AN EXPERIMENTAL STUDY OF INTENSITY DEPENDENT BEAM LOSS MECHANISMS DURING THE INJECTION PERIOD OF THE KEK PS 12 GeV MAIN RING

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Abstract

Beam loss mechanisms during the injection period of the 12 GeV main ring of the KEK proton synchrotron have been studied to achieve higher intensity. Measurement of the transverse beam profiles using flying wires has revealed the characteristic temporal change of the beam profile within a few milliseconds after the injection. In both horizontal and vertical direction the beam profile of a few ms after the injection was wider for the lower betatron tune for the measurement between about 7.05 to 7.25 unless the aperture limited the beam size. The beam survival for the rest of the injection period was better for the wider beam. A multiparticle tracking simultaion program, ACCSIM, taking account of space charge effects, nonlinear effects of the sextupole and octupole magnets and closed orbit distortion has successfully reproduced the beam profiles.

1 INTRODUCTION

Beam loss mechanisms during the injection period have been studied at the 12 GeV main ring of the KEK proton synchrotron. Nine bunches of 500MeV proton beams are injected with the intensity of 1.4×10^{12} protons per bunch in a typical operation mode with the interval of 50 ms. The typical beam loss is so far about 10 % or more through the injection period of 500 ms and has been one of the key issues for the further intensity upgrade.

A modification of the transverse beam profile after the injection has been empirically known to be dependent on the betatron tunes and the beam intensity. The betatron tunes of both the horizontal and vertical direction have been optimized for miminum beam loss and set to $(\nu_x,\nu_y) \simeq$ (7.13,5.25) for the high intensity operation.

2 RAPID CHANGE OF BEAM PROFILES AFTER THE INJECTION

The flying wire transverse beam profile monitors have been operated at the main ring and have demostrated the wide dynamic range of more than two orders of magnitude and the position accuracy of 0.4 mm [1]. It takes about 3 ms for the wire to scan a typical size of the injection beam. The wire scanning can be initiated once in an acceleration cycle of the main ring at an arbitrary timing using a delayed trigger with respect to the injection kicker timing signals or the acceleration cycle timing signals.

A new stroboscopic procedure has recently been established to reconstruct the beam profile that quickly changes with a time scale of 1 ms or less. A series of profile data are acquired by changing the trigger setting with an increment of 0.2 ms. They are then rearranged to reconstruct the simultaneous profiles.

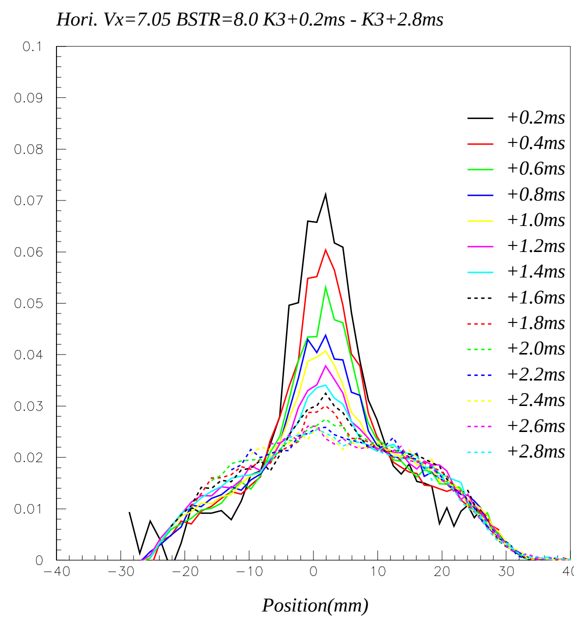

Figure 1: Horizontal beam profiles of 0.2 ms to 2.8 ms after the injection when the horizontal tune was 7.05 and the beam intensity was 8.0×10^{11} ppp at the booster extraction.

When the beam intensity was set to 8.0×10^{11} ppp at the booster extraction, the horizontal flying wire data were taken and the beam profile 0.2 ms to 2.8 ms after the injection were reconstructed as in Fig. 1. The horizontal tune in this case was 7.05 which is not the nominal operation value. A significant beam loss has been observed within a few ms under the condition. The reconstructed profile shows a notable change of the distribution. The profile at 0.2 ms after the injection consists of a narrow peak and a broad distribution. The narrow peak diminishes in 2 ms, and only the broad distribution remains.

The same procedure was applied for the horizontal tune of 7.11 which is near the nominal operation value. The reconstructed profiles are shown in Fig. 2. The profile at 0.2 ms after the injection still consists of a narrow peak and a broad distribution. The narrow peak diminishes in 1 ms, and only the broad distribution remains as in the case of the tune of 7.05. The narrow peak of this case is, however, less significant than that of the previous tune, and the beam loss is not either significant in this case.

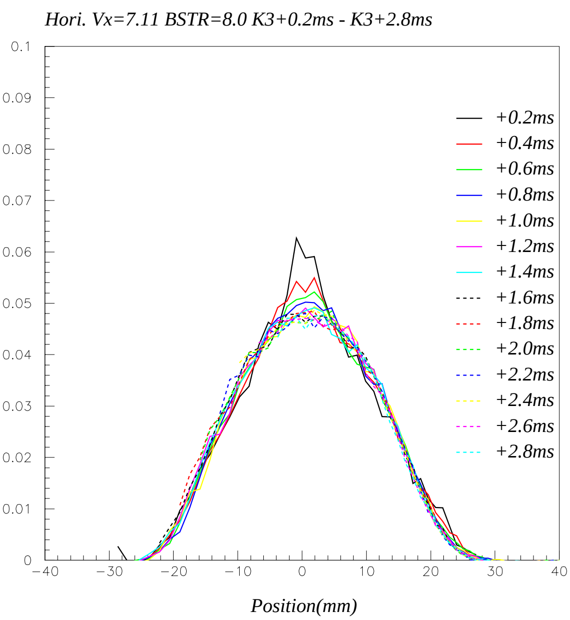

Figure 2: Horizontal beam profiles of 0.2 ms to 2.8 ms after the injection when the horizontal tune was 7.11 and the beam intensity was 8.0×10^{11} ppp at the booster extraction.

3 BEAM WIDTH

The beam profiles about 3 ms after the injection were acquired for many sets of the betatron tunes and the beam intensity. The modifications of the beam profiles are rather small for many sets of the betatron tunes after 3 ms from the injection. The acquired horizontal beam profiles were fitted with the Gaussian function and the sigma as a function of the horizontal tune is plotted in the Fig. 3. The horizontal profile is wider for the lower betatron tune. The modification is more enhanced for the higher beam intensity.

The same analysis were done for the vertical direction and the vertical beam width as a function of the vertical tune is plotted in the Fig. 4. As in the case of the horizontal direction the vertical profile is wider for the lower betatron tune, unless the beam width reaches the aperture limit. The beam profile then became narrow with a siginificant beam loss in a few milliseconds after the injection.

4 BEAM SURVIVAL

In order to diminish beam losses systematical measurement was conducted. Fig. 5 shows an example of the measurement. Five horizontal tune settings were chosen from 7.05 to 7.25 while the vertical tune was fixed to 5.17. The

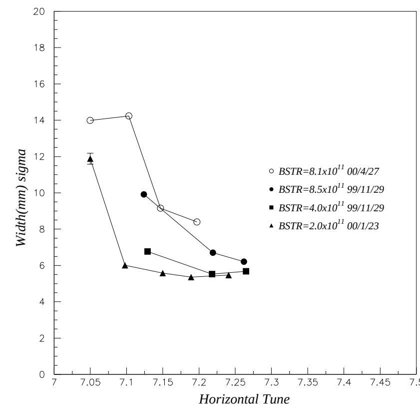

Figure 3: Horizontal beam width as a function of the horizontal tune. The beam width is one sigma of the fitted Gaussian.

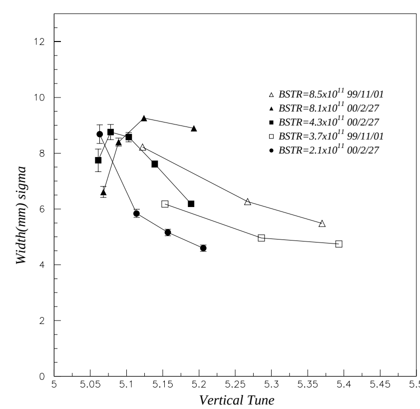

Figure 4: Vertical beam width as a function of the vertical tune. The beam width is one sigma of the fitted Gaussian.

injected beam intensity was set to 8.1×10^{11} ppp at the booster extraction throughout the measurement. The beam survival was the best at the tune of (7.10,5.18) among the five cases. The same procedure was repeated with changing the vertical tune and the injected beam intensity.

For the rest of the injection period the better beam survival was observed for the wider beam profile in both horizontal and vertical direction. When the injected beam intensity is about 8×10^{11} ppp at the booster extraction, the beam width is almost maximum for both horizontal and vertical direction at the tune of (7.10,5.18). The best tune value for the beam survival, as well as the beam width, depends on the beam intensity.

5 ACCSIM MULTIPARTICLE TRACKING SIMULATION

Multiparticle tracking simulations have been performed using the program ACCSIM [2] and the indendently devel-

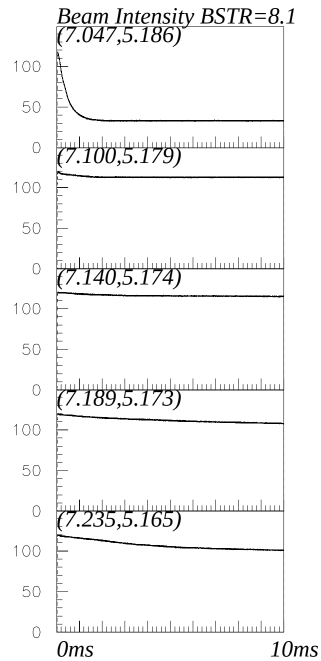

Figure 5: Beam intensities as a function of the time after the injection for five cases of the tune settings (ν_x,ν_y). The injected beam intensity was set to be equal for the five cases and 8.1$\times10^{11}$ ppp at the booster extraction.

oped Hybrid Tree-Code [3]. Space-charge effects, nonlinear components of sextupole and octupole magnets and closed orbit distortion were included in a realistic manner in ACCSIM. Fig. 6 shows the horizontal beam profile of 0.15 ms after the injection for the horizontal tune of 7.07 and 7.13 and the injected beam intensity of 8$\times10^{11}$ ppp. The simulation qualitatively produced the measured beam profiles. Other sources of nonlinear components such as multipole components of the bending magnets and quadrupole magnets are yet to be included and the simulation results would be then quantitatively compared with the measurement.

6 CONCLUSIONS

Measurement of the transverse beam profiles using flying wires has revealed the characteristic change of the beam profile within a few milliseconds after the injection. In both horizontal and vertical direction the beam profile of a few ms after the injection was wider for the lower betatron tune for the measurement between about 7.05 to 7.25 unless the aperture limited the beam size. The beam survival for the rest of the injection period was better for the wider beam. A multiparticle tracking simultaion program, ACCSIM, taking account of space charge effects, nonlinear effects of the sextupole and octupole magnets and closed orbit distortion has successfully reproduced the beam profiles.

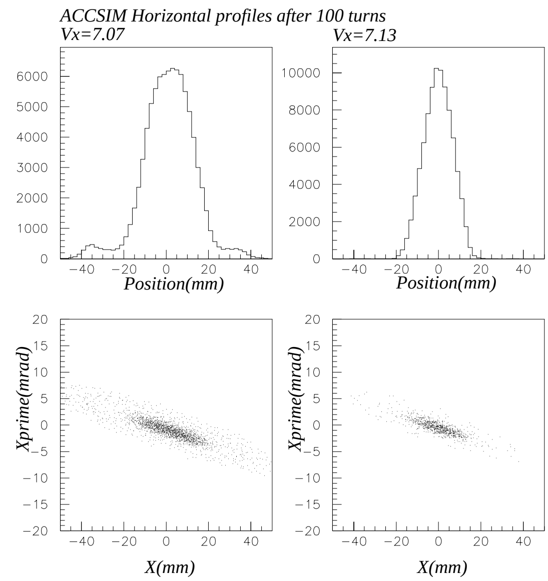

Figure 6: Horizontal beam profiles of 0.15 ms after the injection for the horizontal tune of 7.07 (left) and 7.13 (right) and the injected beam intensity of 8$\times10^{11}$ ppp, predicted by ACCSIM.

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[3] Y. Shimosaki and K. Takayama, in this proceedings.