COLLIDING OR MERGING BEAM SECTION

A. Noda, ICR, Kyoto University, Uji, Kyoto, Japan

Abstract

A possible section commonly used by two rings for colliding or merging ion or electron beams is presented. The magnetic rigidity less than 1T•m is treated. For the case of merging of ion beams or colliding ion and electron beams, it is impossible to separate the beams with exactly the same magnetic rigidity into two rings. So here the separation of beams with the difference of magnetic rigidity larger than 10% into the two rings is treated.

1 INTRODUCTION

Techniques for colliding the beams has been mainly utilized as the tool to realize the highest possible center of mass energy for the investigation of fundamental constituents of materials. This technique seems to be useful also for the research of atomic or molecular physics by merging or colliding highly charged ions or electron beams. Utilizing the storage ring, it has become possible to realize highly ionized ions with small relative velocity. So it is possible to investigate the interactions between highly charged ions with small relative velocities. In the laboratory frame, the equilibrium charge state is not so high at the small velocity and it is not possible to realize such a high charge state. This method, however, is usually limited only for interactions between the same ions. At TSR in MPI Heidelberg, simultaneous accumulation of different ions (d^+ and O^{8+}) with almost the same magnetic rigidity had been demonstrated, utilizing the long beam life of electron cooled beam at the TSR and changing the provided ion beam species supplied by the injector MP-Tandem[1]. This method, however, also has a severe limit on the ion species to be accumulated at the same time. In order to investigate the interaction between ions with the same velocity and different magnetic rigidity, it is desirable to have such a configuration as composed of two rings which commonly use the same straight section as a part of their circumferences. An example is shown in Fig.1, which is composed of a hexagonal ring (ring-1) and a race-track ring (ring-2). In the case of ion-ion "merging" or "colliding", ion beams are circulating in the two rings, while the direction of the two ion beams are the same for "merging" and opposite for "colliding". If the ion beam in the ring-2 is replaced by an electron beam, then the section can also be used only by exchange between "merging" and "colliding". With this configuration, it is possible to merge the beam with different magnetic rigidity, for example, C^{6+} and C^{5+} with the same velocity. If we want to realize simultaneous accumulation of these ions with the same velocity, a momentum acceptance as large as 17% is needed, which is not so easy to attain. In the present configuration, most severe situation is anticipated for the case where the magnetic rigidities of the beams in the two rings are very close between each other. If their difference is small enough compared with the acceptance of a single ring, then they can be stored into a single ring. So we limit ourselves for the case where the difference is larger than 10%, assuming the momentum acceptance up to 10% might be possible with a single ring.

In the next section, we will search the possible configuration of such merging section utilizing reasonably attainable accelerator technique. Then the colliding section compatible with the above merging section is studied in section 3 and finally the total system is discussed.

2 MERGING BEAM

In order to incorporate two rings, the interference between lattice magnets in the two rings should be carefully avoided. Assuming the maximum magnet size in the horizontal direction (i.e. the distance from the central orbit to the outermost part of the magnet) to be less than 0.3 m,

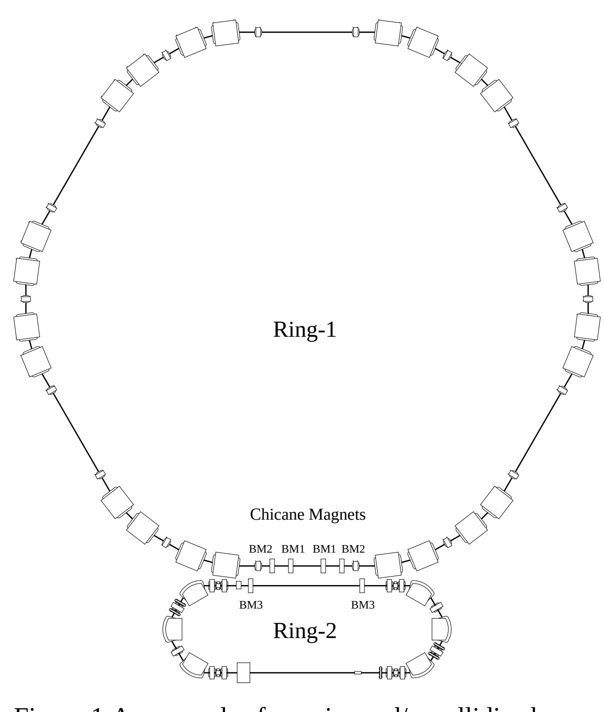

Figure 1:An example of merging and/or colliding beams in the two rings.

we study about the layout where the straight sections of the two rings are separated 0.65 m from each other when no magnets to merge the two rings are excited.

For the purpose of merging ion beams with different magnetic rigidity, the orbits of both rings are shifted to the direction opposite to the racetrack-ring as shown in Fig. 2 by solid line (Bρ=1Tm) and dotted line (Bρ=0.9 Tm). The merging section has reflection symmetry about the point indicated as "Merging Center" in the figure. To give a quantitative evaluation, we take an example to merge ion beams of charge to mass ratio 1/2 and magnetic rigidity of 1 Tm with $^{40}Ar^{18+}$ beam with the same velocity as the above ion. The difference of magnetic rigidity of these beams are 10%. Main parameters of these beams are listed in Table 1.

Table 1: Example of Merging Ion Beam

Ring	Ring-1	Ring-2
Bρ	1 Tm	0.9 Tm
ε(Example of Ion)	18/40($^{40}Ar^{18+}$)	1/2($^{12}C^{6+}$, $^{16}O^{8+}$, etc.)
T_N	9.7 MeV/u	9.7 MeV/u
β	0.143	0.143

The chicane magnets to shift the central orbits consist of BM1, BM2, SM and BM3. The field strength are 1T for BM1 and BM2 and 0.251T for BM3. Field strength of 0.5T is assumed for the septum magnet, SM, with septum thickness of 9mm, which seems technically feasible. In Table 2, parameters of these magnets are listed up.

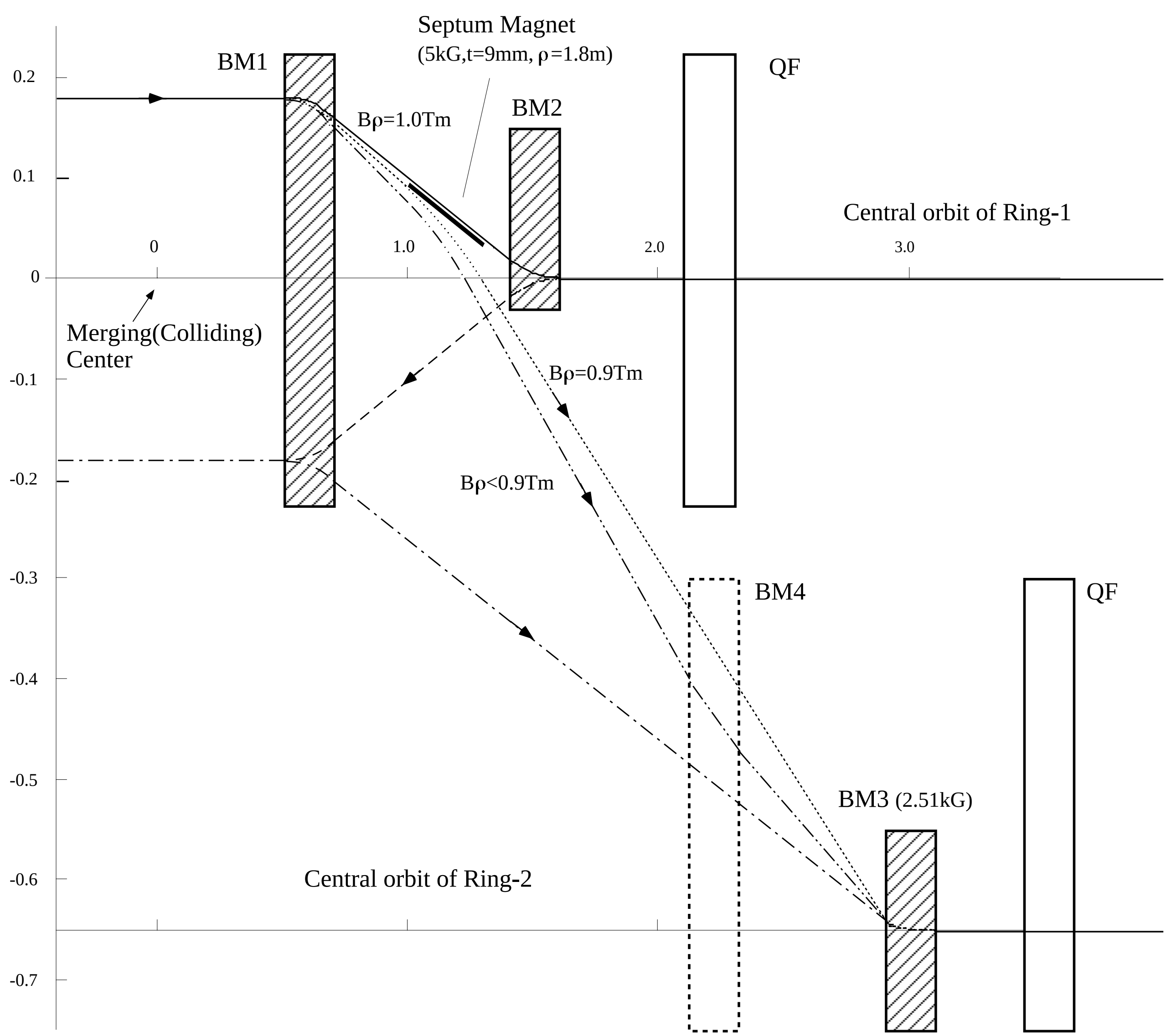

Figure 2: Merging and colliding section between two rings.

Both beams given in Table 1 come into BM1 at the same radial position (x=0.18m) and are separated by BM1 as large as 9.1mm at the entrance of SM. These separated beams are guided just on the central orbits of ring-1 and ring-2 with use of BM2 and BM3, respectively.

In case where magnetic rigidity of the beam in ring-2 is smaller than the above value (0.9Tm), the beam is deflected much larger with BM1 and SM and it is easily understood that the beam is well guided to the central orbit of the ring-2 with additional use of BM4 between BM2 and BM3 as is indicated in the figure by a dash-two dotted line.

Merging of ion and electron beam is similar to the case of collision of ion beams to be treated in the next section.

3 COLLIDING BEAM

In case of head on collision of ion beams, the velocities of two beams are opposite and they are deflected into the opposite direction by BM1. So two beams in ring-1 and ring-2, which are 0.65m separated in distance are overlapped at the position where x is -0.18m as shown in Fig.2 by dashed and dash-dotted lines. It is easy to guide both beams onto the central orbits of ring-1 and ring-2 by BM2 and BM3, respectively. The distance of 0.65m between both rings and field strength of BM3 are decided so as to enable both configurations of "Merging Beam" and "Colliding Beam" with the same positioning of BM1, BM2 and BM3.

The collision between ion and electron beams is similar to the case of merging ion beams treated in the previous section.

4 DISCUSSION

It is shown that the merging of ion beams (collision of ion and electron beams) and collision of ion beams (merging of ion and electron beam) are realized with the same arrangement of additional chicane magnets located at the straight sections. The effects of chicane magnets on beam dynamics, however, needs further careful studies. According to preliminary study until now, it might be possible to design such a lattice as is affected not so much by the chicane magnets. The presence of chicane magnets, however, necessarily disturbs the dispersion function at the straight section. So the discussion given here confine ourselves only for the cases where circulating beams in two rings are well cooled down and their momentum spread are small enough.

With this configuration, two components beam consisting of two different ions with exactly same velocity is expected to be realized, which is expected to give a new information of the behavior of the beam.

5 ACKNOWLEDGMENTS

The author would like to present his sincere thanks to Prof. M. Inoue for his valuable discussions about this work. His thanks are also due to Mr. H. Tonguu for his cooperation to prepare figures for this presentation.

REFERENCES

[1] M. Grieser et al., "Advanced stacking methods using electron cooling at the TSR Heidelberg", Proc. of the 19th INS Symp. on Cooler Rings and Their Applications, Tokyo, Japan, 1990, pp190-198.

Table 2:Parameters of Chicane Magnets

Magnet	**BM1**	**BM2**	**BM3**	**SM**
Magnetic Field	1T	1T	0.251T	0.5T
Core Length	0.2m	0.2m	0.2m	0.3m
Aperture	for both beams	only for beam in ring-1	only for beam in ring-2	only for beam in ring-2