booster scraping effect on the RHIC beam emittance is decisive for the scraping ratio smaller than about 2.5. For Booster scraping ratio larger than 2.5, it remains to see if further improvement in the beam emittance is possible.

3. In Fig.1C, the BtA transfer efficiency is plotted against the Booster scraping ratio. The BtA efficiency is the ratio of Aearly and Blate, and Aearly is the beam intensity measured by the current transformer right after the AGS injection. Approximately, with the Booster scraping ratio from 1.2 to 2.8, the transfer efficiency is increased from 70% to 95%. The Booster vertical scraping affects mainly the beam vertical size, as verified by all BtA multiwires, including MW006. The horizontal size is much less affected. Therefore, the improvement of the BtA transfer

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efficiency shows that the vertical aperture in BtA line, and/or at the Booster extraction and AGS injection, is tight. The ratio from 70% to 95% shows that this is a significant aspect in terms of RHIC bunch intensity improvement.

4. In Fig.1D, the AGS transmission of AXCBM/Aearly is plotted against the Booster scraping ratio. AXCBM is the beam intensity measured by the current transformer at the top energy in the AGS, and it is about 5% higher than the bunch intensity measured at the RHIC injection. Again, the transmission is improved from some 65% to 95% along with the increase of Booster scraping ratio from 1.2 to 2.8.

Note, that several important factors are not presented at all in the plots in Fig.1. The most important one is the Booster input intensity, and others are the RHIC bunch intensity and the proton source current. The RHIC bunch intensity can usually be determined by the Booster input intensity and the Booster scraping ratio, if the BtA, AGS, and RHIC transmissions are relatively constant.

In general, the lower the Booster input intensity (often associated with less turns of the Booster injection), the higher the polarization and smaller the emittance. Similarly can be stated for the RHIC bunch intensity.

In Table 1, the maximum and minimum of the Booster input intensity and the RHIC bunch intensity at the end of the injection for pp06 and pp08 fills shown in Fig.1 are listed. The mean values are also listed for comparison.

Run	pp06			pp08		
	max	min	mean	max	min	mean
Booster input intensity, 10^{11}	5.85	3.43	4.84	6.20	4.35	5.08
RHIC bunch intensity, 10^{11}	1.57	1.10	1.46	1.80	1.19	1.51

Table 1: Maximum, minimum and mean of Booster input intensity and RHIC bunch intensity at the end of the injection for fills shown in Fig.1.

Additional comments are toward some fills in Fig.1 for pp06 and pp08. These fills are marked by circle or square. Each of these fills are indicated in one sub-plot by the fill number, and it can be easily identified by the same Booster scraping ratio in other sub-plots.

The fills 7926 and 7944 in pp06 are off the trend line (the thin magenta lines in Fig.1) in some or all sub-plots in Fig.1, attempts are made to explain why. The Fills 9983, 9986, and 9998 are with the largest scraping ratio in pp08, but the polarization and/or emittance improvements are less satisfactory compared with the fills in pp06, which have similar scraping ratios. Explanations are made.

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1. Fill 7926 in pp06. This fill has a very low BtA transfer efficiency, 0.68, for its scraping ratio of 2.4. The reason is not clear. With a reasonable Booster input intensity of 4.62×10^{11} protons (average 4.84×10^{11} protons), the resulted RHIC bunch intensity is the lowest, 1.10×10^{11} protons. This is compared with the mean of 1.46×10^{11} protons. This fill has no special merit in understanding the Booster scraping effect.

2. Fill 7944 in pp06. This fill has the lowest Booster input intensity, 3.43×10^{11} protons (average 4.84×10^{11} protons). Yet with decent BtA and AGS transmissions, the resulted RHIC bunch intensity is 1.53×10^{11} protons (average 1.46×10^{11} protons). The fill 7944 also has the polarization of 64% and the small emittance of $17.4 \ \pi\mu m$. This fill shows what might be achieved with a low Booster input intensity, but apparently this approach has a limit when the RHIC bunch intensity needs to be pushed.

3. Fills 9983 and 9986 in pp08. These two fills are very similar, and their Booster input intensities are the highest, with 6.10×10^{11} and 6.20×10^{11} protons. The resulted RHIC bunch intensities are also the highest, 1.80×10^{11} and 1.68×10^{11} protons, with large emittance of 24.0 $\pi\mu m$ and 23.4 $\pi\mu m$, respectively. The effect of the high Booster input intensity is demonstrated in the low polarization and large emittance. The BtA transmission of Fills 9983 and 9986 is only 0.78 and 0.74, which are low. There is a possibility that if more Booster scraping is applied, better polarization and smaller emittance could be achieved, with a decent bunch intensity in RHIC. In Table 2, the Fills 9983 and 9986 in pp08 are compared with 5 fills having the highest Booster input intensities in pp06. All these fills in pp06 have larger scraping ratio (average 2.93) than the Fills 9983 and 9986 (average 2.14).

Run	pp06					pp08	
Fill	7825	7826	7827	7855	7856	9983	9986
Booster input, 10^{11}	5.82	5.77	5.68	5.85	5.73	6.10	6.20
Scraping ratio, Binput/Blate	3.10	2.93	2.90	2.93	2.81	2.17	2.11
RHIC beam emittance, $\pi\mu m$	17.2	17.6	17.9	16.7	17.7	24.0	23.4
RHIC bunch intensity, 10^{11}	1.49	1.48	1.47	1.51	1.53	1.80	1.68

Table 2: The Fills in pp06 and pp08 having highest Booster input intensity, the scraping ratio of Binput/Blate, and the RHIC beam emittance and bunch intensity

4. Fill 9998 in pp08. The polarization and emittance of this fill are good, with the Booster input intensity of 5.30×10^{11} protons (average 5.08×10^{11} protons) and the scraping ratio of 2.29 (average 1.71). With poor transmissions at both BtA and AGS, the RHIC bunch intensity is only 1.21×10^{11} protons, close to the lowest one (1.19×10^{11} protons). We note that this fill was intended to demonstrate higher polarization with lower beam intensity, therefore, the beam transmission efficiency was not subjected to improve.

References

[1] S.Y. Zhang, L. Ahrens, H. Huang, and K. Zeno, Polarization Issues in Run 2008, C-A/AP/316, BNL, July 2008.