The 8th Symp. on Accelerator Science and Technology, 1991, Saitama, Japan

SLOW EXTRACTION AT THE COMPRESSOR/STRETCHER RING (CSR) OF THE JAPANESE HADRON PROJECT

C.Ohmori, Y.Kamiya1) and M.Kihara2)

Institute for Nuclear Study, The University of Tokyo, Midori-cho 3-2-1, Tanashi-shi, Tokyo 188, Japan

1)Institute for Solid State Physics, The University of Tokyo ,Roppongi, Minato-ku, Tokyo 106, Japan

2)National Laboratory for High Energy Physics ,Oho 1-1, Tsukuba-shi, Ibaraki 305, Japan

Abstract

The slow extraction from CSR has been examined by simulation. The time structure of the beam spill, the beam loss at the extraction septum and the emittance of the extracted beam are calculated.

Introduction

The Proposed Japanese Hadron Project consists of the 1GeV linac, the CSR and three experimental facilities. These facilities are E, M and N arenas for experiments using exotic nuclei, mesons and neutrons, respectively. The CSR aimes at compressing long beam pulses from the linac and supplying the beam to the M and N arenas with a repetition rate of 50Hz. The long pulse of 400μs is compressed into two bunches, the time duration of which is normally 200ns. The N arena uses one bunch of this time duration. Another bunch is extracted to the M arena after changing the time structure of the beam. The beam is further compressed to the ultra-short pulse of 20-30ns in duration for experiments using muons. In addition, the continuous beam is supplied to the M arena for experiments using pions. The M arena chooses the time duration of the extracted beam between the ultra-short pulse and the continuous beam. Two different operation modes are called the ultra-short pulse mode and the stretcher mode, respectively. The CSR will supply an average current of 100μA to each arena.

The conceptual design work on the CSR began in 1988. The results have been reported[1,2]. The fundamental lattice of the CSR is a FODB cell and the whole ring consists of 16 superperiods, as shown in Fig.1. Each cell is composed of a 2.8m long bending magnet, two quadrupole magnets and a 5.7m long drift space. Two drift spaces are used to implement the electric and magnetic septums for slow extraction(see Fig. 1)[3].

In this paper, we describe the slow extraction from the CSR. By using the technique of particle tracking the emittance and time structure of the extracted beam are calculated. The emittance and time structure of the extracted beam are optimized by changing the ring chromaticity and the RF acceleration program, respectively. The beam loss ratio at the septum is also estimated.

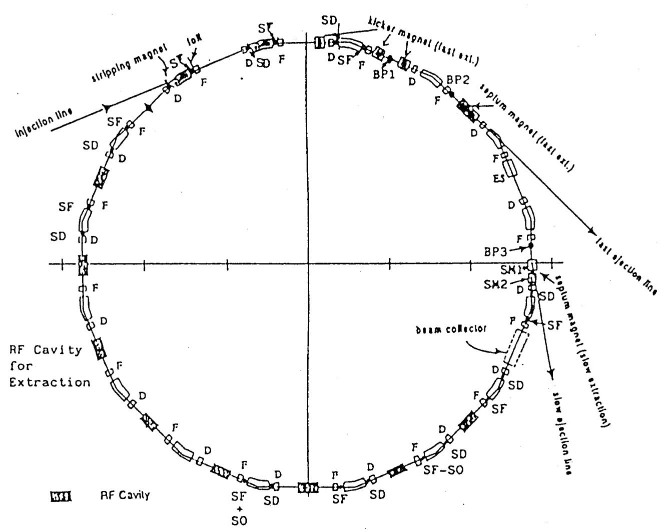

Fig. 1 Layout of the CSR and its equipments for slow extraction. ES and SM1,2 are electric and magnetic septums, respectively. SF and SD are the sextupole magnets for the chromaticity correction. S0 and -S0 are resonance exciters.

Principle of the slow extraction

It is a feature of the slow extraction at the CSR that the circular beam emittance is as large as 30πmm.mrad in order to relax the space charge effect on the stored beam which is caused by high intensity. Another feature is a rather short extraction time (less than 20ms), which is limited by the high repetition rate. Therefore we have proposed a scheme of shifting the operating point through momentum change by acceleration, which is fast enough to accomplish extraction within the limited duration. In order to reduce the beam loss during the extraction process, it is necessary to attain a reasonably large turn separation, comparing with the effective thickness of the first septum. It is also required to keep the angle of the extracted beam fixed at the septum for the reduction of the emittance of the extracted beam as well as for the reduction of the effective thickness. For this reason, a scheme to overlap outgoing separatrices at every instant by using the third order resonance extraction has been proposed[3]. The condition of overlapping outgoing separatrices with various emittances is given by W. Hardt as follows[4];

$$\xi_H=\frac{S}{4\pi Q(D'\cos\phi_e-D\sin\phi_e)}, \quad (1)$$

with ξ_H the horizontal chromaticity defined by $(\Delta Q/Q)/(\Delta p/p)$, S the strength of the resonance exciting sextupole, ϕe the angle which the outgoing separatrix makes with the X coordinate of the normalized phase space, D and D' the normalized dispersion function and its derivative. ϕe depends on the betatron phase difference between the sextupole magnet and first septum. If the locations of the sextupole magnet and septum are given, D, D' and ϕe are determined. S is decided by the turn separation required and the beta function at the septum. The turn separation is chosen to be 10mm[3]. The suitable value of the chromaticity is derived by the Eq. (1).

Slow Extraction System of the JHP

The locations of equipments for the slow extraction are shown in Fig.1. The orbit bump to make an aperture minimum at the first electric septum(ES) is produced with three DC-excited bump magnets, BP1, BP2 and BP3, which are arranged to make no orbit distortion outside the region of these magnets. The chromaticity is corrected by 20 sextupole magnets located between the dipole and quadrupole magnets. In the bump orbit, there are no sextupole magnets in order to avoid the interference between the adjustment of the bump orbit and the chromaticity correction. Two sextupole magnets(S0 and -S0) as the resonance exciters are located between the QF and dipole magnets. As the phase advance between two exciters is near to 180 degrees and the polarity is opposite, their contribution to the horizontal chromaticity is very small.

The first electric septum is located 2m downstream from QF in a drift space, as shown in Fig.1. The gap, length and electric field strength of the septum are 13mm, 2.5m and 60kV/m, respectively. We assume 0.1mm as the effective thickness of the septum which includes the error in setting the septum wires.

Beam Tracking

The beam tracking calculation for the slow extraction at the CSR, which is based on the matrix formalism, has been performed. The effect of the sextupole field is taken into account by the thin-lens approximation. The effect of RF acceleration and the motion in longitudinal phase space are also taken into account. The operation point at injection is chosen to be (4.338, 3.25). At this point, the beam of an emittance as high as 30πmm·mrad is stable. The chromaticity is corrected according to Eq.(1), to satisfy the overlapping condition of outgoing separatrices. Figure 2 shows a result of tracking calculation about a single particle. It can be seen that the particle shifts to the outside with acceleration. In this figure, the effect of momentum variation in the longitudinal phase space can be observed. Note that the variation of the momentum becomes slow when the phase of the particle is near the equilibrium phase of the longitudinal motion. Since the betatron frequency approaches to the resonance, the area of the separatrix becomes small and the particle is extracted. If the chromaticity is corrected, the particles with the different amplitudes are overlapped as shown in Fig. 3.

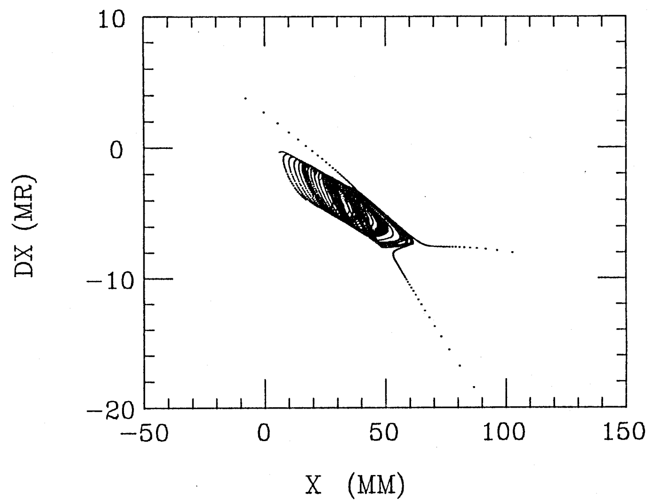

Fig. 2 The motion of a particle in the horizontal phase space. The electric septum is located at the position apart from the designed orbit by 100mm.

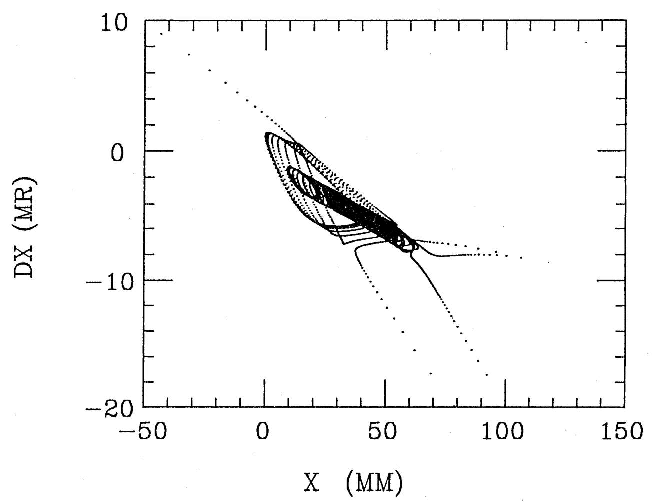

Fig. 3 An example of overlapping of outgoing separatrices between two particles with different amplitude.

The multi-particle tracking will show the emittance and time structure of the extracted beam. Four hundred particles are generated randomly in the horizontal and longitudinal phase space. The initial horizontal and longitudinal emittances are 30πmm·mrad and 11.2MeV·rad, respectively. The results by the multi-particle tracking are shown in Fig. 4. The beam emittance of the extracted beam is about 0.8πmm·mrad. By assuming the thickness of the septum wire is 0.1mm and the particles which hit the septum will be lost, the beam loss ratio is 1.2%. In the case of the calculation of the loss ratio, 1600 particles were generated. Figure 5 shows the beam spill of the extracted beam. The dashed line is an example of the beam spill when the rate of change in the RF frequency is chosen a 1.82Hz/turn and the RF voltage is fixed to 30kV. The solid line shows a case that the RF voltage and the rate of change in the RF frequency are decreased to 0.27Hz/turn and 15kV at the initiation of the extraction. The figure shows that a flat and long beam spill can be made.

Conclusions

We have made the multi-particle tracking calculation on the CSR. By satisfying the overlapping condition, the extracted beam emittance becomes small. The time structure of the beam spill can be controlled by the RF acceleration. The beam loss ratio at the first septum is 1.2%.

References

[1] Report of the design on the compressor/ stretcher ring of the Japanese Hadron Project, JHP-11, KEK Internal 88-9.

[2] Y. Kamiya et al., Proc. of 14th International Conf. on High Energy Accelerators, Tsukuba Japan, Aug. 22-26, 1989.

[3] A. Noda et al., Proc. of European Particle Accelerator Conf., Nice, France, 1990.

[4] W, Hardt, PS/DL/LEAR NOTE 81-8(1981).

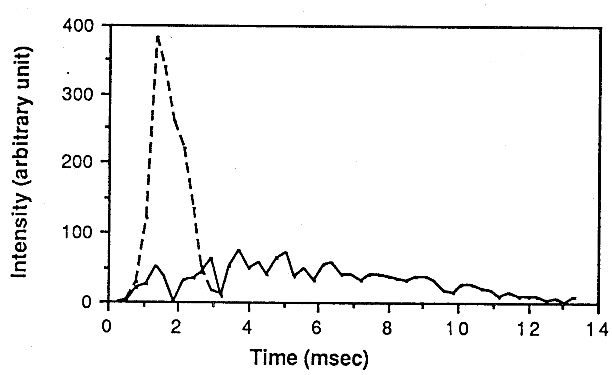

Fig.5. Calculated time structures of the beam spill.

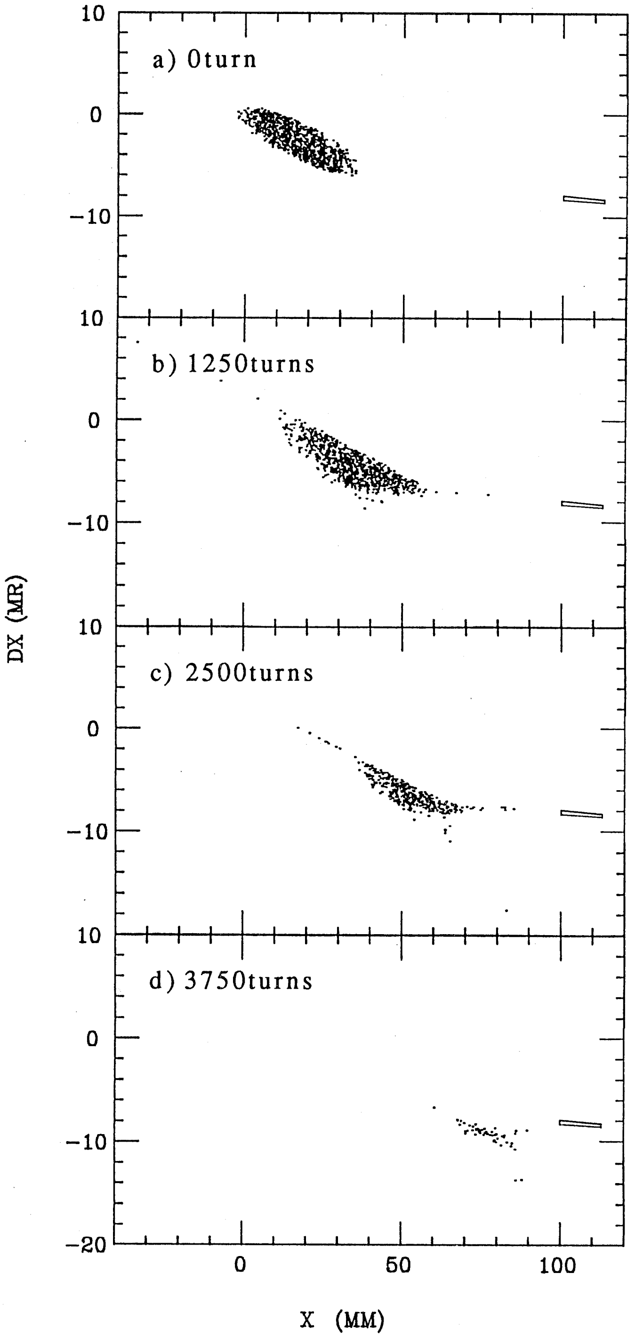

Fig. 4 Results of multi-particle tracking. All particles are extracted through the solid box in these figures. Figures (a)-(d) show the particles after 0, 1250, 2500, 3750 turns, respectively.