Progress report on the Collector Ring (CR)

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To strengthen the Russian Contribution to the FAIR Project it was proposed to transfer a major part of the CR project responsibility from GSI to BINP (Novosibirsk). As a first step in this progress a Memorandum of Understanding (MoU) between FAIR, GSI and BINP has been signed. According to the MoU the BINP will take over the responsibility of design, construction, installation and commissioning of the CR system and major components. In order to secure a sound technical reference for this process the GSI CR project group updated the TDR of the

Collector Ring. BINP will provide an accelerator that fulfills the entire set of machine parameters described in this document. GSI remains responsible for the stochastic cooling, the RF system, the data supply, the control system and the experimental devices.

In 2013 three workshops between GSI and BINP took place, where the technical aspects of the CR magnets and vacuum system were discussed. At the end of the year a BINP project group for the collector ring was established. With the reception of the - by GSI produced - project documentation this project group started to investigate the system layout and to design and specify the dipole and vacuum units.

System design

3D CATIA model of the CR layout and building have been continued and completed for all ring and building sections. Modifications of the long straight sections of the CR were implemented. For the civil construction planning, major assumptions have been made for the crane and maintenance of the CR components. The CR building documents and drawings have been approved in the first iteration. Major collisions have been identified and removed in an interactive process between the engineering- and ion optical designers. Detailed requests for the supply room conditions were specified according to the component properties.

Ring layout

The distribution of wide and narrow quadrupoles in the ring and the overall lattice cell has been further optimized. The long straight sections of the CR have been modified to have more drift space for diagnostic devices and vacuum components. In this context seven wide quadrupoles are replaced by narrow ones. The number and position of the injection kicker magnets in the CR have been optimised taking into account 3D magnet field calculations of the whole kicker tank consisting of three modules.

Beam dynamics

Proposed straight section modification, where the several wide quadrupoles are replaced by narrow ones, breaks the CR super-periodicity from 2 to 1. Taking into account this aspect and new data about the magnetic field quality of all CR magnets the dynamic aperture has been calculated using the PTC tracking module implemented in the MAD-X code. In particular, the off-momentum dynamic aperture has been computed to determine the available dynamic momentum aperture for the different operation conditions as shown in figure 1.

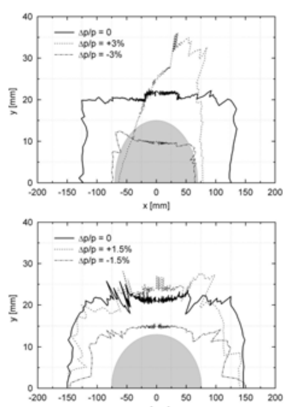

Figure 1: Dynamic aperture in the antiproton (left) and RIB (right) mode operation of the CR with the super-periodicity of 1.

The isochronous mode of the CR has been investigated further in detail. Different sort of nonlinear sources deteriorate the time resolution. It was shown that the influence of sextupole and octupole nonlinear effects can be completely compensated using sextupole and octupole corrections. The decapole effect is the most critical aspect. Without high order correction the required $\Delta T/T$ of 10^{-6} for mass resolution over the full CR momentum acceptance is not achievable. Simulations show that one family of a decapole corrector installed in the dispersive part of the CR is needed. To compensate the influence of the fringe field of quadrupoles on the ΔT the octupole correction is required. Using 4 octupole and 1 decapole families one can reach a resolution of $\Delta T/T = 3 \times 10^{-7}$, which corresponds to the mass resolution of $\Delta m/m = 10^{-6}$ [1].

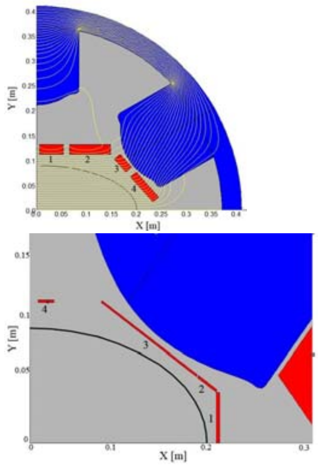

Figure 2: Cross section of sextupole (left) and quadrupole (right) with additional coils for vertical steering and octupole correction respectively.

Magnets

According to the 9th FAIR Machine Advisory Committee recommendations a fast ramping dipole magnet for the CR (1 T/s) must be designed. The time constant of the eddy current decay inside the yoke must be less than 5 ms that requires a yoke lamination thickness less than 2 mm. Requirements on integral field quality and magnet to magnet identity have been reconsidered in this context, too. The demand on the field quality of $\pm 10^{-4}$ has been fixed only for the maximum field level of 1.6 T. In the range below 1.6 T the relative magnet field deviation can be higher with a linear approximation up to $\pm 2.5 \times 10^{-4}$ at the field level of 0.8 T. The parameter “magnet to magnet identity” of the CR dipole magnet of 5×10^{-4} has been specified.

A new design of the wide sextupole magnet with a vertical corrector has been developed. The yoke length of the sextupole magnet is reduced by 10 cm. The four different coils must be embedded in the sextupole aperture over the vacuum chamber as shown in figure 2 (left). The design has been performed in such way in order to have only one power converter for all these coils.

In figure 2 (right) a preliminary design of the wide quadrupole magnets is shown with four additional coils, which produce the octupole field over the elliptical aperture with the axes of 400 mm and 180 mm. The field profile calculation has been performed using 2D and 3D OPERA codes. All these four coils together induce an additional quadrupole field component, which must be accounted by the main quadrupole magnet.

Injection/ Extraction

The CR requires full aperture kicker magnets with a total kick angle of 21 mrad. The kick flat-top must be at least 440 ns with a uniformity of 2%. The field uniformity of 2% is also requested inside the useful aperture. Due to the large kicker length compared to the available straight sections of the CR, it is necessary to split the kicker into nine modules. They are placed in three tanks, each containing three identical modules.

A 3D magnetic field of the kicker magnet consisting of 3 modules was calculated. In figure 4 the magnet field distribution in the middle plane of one kicker is shown. One can see that a strong field overlap between modules takes place. The particle tracking through this field shows that the effective deflection angle of one kicker tank is 7.1 mrad. The results of the 3D field analysis allowed to reduce the foreseen total amount of kicker modules from 12 to 9.

These kickers will be used both for injection and extraction of the beam in different optical modes within the rigidity range of 8 - 13 Tm. For these purposes a bipolar kicker system is required. One of the advantages of a bipolar kicker system is the possibility to determine the working mode of extraction or injection within a very short time (μs range).

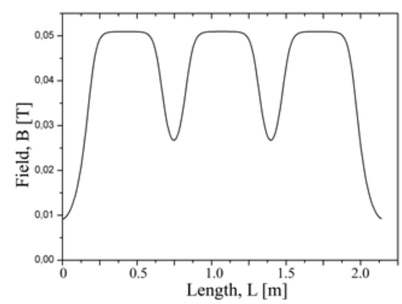

Figure 3: The vertical field distribution of one kicker magnet consisting of 3 modules. Here $(BL)_{eff}$=92 mTm, which gives kick angle x‘=7.07 mrad.

Vacuum system

A bake-out of the vacuum system is not foreseen to be installed in the MSV of the FAIR project. However, the possibility of bake-ability in future has been considered. It was agreed that, if it is possible without extra cost and extra development efforts, all components should be designed in such way that they can be baked-out up to 300 °C after the MSV if necessary. In this case appropriate materials for bake-out have to be chosen and installation procedure must be foreseen. For all magnets the combination of magnet yoke aperture, actual vacuum chamber layout and estimated beam shape was analysed together in order to derive the available space for thermal insulation.

For the dipole vacuum chamber the shape and wall thickness must be designed considering dipole requirements to have the possibility of fast ramping of 1 T/m.

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Stochastic cooling

The procurement procedure for the 1-2 GHz power amplifiers at the kickers was underway in 2013. The intermediate Cu cryoshield was assembled, successfully mounted into the prototype pick-up tank and finally gold plated. The notch filters have been finalized. Progress was made towards the design of the electrodes of the Palmer pick-up. More information one can find in ref. [2]. The new software development for Palmer cooling study has been performed [3].

References

[1] S. Litvinov, D. Toprek, H. Weick, et al., Nucl. Instr. and Meth. A **724** (2013) 20

[2] C. Dimopoulou et al., ”Developments for the CR stochastic cooling system”, this annual report

[3] M. Dolinska et.al., ”Software development for stochastic cooling study in time domain”, this annual report