DESIGN OF A COLLECTOR RING FOR ANTIPROTON AND RARE ISOTOPE BEAMS

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Abstract

Efficient collection and fast cooling of secondary beams are major objectives of the new accelerator/storage ring facility recently proposed at GSI [1]. Present ideas concerning the lattice design for operation of a large acceptance Collector Ring (CR) are presented. The CR has to be optimised for fast stochastic cooling, its lattice designed for three different optical modes. One is necessary for rare isotope beams (RIB) and another one for antiproton beams, both requiring fast stochastic cooling. RI beams shall be injected to the CR at 740 MeV/u with a horizontal emittance of 240 mm mrad, a vertical emittance of 130 mm mrad and momentum spread of 3% (FW). For 3 GeV antiprotons the transverse and momentum acceptances have to be 240 mm mrad and 6%, respectively. Furthermore, the ring shall be operated in the isochronous mode (i.e. at transition energy) for time of flight (TOF) mass spectrometry of short-lived RI nuclei. Particle tracking simulations for the different optics, taking into account higher order field effects, have been carried out. In addition, some aspects of beam injection and extraction are discussed.

1 INTRODUCTION

The CR is an important part of the GSI future project [1]. Its main purpose is the fast reduction of the phase space volume occupied by secondary RIBs or by antiproton beams. The required phase space reduction is achieved by the operation of a fast stochastic cooling system with e-folding cooling times for RIB of the order of 100 ms for RIBs and 1 s for antiproton beams.

The CR is a large acceptance ring providing the following main functions:

- stochastic pre-cooling of radioactive ion beams (RIBs) at 740 MeV/u
- stochastic pre-cooling of antiprotons at 3 GeV
- mass measurements of short-lived nuclei by measuring their revolution time (isochronous mode).

In the isochronous mode the ring is tuned to transition in order to get rid of the frequency spread due to different longitudinal momenta of beam particles [2]. The CR is designed for a maximum magnetic bending power of 13 Tm. This leads to different relativistic parameters for RIBs with a mass to charge ratio of A/q<2.7, on one hand, and antiproton beams with A/q=1, on the other hand.

Single bunches will be injected with a short pulse length of 50 ns. A full aperture kicker is used to fill thewhole horizontal acceptance of the ring. Immediately after injection, bunch rotation and active debunching reduce the momentum width to a value which is acceptable for the stochastic cooling system. After stochastic cooling the beam is re-bunched and transferred to the next ring, the NESR [3].

The optical ring design presented in this paper is a result of the general scenario presented above.

2 COLLECTOR RING (CR)

2.1 Machine Parameters and Lattice

First concepts of the CR layout were based on the split ring optics [4,5]. In contrast, the present layout of the CR consists of two identical arcs, where the envelopes in the arcs are characterised by a large dispersion function inside the central dipole magnets, in order to achieve the necessary large values of the local α_p.

With two symmetric arcs one can increase essentially the dynamic aperture of the ring for all modes of operation. In addition, the momentum acceptance of the isochronous mode is much larger than in case of the split ring optics. Since γ_{tr} is lower for the symmetric ring, this leads to a reduction of the rf-voltage in the bunch rotation

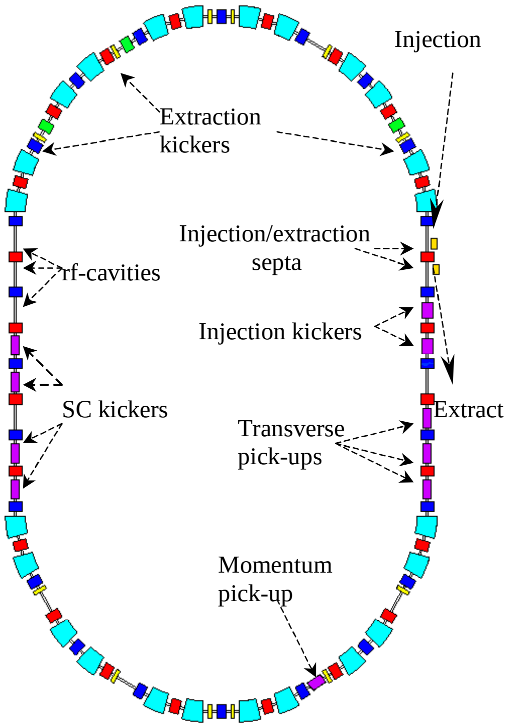

Figure 1: Layout of the CR

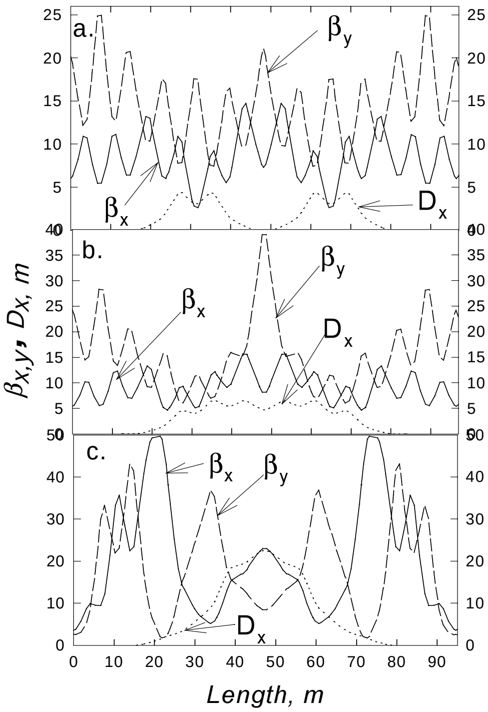

Figure 2: Twiss parameters of the CR over half of the ring at different optic modes a.-Pbars, b.-Rib, c.-Isochronous.

cavities. The collector ring has been designed to operate at different optical modes (RIBs, antiprotons and isochronous mode). Because of the different Lorentz factors for the different modes the reduction of $\eta_{p\text{-}k}$ leads to very different values of the average dispersion in the arcs. The lattice functions according to those settings over half of the ring are shown in Fig. 2.

Between two arcs there are two long straight sections for the installation of the SC system components, RF-cavities for bunch rotation, and the injection/extraction elements (Fig. 1). Lumped sextupoles and sextupolar field components in the quadrupole magnets are needed in the arcs for chromaticity correction.

2.2 Dynamic Aperture

The field errors in the arc magnets will determine the dynamic aperture of the CR. In the following, the dynamic aperture is estimated roughly with a limited number of initial conditions and a small subset of machine imperfections. After an optimisation of sextupoles the dynamic aperture has been calculated by both the MAD and the MIRKO codes. A lattice was assumed, where the aperture is not limited by walls. As an example the results calculated by the MIRKO code are shown in Fig. 3. The figures show the boundary of stability in the region within which particles survived 1024 turns. One can see that the required horizontal ring acceptance of 240 mm mrad is much smaller then the stable region. This indicates that enough acceptance has been reserved. Similar results have also been obtained by the MAD code, again tracking 1024 turns. Such calculations can be refined at a later stage as soon as more information on the field quality is available.

Table 1. Summary of major CR parameters

Max.mag.rigidity, $B\rho$, Tm	13		
Circumference, C, m	192		
Superperiodicity	2		
Lattice type	FODO		
	Pbar	RIB	Isoch.
Max. energy, E, MeV/u	3000	740	790
Hor. acceptance, mm•mrad	240	240	70
Ver. acceptance, mm•mrad	240	130	50
Momentum acceptance, Δ p/p,%	6	3	1.4
Betatron tunes, Q_x	3.63	3.42	2.36
Q_y	2.62	2.62	3.36
Transition gamma, γ_{tr}	4.3	2.9	1.84

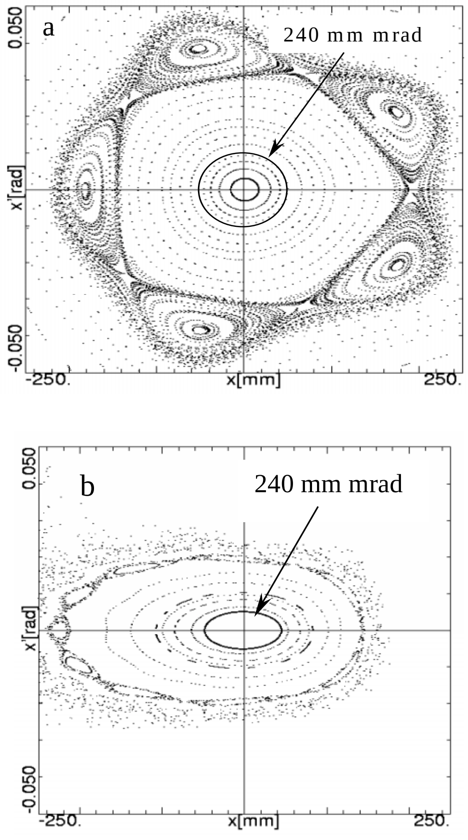

Figure 3: Dynamic aperture of the CR with (a) RIB optics and (b) antiproton optics.

2.3 Injection and Extraction

An important feature of the CR is its large injection acceptance, which is obtained by installing full aperture kickers and by adjusting the injection channel to the ring acceptance. The trajectories of the injected and the extracted beams between the first injection septum magnet and the last injection kicker magnet are shown in Fig. 4. For the injection and extraction one has to use three septum magnets, one of them will serve for both injection and extraction. This common septum will be pulsed with angle variation from of 110 mrad at injection to 50 mrad at extraction. The septum copper thickness must be 15 mm whilst a 25 mm beam separation is needed at the kickers. The injection septum magnets are placed between two quadrupoles, while the injection kicker magnets are about 90° in advance of the centre of the septum magnet (Fig. 4a).

The extraction acceptance requirements are more relaxed, as the beam to be extracted is already cooled. The three extraction kickers are placed inside the arc as shown in Fig. 1. Depending on the ring optic only two of these kickers will be used for extraction to provide the 70 mm displacement of the beam at the common septum magnet as it is shown in Fig. 4b.

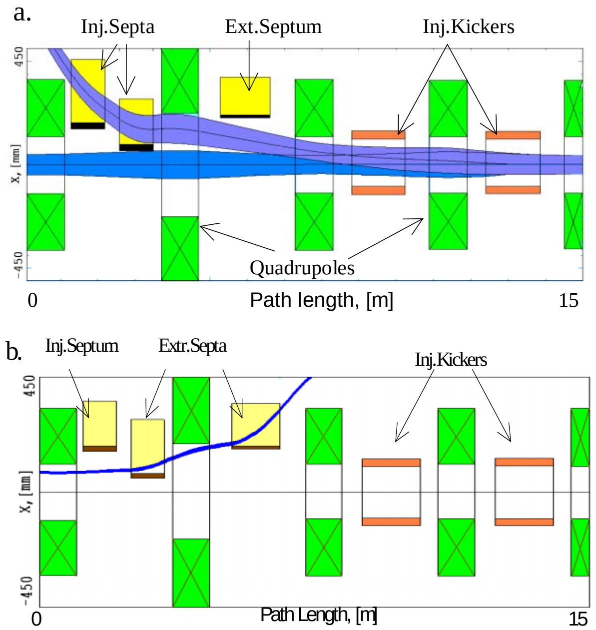

Figure 4: Injection (a) and extraction (b) schemes of the beam for CR

2.4 Stochastic Cooling R&D

The design of the stochastic cooling system will involve

- design of pick-up and kicker electrodes which are suited to cooling of RIBs and antiprotons at two different beam velocities
- reduction of the pick-up noise temperature
- tests of suitable power amplifiers
- simulations involving the solution of Fokker-Planck equations with the aim of retrieving optimum cooling parameters
- development of plunging mechanisms moving electrodes towards the beam during cooling

The progress of the pick-up design is documented at this conference [6]. Fig. 5 shows how such structures could be implemented in the CR as Palmer pick-ups. This design is rather demanding, because the betatron amplitudes are considerably larger than the position difference due to dispersion. A suitable electrode configuration should yield an optimum sensitivity at the revolution harmonics, whereas the betatron sidebands should be suppressed. As the sideband amplitude is proportional to the mean sensitivity gradient seen during a betatron oscillation, the oscillating particles should perform much of their betatron motion in a region of constant sensitivity.

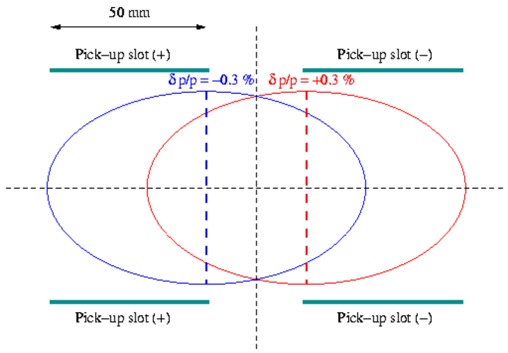

Figure 5: Palmer pick-up electrode configuration.

The pick-up and kicker tanks which have been used at the former AC at CERN were equipped with plunging electrodes [7]. Their mechanics is presently tested at GSI in 2 Hz operation. Meanwhile, they have successfully withstood several hundred hours of operation at this high frequency, ten times faster than for the purpose they were actually built for.

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