Status report of the Collector Ring (CR)

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System Design

In the frame of the progressing building and civil construction planning, a number of modifications in the CR system were implemented. For the civil construction planning, major assumptions have been made for the transportation, installation and maintenance of the CR components. The cross sections of the routes for transportation, the major transportation equipment and cranes were specified and summarized in a CR building specification document. The design of the CR layout accounting for all major ring components as simplified 3D CATIA models has been continued and completed for all ring sections. Major collisions have been identified and removed in an interactive process between the engineering- and ion optical designers.

In the context of the completion of the dipole, quadrupole and sextupole magnet designs the overall lattice cell has been further optimized. Cable lists, including cable types, numbers and start and end points have been established. Detailed requests for the supply room conditions were specified and information for component properties were handed over to the building planners.

Radiation of the CR system

The beam of 3 GeV negative particles ($\Delta p/p$=6%) is injected from the p-bar separator into the CR. The ratio of pions to antiprotons is 100. These pions all decay in the CR. The detailed particle tracking in the ring in a combination with FLUKA simulations shows that the maximal radiation load for all CR system will be about 2.4 Gy/day if the CR operates 100% in the antiproton regime with a cycle time of 10 s.

Beam dynamics

The multipurpose operation of the CR requires that the orbit of the particle trajectories must be as smooth as possible in order to avoid the ring acceptance reduction at injection. Systematic studies of the Closed Orbit Distortion (COD) for all CR optics have been performed to define requirements for the corrector magnets, which were considered to be integrated either in the dipole or in the sextupole magnets. In calculations the random misalignments, roll and longitudinal placements of the dipoles, quadrupoles and Beam Position Monitor (BPM) in both horizontal and vertical planes have been introduced. Table 1 summarizes the results of these calculations, where the rms and maximum corrector strength required ("kick angle" in the table) to correct the closed orbit error in each case is given. In determining the maximum corrector strength we have considered the envelope of maximum corrector strength ignoring a few which lie outside this envelope. In the worst case considered, where the sigma of the magnet misalignment is 0.5 mm and magnets have a roll with a sigma of 0.5 mrad, the envelope of the maximum corrector strength required about ±3 mrad. If we can achieve this level of alignment tolerance, we will be operating the correctors with a maximum strength of 3 mrad giving us enough strength to correct for any unforeseen problem.

Table 1. Calculated Closed Orbit Distortion (COD) before and after correction in the horizontal (H) and vertical planes (V). 12(dip) means 12 correctors integrated in the dipole magnet. 6(h/v) - 6 horizontal/vertical combined corrector magnets in the long straight sections

	correctors	COD rms/max (mm)		rms/max (mrad)
		Before cor	After cor	Kick angle
H	12(dip)+6(h/v)	7.8 / 18	0.9 / 4.1	0.7 /2.4
V	12(dip)+6(h/v)	4.1 / 11.2	1.5 / 5.2	0.9 /3.1
V	24(sex)+6(h/v)	4.1 / 11.2	1.3 / 3.3	1.2 / 4.7

Different isochronous settings have been calculated [1], which give the possibility to measure masses of very exotic nuclei with mass-to-charge ratio up to A/q=4.1. The influence of the various field imperfections has been investigated and a proper sextupole-octupole correction scheme has been found. The required strength of octupole correctors should be within 100-600 G. Due to this correction the necessary mass accuracy $\Delta m/m=10^{-6}$ can be achieved for $\Delta p/p= \pm 0.2\%$. More details about the isochronous mode of the CR can be found in ref. [1].

Magnets

With the goal to procure the CR dipole magnets in 2013 the design of the dipole magnet has been slightly modified and completed. The detailed CR dipole specifications have been prepared at the end of 2012.

The CR optics of the injection scheme requires that the septum magnet deflects the incoming beam by 125 mrad onto the injection orbit. This requires a bending strength of 1.7 Tm. Initially a dc septum magnet was considered but quickly abandoned for the present pulsed magnet design. This decision was taken because of both the cooling problems anticipated with a calculated 398 kW power dissipation and the high running costs. To have a moderate power converter solution, the full-sine 600 ms (rise/fall time of 150 ms and flat top time of 5 ms) driving pulse is proposed. This gives the ramping rate of about 6.1 T/s. According to an ANSYS calculation, due to eddy currents the power dissipation in the injection septum chamber during the pulse is 1 kW. At the nominal operating conditions the mean power dissipation is about 79 kW for the cycle time of 1.5 s.

Power Converters

The concept of the power converter for the injection septum magnet has been reconsidered. To reduce losses due to eddy currents in the magnet and the vacuum chamber, the ramp up time was increased from 20 ms to 150 ms. The extraction septum power converter will be fast pulsed. The pulse power will be supplied by a capacitor of 90 mF capacitance; the required charging voltage is 850 V at the nominal peak current of 6.5 kA. The converters, both for the bending magnets and for the quadrupoles, form complicated networks with interlaced main and trimming supplies. The high stability requirements for the dipole power converter to handle the mass measurements (10^{-6}) are an additional challenge. In addition to a short time stability better than 10 ppm, the accuracy of the power converter is required to be 50 ppm.

RF system

The detailed specification have been established, proved and accepted by the FAIR company. A technical concept developed by GSI is considered as basis for further CR debuncher development. The main parameters of all subcomponents have been worked. A main contractor "Research Instruments" (RI) has been found and the technical design of the CR debuncher system is currently developed together with RI. The acquisition of the power supply units will start after the technical design has been established in Q3/2013. A variety of other subcomponents like the driver amplifier or the LLRF system is currently developed in house or in collaboration with different companies. The preseries RF station will be integrated by RI at GSI in Q4/2014.

Injection/extraction

The full aperture kicker magnet will be able to produce a field of 50 mT with a rise/fall time of 200 nsec in a magnet aperture of 290 x 160 mm^2 and over a total magnetic length of 1.35 m. For proper beam injection and extraction, 4 individual vacuum chambers are required, each is equipped with 3 kicker modules. The 3D field of the kicker magnets consisting of 3 modules is calculated. The particle tracking through this field has been done to define acceptable field performance on the flat top. Because of the field inhomogenity over the horizontal aperture the acceptance of the CR is predicted to be less by about 3% compared to the ideal linear optics. The kick variation in the median plane is required to be less than 2%. The preliminary design of the full aperture kicker magnets is still under study.

Beam diagnostics

The beam position monitor (BPM) is a prioritized component of the CR beam diagnostic. Beam position measurement with an accuracy better 5 mm for first turn diagnostics and an accuracy better 1 mm for the closed orbit measurement are specified. At the present stage the BPM electrodes are considered to be based on the spiral shape geometry. The disadvantage of such a geometry is a strong coupling between orthogonal electrodes. Therefore, the correlation between the electrode voltages and beam positions is not straightforward as, for example, in "shoe-box" type BPM. A realistic BPM model is used in numerical simulations in order to optimize the position calculation algorithm. This work is ongoing. Since the BPMs will be installed inside the wide aperture quadrupole magnets, their additional constraints to the BPM vacuum chamber are defined. The preliminary design of the spiral shaped electrodes and vacuum chamber, which must be of star-like shape, are shown in Fig.1. The Detailed Specification, which serves as an entry point for third parties, is in the final stage of preparation.

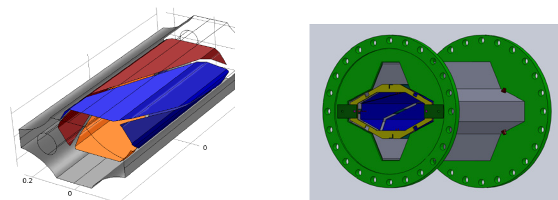

Fig1. Schematic drawing of the spiral-shape BPM electrodes inside the vacuum chamber (left) and preliminary vacuum chamber design (right).

Vacuum system

To reach the required beam lifetime, a vacuum pressure in the range of 10^{-9} mbar is needed. Therefore calculations of the pressure profile along the ring, where performed for various pumping speeds and pump positions to find the optimum positions [2]. Due to the required large aperture in the beam pipe (up to 480 mm horizontally) a new DN500CF was developed and tested. More details on this can be found in ref. [3]. In addition the first detailed specification of some vacuum chambers has been established. They describe in detail the required material properties, production and cleaning procedures.

Stochastic cooling

The CR serves mainly for fast stochastic cooling (SC) of antiproton and rare isotope beams, which have different velocities and requirements. The RF-block diagram of the SC system has been laid out; the technical specification of the 1-2 GHz power amplifiers has been written. The pickup slotline electrodes were further optimized, the first ceramic electrode plates have been delivered. Simulations of the Faltin electrodes for the Palmer pickup tank are underway. Two novel linear motor drive units were constructed; their synchronous operation will be tested at the GSI prototype pickup tank. A numerical code for solution of the 2D Fokker-Plank equation has been written. For more details see ref. [4].

References

[1] H. Weick et al., "Isochronicity Correction for Mass Measurements in CR", GSI Scientific Report 2012.
[2] J. Kurdal et al., "Vacuum Calculations of the FAIR Collector Ring", GSI Scientific Report 2012.
[3] L. Urban et al., "Analysis of ad DN500CF flange for the Collector Ring at FAIR", GSI Scientific Report 2012.
[4] C. Dimopoulou et.al,. "Developments for the CR stochastic cooling system", GSI Scientific Report 2012.