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Linac Beam Momentum Spread

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AGS Complex Machine Studies (AGS Studies Report No. 356) Title: Linac Beam Momentum Spread
Study Period: June 8-9, 1996
Participants: C. Whalen and S.Y. Zhang
Reported by: S.Y. Zhang
Machine: Booster
Beam: Proton
Tools: Booster RF, PUE
Aim: To detect the Linac beam momentum spread variation and its influence on the Booster RF capture.

Linac Beam Momentum Spread

1 Summary

1. In 1996 HEP run, deterioration of Linac beam momentum spread was observed, which affected the Booster RF capture, and the Booster and AGS performance.

2. There are large quantitative gaps between different measurements and calculations.

2 Overview

The Linac beam momentum spread used to be measured at HEBT. According to J. Alessi, the 90% energy spread was $dE = \pm 0.5\ MeV$, which implies that $dp/p = dE/\beta^2 E = \pm 0.5/(0.566^2 \times 1138) = \pm 0.14\%$. The acknowledged Linac beam momentum spread is $dp/p = \pm 0.2\%$. Meanwhile, J.M. Brennan measured the momentum spread in a different way as $dE = \pm 1.2\ MeV$, implying $dp/p = \pm 0.33\%$.

The RF bucket half height at the injection was about 1% in terms of momentum deviation $\Delta p/p$, at the 3 $Tesla/s$ Bdot porch, with 85 KV RF voltage.

Several times in 1996 HEP run, the Linac beam momentum deterioration was suspected to cause frequent tuning of RF capture at the Booster. A period of June 8 to June 16 will be used for illustration. Major events happened during this period are as follows.

1. June 8. The Booster injection was under constant tuning for RF capture. The AGS extraction intensity was 49 TP, well below the typical good run, 60 TP. A measurement for the Booster half turn injection debunching was performed, which will be discussed in the next section.

2. June 9. The machine performance was improved, and the AGS extraction intensity was 55 TP. Another measurement was performed, which also will be discussed later.

3. June 10. J. Alessi and V. LoDestro found that there was 7 mA beam loss between Mod 9 and LTB. Retuned back to Mod 4. The Linac beam was brought back to 34 mA.

4. June 12. When BLIP was brought on, the transmission efficiency from Tank 9 to BLIP was 80%, the beam loss can only be caused by large momentum spread induced dispersion scraping. Several Tanks' phase were adjusted, the transmission efficiency back to 97%.

5. June 16. The typical Booster late intensity was restored to 90 TP, and the AGS extraction intensity was about 60 TP.

3 Measurement

In June 8, the machine was in a bad condition. The Booster input-early-late and the AGS extraction intensities were 142-82-66-49 TP. This is compared with the typical 1996 HEP good run, with 150-100-90-60 TP. The debunching at the Booster ring for the half turn injection of the Linac beam is used to look at the beam momentum spread. The D2 PUE Sum signals at the first and second turns and around the 40 th turn are shown in Fig.1. The chopper was set to 90 degree, and RF was off. In about 50 turns, the debunching was completed, which gives rise to the debunching time $t_{db} = 60\ \mu s$. The beam momentum spread can be estimated by using

$$t_{db} = \frac{\pi - \Delta\phi}{2\pi f_0 h\, |\eta|\, dp/p}$$

where $\Delta\phi$ is the half bunch length, f_0 is the revolution frequency, which is 836 KHz, and in this case we have $h = 1$. Note that this formulation is for the case that the beam momentum spread is smooth, e.g. the particle distribution is in a Gaussian or parabolic. This is not true for the Linac beam. We use it anyway. For 90 degree chopper, $\Delta\phi = 0.125\ \pi$. Thus, we get $dp/p = \pm 1.38\%$, where we used $\eta = -0.634$. This momentum spread looks very large, however, considering the RF bucket half height $\Delta p/p = 1\%$, and also the bad performance of the machine, it is not completely impossible.

In June 9, the machine performance was improved. The Booster input-early-late and the AGS extraction intensities were 149-91-78-55 TP. The half turn injection debunching is shown in Fig.2. On the bottom, the overall debunching is also shown. It can be observed that the large bulk between the core of the distribution shown in Fig.1b is reduced. In fact, assuming the large bulk shown in Fig.1b is 0.5 μs ahead of the core after 40 turns, then we can estimate its momentum deviation from the core of the beam. This is $dp/p = 0.5/48\,|\eta| =$ 1.6%. The particles in the bulk are unlikely to be captured, which might be used to explain the bad performance of June 8.

Another two half turn injection debunchings performed by C. Whalen are shown in Fig.3 for comparison. In Fig.3a, a debunching performed at May, 1994 is shown. At the end of the plot, the beam signal is still there after more than 80 turns. This can be compared with the one on the bottom of Fig.2. C. Whalen recollected a good debunching as long as 200 turns. For this case, we get $dp/p = \pm 0.35\%$, which is very close to J.M. Brennan's measurement. In Fig.3b, a debunching of Feb. 1996 is shown, where the bunch has virtually not changed in 40 turns. This is also to compare with the one in Fig.2.

4 Discussion

1. The results presented in this report is not complete, and all the results are open for discussion. The Linac beam momentum spread variation, however, has been clearly indicated. The large quantitative gap between different measurements and calculations needs more attention in future studies.

2. The Linac beam momentum spread variation has profound influences on the performance of the HEP run. In specific, when the Linac beam momentum spread changes, the Booster injection has to be retuned, among them, the Pkr, the RF Track, etc. This affects the beam profile in both transverse and longitudinal. After this step, to retune

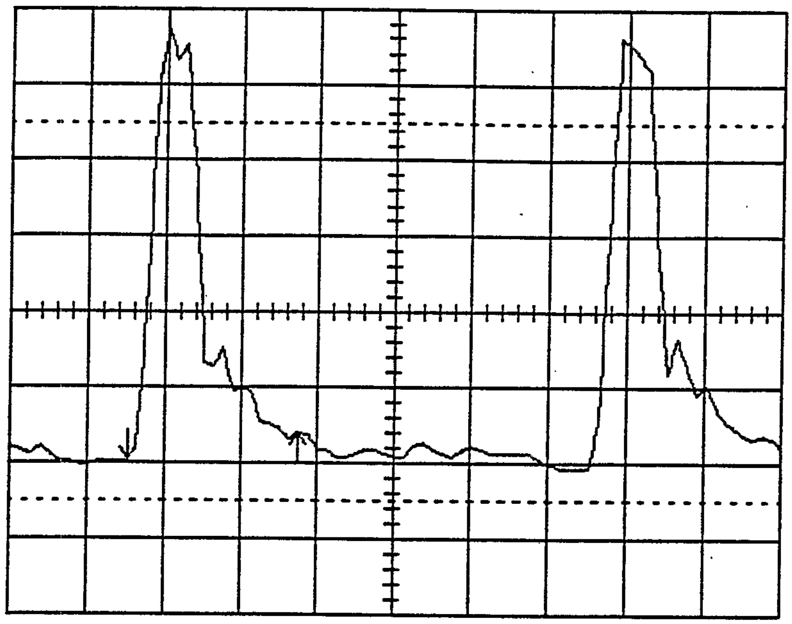
the Booster acceleration, extraction, the BTA transfer, even the AGS could gain a little more intensity, and the machine optimization established in a period of weeks is lost.

3. The beam momentum spread variation has two aspects. One is represented by dp/p, implicitly assuming smooth distribution. Another one is also important, as observed in Fig.1b, i.e. a bulk of beam carries different momentum from the core of the beam. The momentum distribution is by no means smooth. In this case, the measurement, the calculation all become very difficult.

4. In 1996 HEP run, sometimes the Booster intensity suddenly drops by 10 TP, without any indication of the variation in the Linac beam profile and the machine operation condition. Then the machine comes back itself. This is probably also because of the beam momentum spread variation. The beam momentum spread is the only important beam parameter not under on-line detection.

5. The stabilization of the beam momentum spread is very important for the operation. Also to make the distribution smooth, i.e. to eliminate the glitches in the distribution, is important. To further improve the Booster RF capture, the smaller beam momentum spread will also be helpful.

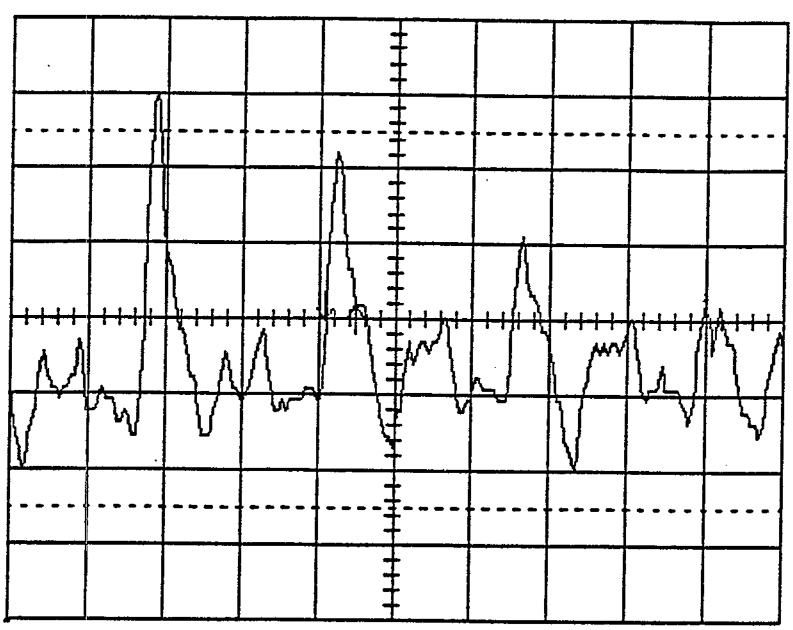
June 8, 1996



0.2 $\mu s/Div$

First and Second Turns

Fig. 1a

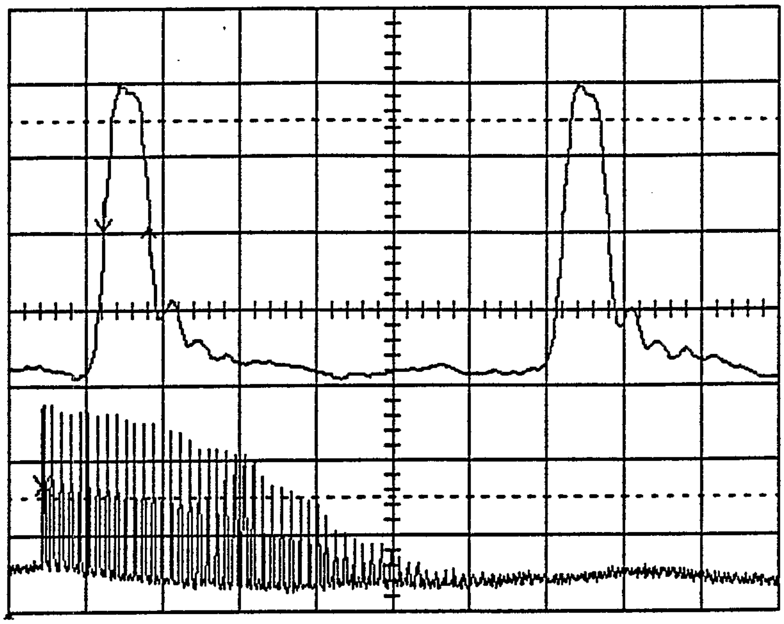


0.5 $\mu s/Div$

Around 40th Turn
(Scale is enlarged)

Fig. 1b

June 9, 1996



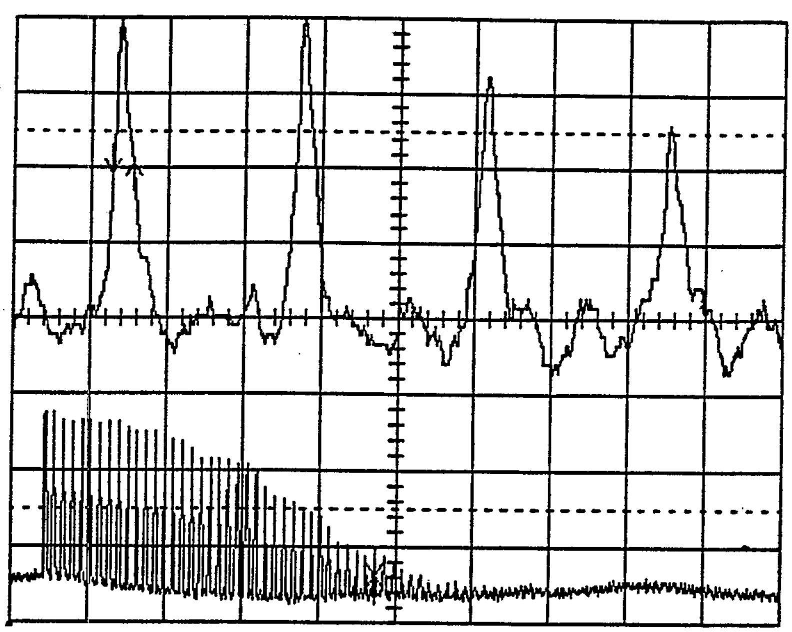
First and Second Turns

0.2 *μs/Div*

Debunching

10 *μs/Div*

Fig. 2a



Around 40th Turn

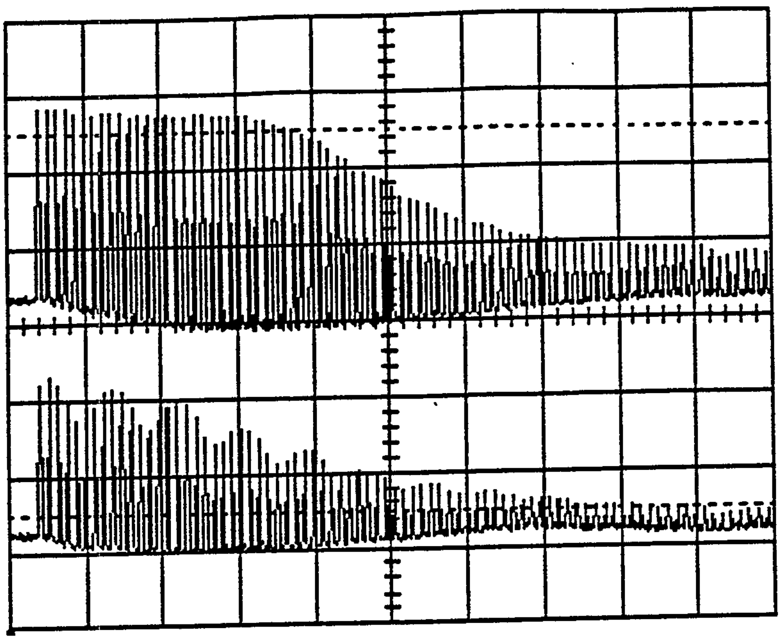
(Scale is enlarged)

0.5 *μs/Div*

Debunching

10 *μs/Div*

Fig. 2b



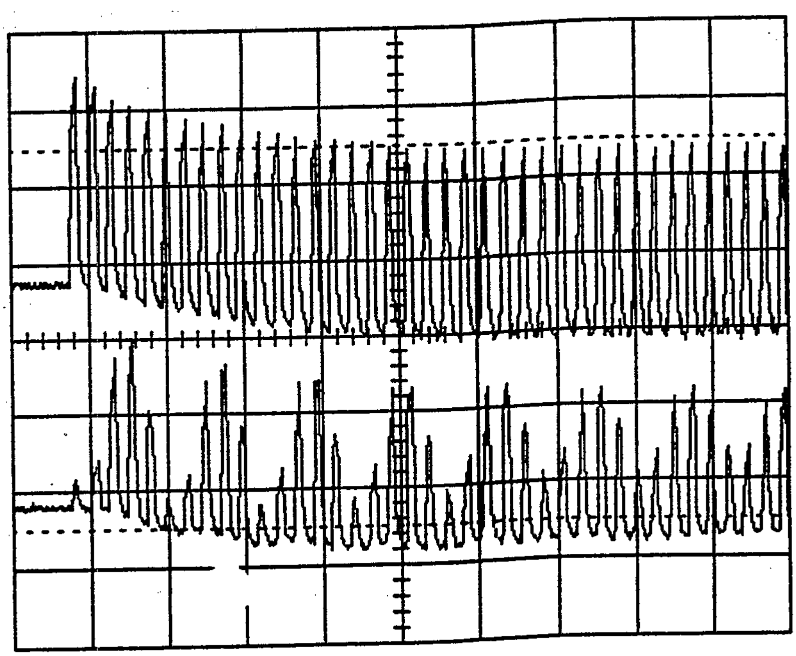
May 1994

D2 PUE Sum

Diff.

10 $\mu s/Div$

Fig.3a



Feb. 1996

D2 PUE Sum

Diff.

5 $\mu s/Div$

Fig. 3b