DESIGN OF BOOSTER SYNCHROTRON FOR MUSES

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Abstract

A Booster Synchrotron Ring (BSR) is proposed for RIKEN RI beam factory. The BSR is part of Multi-Use experimental Storage Rings (MUSES). The BSR functions exclusively for acceleration of ion and electron beams. The maximum accelerating energy is, for example, to be 3 GeV for proton; 1.45 GeV /nucleon for light ions of q/A=1/2; 800 MeV/nucleon for heavy ions of q/A=1/3. In this paper some results of lattice study of the BSR are presented. In this search, the ring circumference (168.4836 m), the maximum Bρ-value (14.6 Tm) are fixed, and chromaticity is corrected by two families of sextupole magnets.

1. LATTICE REQUIREMENTS

The lattice structure is supposed to be as compact as possible. Basically FODO structure is used, and we adopt a racetrack type to accommodate two long straight sections. Two long straight sections are used for fast and slow extraction of ion and electron beams, and each of them contains four long drift space where RF cavities and kicker magnets are inserted.

2. CONSTRAINS

In this design, the total length of the structure is 168.484m which is 5 times the SRC extraction radius, and the maximum magnetic rigidity is 14.6Tm. Those values is determined by a requirement that heavy ions with q/A=1/3 are accelerated up to the energy of 800 MeV/nucleon. Transition γ was allowed to be as high as 4.77, a value still satisfactory for beam stability.

3. BSR LATTICE DESCRIPTION

As shown in Fig.1, the BSR consists of two arc sections and two long straight sections. Each arc section is mirror symmetrical system, and there are two bending cells. Each bending cell which is a dispersion suppresser arc consists of four FODO cells because this number of cells is specified to raise γ_t sufficiently large. And the dispersion in the straight sections is zero. The length of a dipole magnet of 1.911 m is determined by the circumference specification. The maximum magnetic field of a dipole (1.5 T) is determined by required maximum rigidity of particles 14.6 Tm. The lattice is specified for eight families of quadrupoles; QF1 and QD1, QF4 and QD4 in the arcs, QF2 and QD2, QF3 and QD3 in the long straight sections. The structure of one FODO cell and short straight section in the arc are given as follows.

$$\mathrm{cel}=\mathrm{QF1}\,\underline{\;d_1\;}\,\mathrm{B}\,\underline{\;d_1\;}\,\mathrm{QD1}\,\underline{\;d_1\;}\,\mathrm{B}\,\underline{\;d_1\;}$$
$$\mathrm{cel2}=\mathrm{QF1}\,\underline{\;d_2\;}\,\mathrm{B}\,\underline{\;d_2\;}\,\mathrm{QD1}\,\underline{\;d_2\;}\,\mathrm{B}\,\underline{\;d_2\;}$$
$$\mathrm{str2}=\mathrm{QF4}\,\underline{\;d_3\;}\,\mathrm{QD4}\,\underline{\;d_s\;}\,\mathrm{QD4}\,\underline{\;d_3\;}\,\mathrm{QF4}$$

so, the lattice of each arc section (60.365 m) is

arc=(cel,cel2.cel2,cel,str2,-cel,-cel2,-cel2,-cel)

In this structure, d1 (d2) is 0.5 m (0.511 m) drift between dipoles and quadrupoles which is used for sextupole magnets for chromaticity correction and corection magnets for COD correction.

The two long straight sections are also mirror symmetry. The lattice of each section (23.876 m) is

$$\mathrm{str1}=\underline{\;d_s\;}\,\mathrm{QF2}\,\underline{\;d_3\;}\,\mathrm{QD2}\,\underline{\;d_s\;}\,\mathrm{QD3}\,\underline{\;d_3\;}\,\mathrm{QF3}\,\underline{\;d_3\;}\,\mathrm{QD3}\,\underline{\;d_s\;}\,\mathrm{QD2}\,\underline{\;d_3\;}\,\mathrm{QF2}\,\underline{\;d_s\;}$$

where, d_S is a free space with a length of 4.819 m which is used for RF cavities, injection kickers or other device.

Then, the whole lattice of BSR is described as follows.

BSR=(arc,str1,arc,str1)

Tune values are chosen from the tune diagram shown in Fig.2. The parameters of the lattice are summarized in Table 1. The β and dispersion functions are shown in Fig.3. Transition γ is 4.786 and the peak dispersion is 3.206 m. The peak β function are 14.514 m in horizontal direction and 18.129 m in vertical direction. These calculation is performed using the MAD program.

Table 1. Lattice Parameter of BSR

Circumference	C=168.4836 m
Average Radius	R=26.815 m
Max. Magnetic Rigidity	Bρ=14.6 Tm
Momentum Compaction	α=0.0437
Transition gamma	γ_t=4.786
Betatron Tune Values	Qx/Qy=6.280/4.969
Natural Chromaticity	Q'x/Q'y=-7.545/-7.119
Max. β Amplitude	βx/βy=14.514m/18.129m
Max. Dispersion	Dx/Dy=3.206m/0.0m

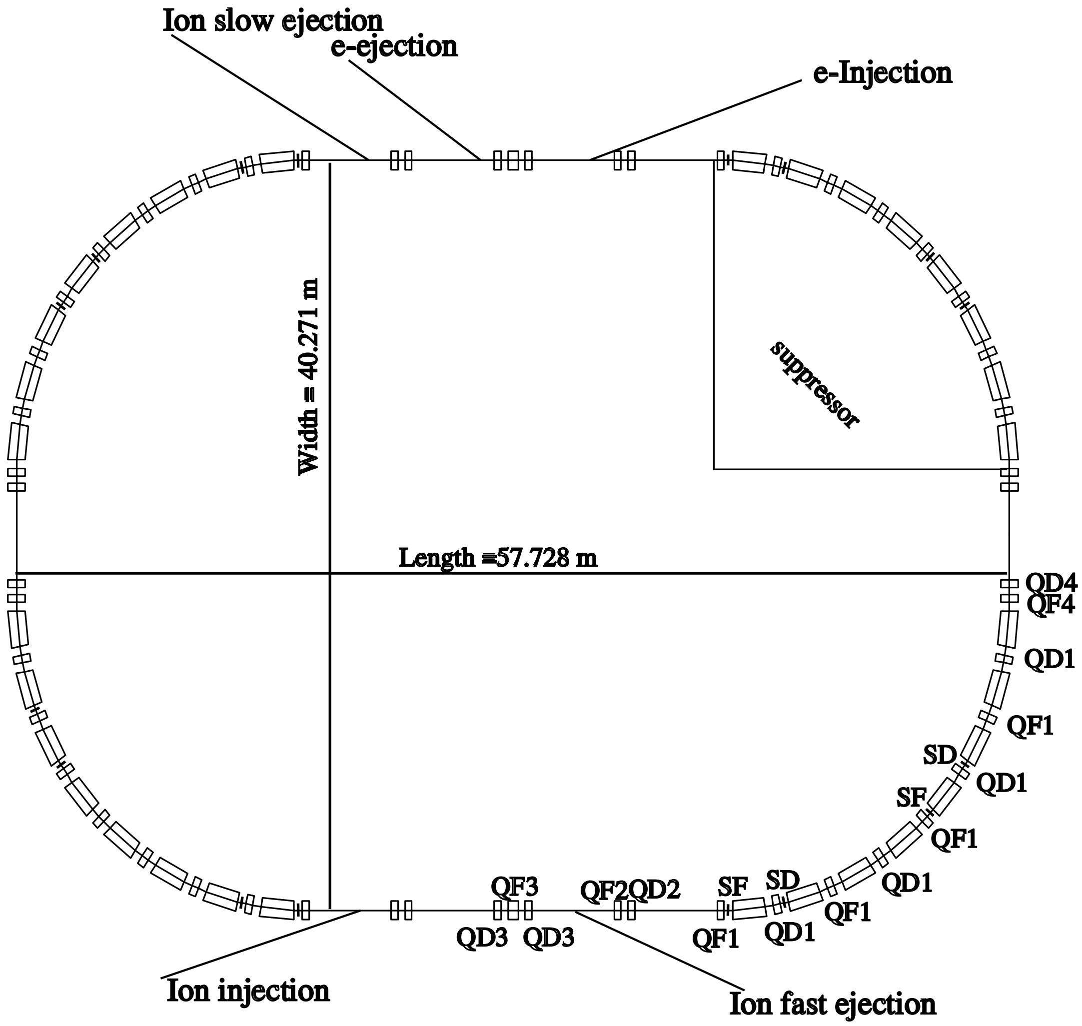

Fig.1 A Layout of the BSR

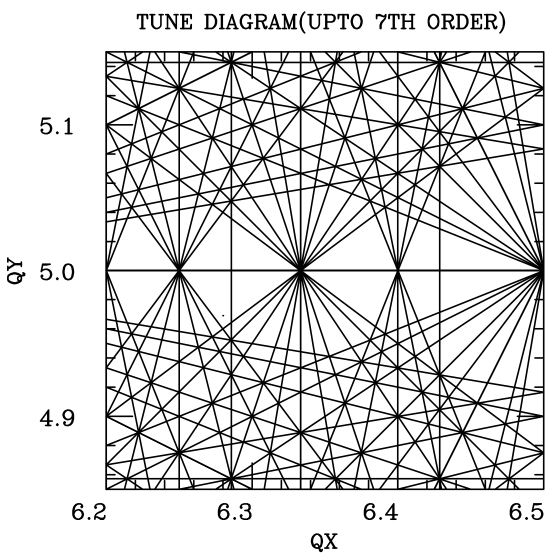

Fig.2 Tune diagram

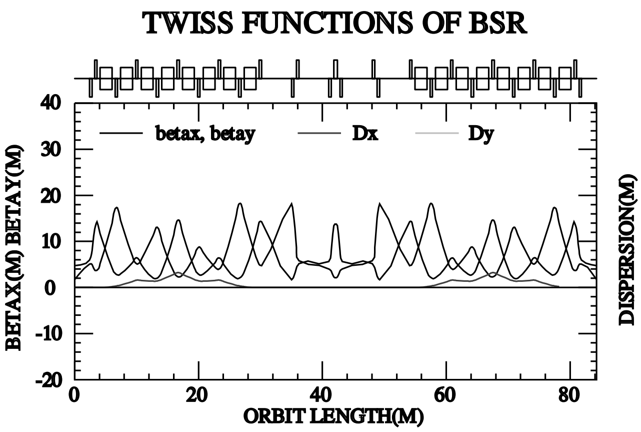

Fig.3 β and dispersion functions along the lattice

4. DYNAMIC APERTURE

The dynamic aperture is seriously reduced when chromaticity is corrected. The reason for this is the demand of the low average value of dispersion in a ring, corresponding to high γ_t. In this lattice, natural chromaticity values are -7.545 (horizontal) and -7.119 (vertical) , and are corrected by two families of sextupoles, (focusing and defocusing), associated with their respective quadrupoles as indicated in Fig.1. Same family's sextupoles in one bending cell are located π apart in phase in order not to excite the resonance with particular amplitude and phase. The normalized field strengths of sextupoles required to correct chromaticity are relatively large: 7.185 m^{-3} for the SF and -11.748 m^{-3} for the SD. The tracking results for the beam with $\varepsilon_x=125\pi$ mm.mrad and $\varepsilon_y=5\pi$ mm.mrad and fully corrected chromaticity are shown in Fig.4. It shows that the motion of particle remains stable. Multi-particle tracking was done to study the motion stability of particles with large beam emittance. Results of multi-particle tracking for the perfect lattice with chromaticity correction are shown in Fig.5. At the initial state, 100 particles are distributed within an emittance range of $\varepsilon_x=125\pi$ mm.mrad and $\varepsilon_y=5\pi$ mm.mrad. After 1000 turns, the motion of particles is stable, without any particle loss. The dynamic aperture is determined by multi-particle tracking for a perfect machine with zero chromaticity over 1000 turns. The largest initial betatron amplitude for which particles are still on a stable orbit we call the dynamic aperture.[1] The above tracking results show that the dynamic aperture of the BSR is larger than $\varepsilon_x=125\pi$ mm.mrad and $\varepsilon_y=5\pi$ mm.mrad. Further tracking has to be performed to obtain information about the main sources of dynamic aperture reduction and to estimate the level of multipole content tolerable in the dipoles.

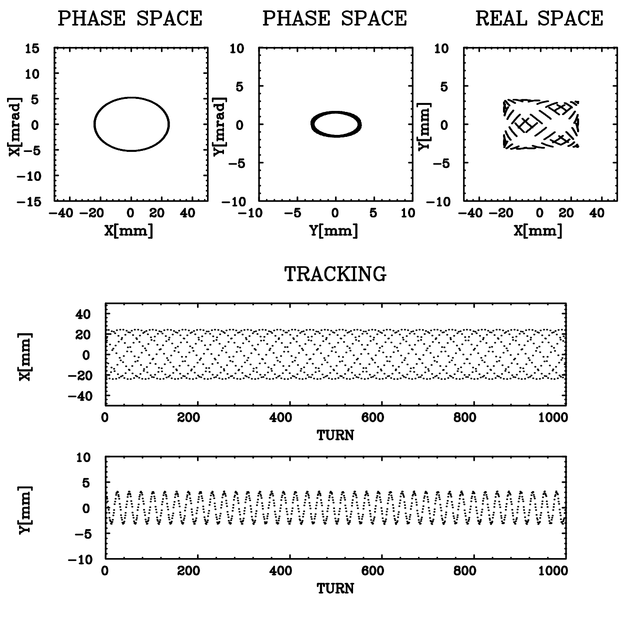

Fig.4 Result of single-particle tracking

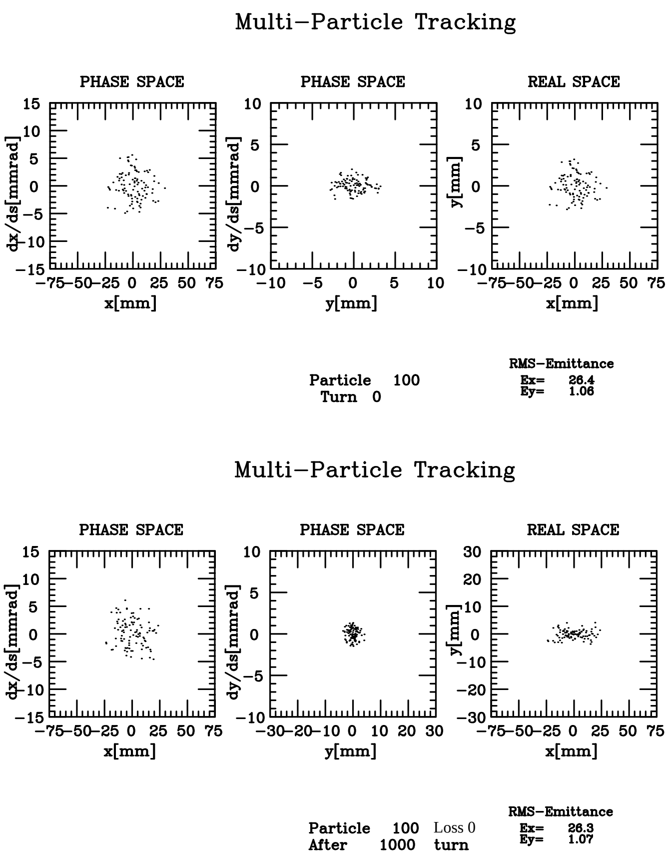

Fig.5 Result of multi-particle tracking

5. SUMMARY

We have designed the lattice of the BSR satisfied the fundamental requirement. This lattice is required to be investigated in detail for placement of all the necessary hardware. Optimization of the lattice of the BSR is under way.

REFERENCE

[1] N.Golubeva, etc., "A Racetrack lattice with missing magnets for the BOOSTER", TRI-DN-91-K192, TRIUMF, 1991.