SNS RING STUDY AT THE AGS BOOSTER *

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Abstract

During the g-2 run at the BNL AGS in early 2000, a 200 MeV storage-ring-like magnetic cycle has been set-up and tuned at the Booster in preparing for the Spallation Neutron Source (SNS) accumulator ring study. In this article, we report the progress of the machine set-up, tuning, some preliminary studies, and the future plan.

1 INTRODUCTION

The high power and low loss SNS accumulator ring [1,2] calls for better understanding on several fronts. In particular, some mechanisms that produce beam loss are not well understood. Relevant issues include longitudinal and transverse beam profiles, the effect of space charge, acceptance to emittance ratio, resonance crossing, foil crossing, multiturn injection painting, and collimations.

An SNS accumulator ring study was, therefore, proposed at the AGS Booster. The study would be performed during a period of two years, mostly on a dedicated user parasiting to high intensity proton runs at the AGS. In later 1999, a list of devices needed for the study was developed, and the preparation was started. However, the AGS g-2 run was moved ahead of the schedule, and it was decided to begin the study, with the primary goals for the magnetic cycle tuning, beam parameters measurement, and preparation for further studies.

Thus, in early 2000, a storage-ring-like 200 MeV magnetic cycle was established at the Booster. The involved works include the magnetic cycle, RF capture, injection set-up, extraction set-up, coherence reduction, tune adjustment, chromaticity, closed orbit, harmonics, and correction bumps, etc. In parallel with the machine tuning, some preliminary studies were performed. Since the Ionization Profile Monitor (IPM) needed some work, in most part of the study, the beam profile was studied by the extracted beam, using the multiwire (MW) in the Booster to AGS (BTA) transfer line. To get an accurate measure of beam size from the multiwire profiles, the beam scraping at the extraction septum needed to be eliminated, and the beam size needed to be reduced. The multiwire measurements indicate that there is an optical mismatch at injection. Therefore, efforts were also focused on the understanding of the Linac to Booster (LTB) line for the matching at the Booster injection. Only in the last two days before the run ended, the IPM become operational, and some profiles were taken.

This study has achieved basic goal that is to establish a usable 200 MeV cycle, and to gather necessary knowledge and confidence for further study, including the bench-marking of simulations, using codes such as SIMPSONS and UAL/ORBIT.

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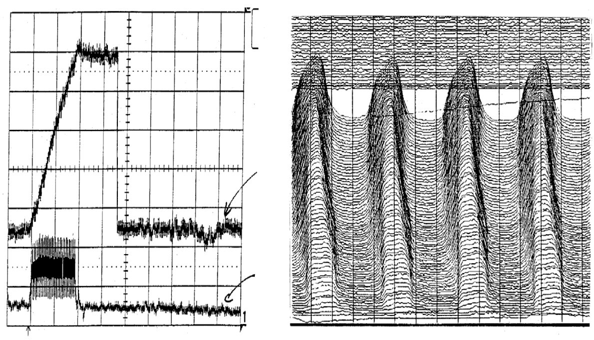
2 BOOSTER PARAMETERS

The set-up of the Booster cycle parameters are considered for easy comparison with the SNS parameters. For the Booster acceptance of 90 $\pi\mu m$, it is to set the beam emittance at 30 $\pi\mu m$ and the intensity at $N = 3.3\times10^{12}$ protons. At the Booster injection energy of 200 MeV, the emittance to acceptance ratio and the space charge effect are comparable with the SNS acceptance of 480 $\pi\mu m$, the beam emittance of 160 $\pi\mu m$, and the intensity of $N = 2.08\times10^{14}$ protons at 1 GeV. The Booster multiturn injection will take 360 turns, which equals 430 μs. At the harmonic 1, the fundamental RF voltage is 45 KV, therefore, the synchrotron frequency of 2.3 KHz implies that 430 μs injection equals 1 synchrotron period, which is comparable to SNS synchrotron frequency of 1 KHz with 1 *ms* injection period. In the machine set-up, however, some of these parameters had to be varied to reduce the beam loss, such as the RF voltage.

3 SORAGE RING MAGNETIC CYCLE

For a storage-ring-like magnetic cycle at the Booster, the machine is essentially different from the conventional Booster magnetic cycle, therefore, it took considerable effort for the tuning. After much work, a usable cycle with acceptable beam loss was achieved. The intensity associated beam loss was observed. Also, it was noticed that the beam loss increased with the higher RF voltage, therefore, the loss may come from the machine momentum aperture limitation.

One running situation is shown in Fig.1. The top trace in Fig.1a is the injection transformer signal, and the bottom is the beam current at the end of Linac, time scale is 0.2 ms/div. A mountain range of the wall current monitor signal, in 1 ms, is shown in Fig.1b. The beam is injected in 0.4 ms and extracted 0.38 ms after the stacking.



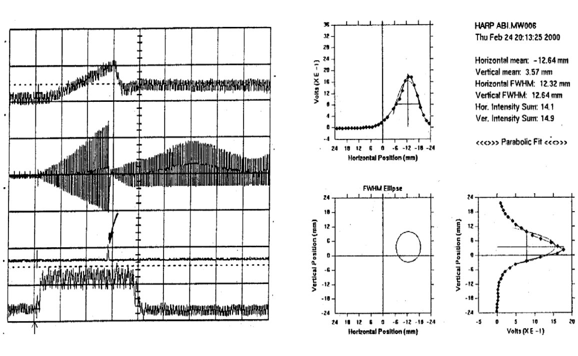
a b

Fig.1: Injection, extraction and mountain range

4 EXTRACTED BEAM

With the IPM under repair, most time in the study, the profile was observed using the extracted beam. The Booster extraction was designed for the beam exit at 1.5 GeV, therefore, the vertical aperture is 25 $\pi\mu m$, and horizontal is 48 $\pi\mu m$, which is actually about 30 $\pi\mu m$, given the large beam momentum spread and the dispersion in the BTA line.

The effort to observe the beam profile without distortion consists of two parts. One is to minimize the beam emittance at the multiturn injection, and another is to steer the beam clear at the extraction channel. After much tuning, the vertical and horizontal beam emittances observed at the BTA MW006 were not less than 10 $\pi\mu m$ in vertical, and 30 $\pi\mu m$ in horizontal.



a b

Fig.2: Observation using extracted beam

In Fig.2a, from the top trace to the bottom are Booster injection transformer signal, the wall current monitor, the fast extraction kicker current, and the Linac beam current. The vertical and horizontal beam profiles are shown on the top left and bottom right in Fig.2b, respectively. The extracted beam intensity was about $N = 2\times10^{12}$.

5 SINGLE TURN EXTRACTION

A turn-by-turn extraction set-up, used during the injection, was devised to allow study of the optical match between the Booster and the Linac. A short pulse of Linac μs, was injected into the Booster, which has a revolution period of 1.2μs. This short pulse was extracted as it passed the extraction channel on the first as well as subsequent turns. The resulting multiwire data showed significant variations in profile width from turn to turn in both planes, supporting the hypothesis that the beam is not optically matched at injection. In Fig.3, vertical and horizontal profiles are shown for one-turn injected beam extracted after 1 to 3 turns stay in the ring, from left to right.

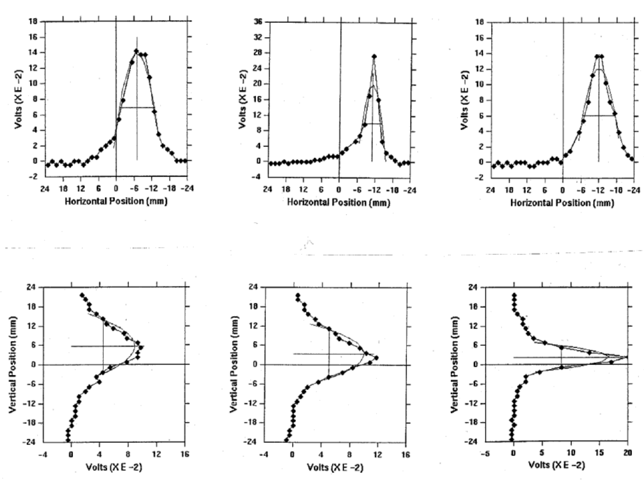


Fig.3: Vertical on top and horizontal on bottom, From left to right, 1, 2, 3 turns extractions

6 LINAC TO BOOSTER TRANSFER LINE

The attention was then paid to the understanding of the Linac beam profile and the Linac to Booster (LTB) transfer line. It is noted that for usual high intensity proton runs, the space charge effect is dominant in the Booster injection, and therefore the longitudinal painting is important in terms of reducing the beam peak current. On the other hand, the Linac beam transverse profile and the injection optics matching are not critical. For SNS ring study, however, the understanding of the Linac beam profile and the LTB line optics becomes indispensable.

This effort was started with measuring the emittance and Twiss parameters of the injected beam from the Linac, using the programs MAD and EMIT. The technique is to vary the strength of a quadrupole in the LTB line and measure the variation of the size of the beam at a beam profile monitor downstream of the quadrupole. In Fig.4, it shows 3 sets of measurement at the MW035 for 15 current set from 100 A to 240 A at the quadrupole QH1 in the LTB.

The measurement shows the horizontal and vertical rms emittance of the Linac beam as 1.15 $\pi\mu m$ and 2.15 $\pi\mu m$, respectively. These are slightly different from the measurement performed before at the LTB line.

With the LTB line model, optics matching at the Booster injection was studied, but time period limited this effort without reaching a conclusion.

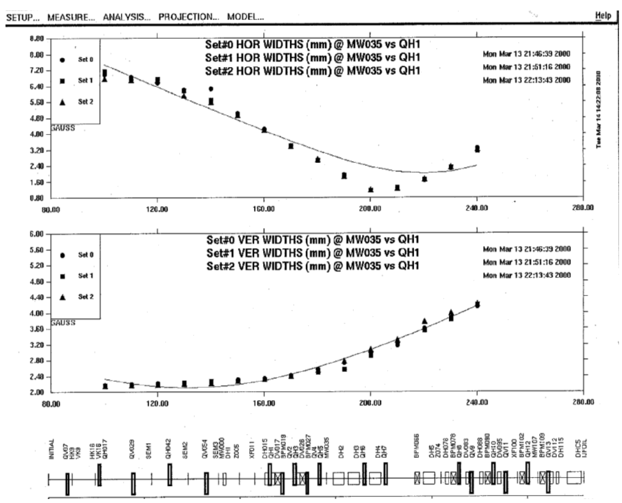


Fig.4: Twiss parameter and emittance measurement, LTB line is shown at bottom

7 IONIZATION PROFILE MONITOR

Just before the end of the run, the Booster IPM became operational after repair. Some beam profiles were taken. The Linac beam was chopped at a ratio of 0.5 with respect to the RF period, or 180 degrees. The beam was injected 320 turns into the Booster. The Booster beam intensity was controlled by ‘sieve’, which is a device located at the front end of the Linac. Setting sieve 10% means that for each 100 microbunches at the Linac, 90 of them are sieved off. This way to adjust the beam intensity, the injection is little affected in both longitudinal and transverse. The intensities were varied from 0.5 TP (1 TP =10^{12} protons) to 6.25 TP. With the IPM parameters of $\beta_x = 9.08$ m, $\beta_y = 7.74$ m, the dispersion function $D = 2.3$ m, and the estimated beam momentum spread of $dp/p = \pm 0.4\%$, the beam

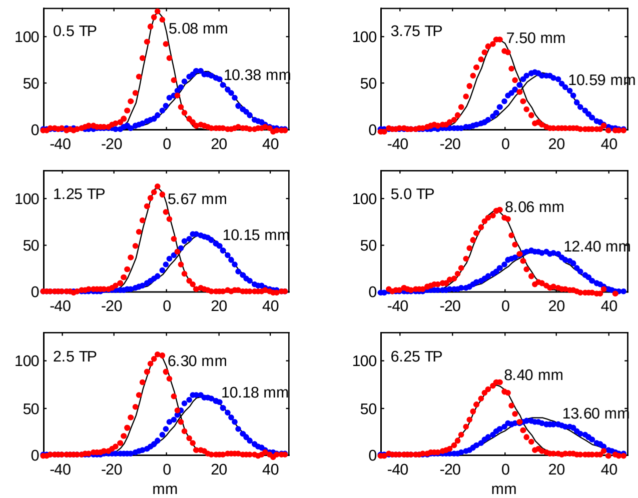


Fig.5: IPM beam profile w.r.t. intensity

emittance for 95% particles at the low intensity was about 50 $\pi\mu m$ and 20 $\pi\mu m$, for horizontal and vertical, respectively. The Booster tunes were set at 4.6 and 4.75 for horizontal and vertical, respectively, which were close to the real tunes.

In Fig.5, the red and blue dots are the measured IPM data for vertical and horizontal beam profiles, and the black line is the Gaussian fit. Beam rms size from the Gaussian fit is also shown. Amplitude of the profile is normalized by the intensity of injected beam. The emittance growth with the intensity increase can be observed. We note that beam loss becomes not negligible at the intensity of 3 TP and up.

8 PREPARATION FOR THE NEXT STUDY

In preparation for the next study, it is decided to add one more MW in the LTB line for better Linac beam profile and LTB line optics measurement. This is very important for the optics matching in the Booster injection, and also necessary for the code bench-marking. A flag will be installed to observe the beam x-y profile, and also for the space charge effect study. To avoid the beam profile distortion at the Booster extraction channel, it will be placed before the extraction septum. Meanwhile, we would like to upgrade the IPM and some application software, before the next SNS ring study at the AGS Booster.

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