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NICA COLLIDER MAGNETIC FIELD CORRECTION SYSTEM

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Abstract

The NICA Collider is a new superconducting facility that has two storage rings, each of about 503 m in circumference, which is under construction at the Joint Institute for Nuclear Research, Dubna, Russia. The influence of the fringe fields and misalignments of the lattice magnets, the field imperfections and natural chromaticity should be corrected by the magnetic field correction system. The layout and technical specification of the magnetic field correction system, the main parameters, arrangements and the field calculations and measurement results of the corrector magnets are presented. The results of dynamic aperture calculation at working energies are shown.

INTRODUCTION

NICA (Nuclotron-based Ion Collider fAcility) is a new accelerator complex currently under construction at the Joint Institute for Nuclear Research, Dubna, Russia. One of the main goals of the NICA project is experimental studies of dense nuclear (baryonic) matter [1]. Two arcs and two straight sections with two interaction points compose the Collider lattice [2]. The FODO optics with 12 periods is chosen for the arc structure. The twin-aperture superconducting dipoles and quadrupoles with the distance between beams 320 mm [3] are used in FODO cells (see Fig. 1). The correction system includes 124 corrector magnets for each beam (46 in arcs and 16 in straight sections) and 8 corrector magnets combined for 2 beams (in interaction point regions), in total 132 corrector magnets.

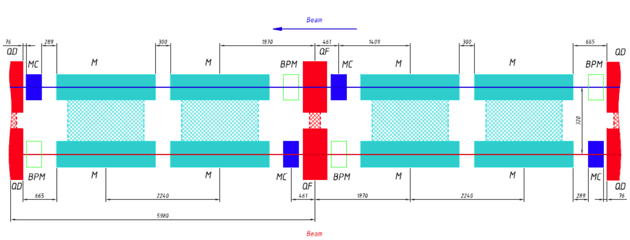

Figure 1: FODO-cell of the NICA Collider.

MAGNETIC FIELD CORRECTION SYSTEM

Corrector magnets are installed in each module of the quadrupole magnet (see Fig. 1, MC) except for special corrector magnets in straight sections of the Collider. As it was shown in [4], the designed lattice structure and the magnetic field correction system of the NICA Collider are made it possible to reach the design parameters. In addition, a dynamic aperture (DA) 8 -9 σ was reached. The main limitation of the dynamic aperture is the effect of the fringe fields (FF) of quadrupole magnets (see Fig. 2). At the present time, a tuning mode for compensation of the betatron tune coupling, ring chromaticity and fringe fields influence have been found. The current state of the results of calculating the beam dynamics for the NICA Collider was carried out in [5].

Random and systematic errors should be compensated by the correction system. The field imperfections, the deviation of magnetic field integrals, the influence of the FF and misalignments of lattice magnets are the sources of systematic errors. In addition, the natural chromaticity and betatron tune coupling are should be compensated too. The main aims for the magnetic field correction system are presented in Table 1. More details can be found in [6].

Table 1: Goals of the Correction System

Field Type	Correction Goal	Field Strength
Normal dipole	Hor. orbit	0.15 T
Skew dipole	Vert. orbit	0.15 T
Normal quadrupole	Betatron tune	3 T/m
Skew quadrupole	Motion coupl.	3 T/m
Normal sextupole	Ring chrom.	175 T/m^2
Normal octupole	DA correction	1300 T/m^3
Normal dodecapole	DA correction	125 000 T/m^5

CORRECTOR MAGNETS

The design of the corrector magnets is based on the Nuclotron corrector magnets. In general, these are superconducting magnets with sector coils and an iron yoke (see Fig. 3). The cooling of the superconducting coils is carried out by an inner cooling cylinder (see Fig. 3, 1). The positioning and electrical insulation of the superconducting coils are carried out with spacer cylinders (see Fig. 3, 2). Structurally, the corrector magnets are separated in 10 groups according to the type of the installed coils. The design of the magnet, the main characteristics and the results of 2D FEM field calculation were presented in [6].

The DA value is reduced to 6 -7 σ based on the results of 3D FEM field calculation of final focusing quadrupole magnets, in particular, by the integral value of the allowed harmonics B_5. For this reason, a special dodecapole corrector magnet has been developed. The superconducting coil with a cooling spacer is mounted directly on the surface of the beam pipe in the centre of the central final focusing

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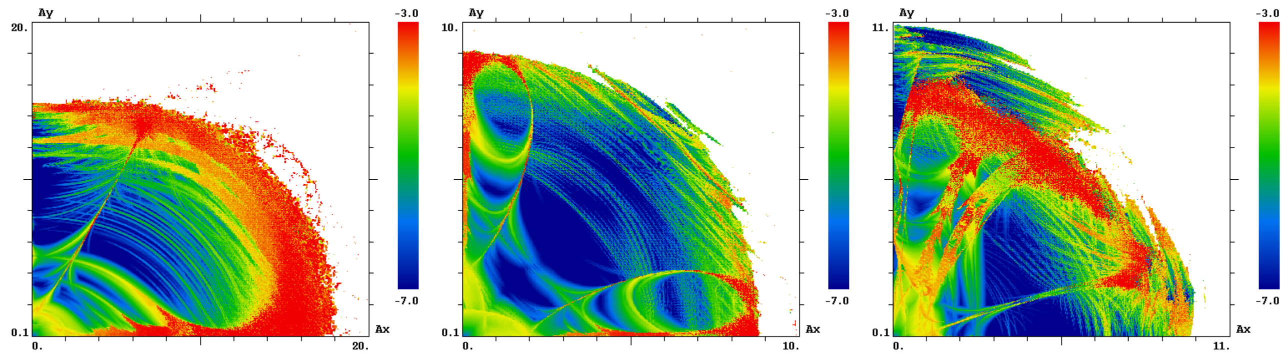

Figure 2: FMA results from the DA calculation (in normalized betatron amplitudes): no FF (left), including FF (center), including FF and correction (right).

quadrupole magnet. An iron yoke is not provided for this type of the corrector magnets.

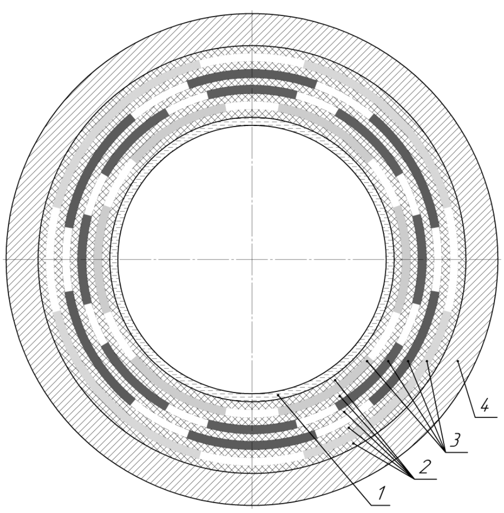

Figure 3: The cross-section view of the corrector magnet: (1) cooling cylinder, (2) spacer cylinder, (3) coils, (4) iron yoke.

The production of the corrector magnets has been organized in the SCM&T Department of LHEP, JINR, Dubna, Russia [7]. At this time, 68.9 % of the corrector magnets have been produced. The procedure of magnetic measurements was carried out for each magnet at an operating temperature of ≈4.6 K. The Hall probe is installed on the surface (R=46 mm) of the magnetic measurement system for quadrupole magnets in the centre of the corrector magnet (see Fig. 4) [6].

Table 2: Magnetic Measurement Results (R_{ref} = 46 mm)

Harmonica	**Measurement**	**2D FEM**
Dipole (B_0)	0.1270	0.1390
Sextupole (B_2)	0.0970	0.0957
Octupole (B_2)	0.0189	0.0212

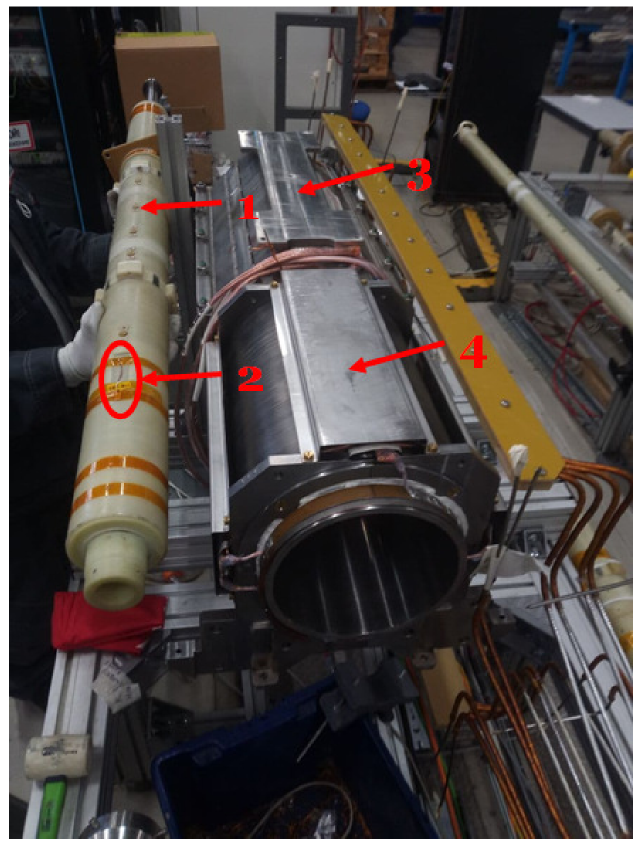

Figure 4: Magnetic measurement probe for quadrupole magnets: (1) probe, (2) Hall sensor, (3) quadrupole magnet, (4) corrector magnet.

The functional relationship of the radial component of the magnetic field from the angular position $B_r(\theta)$ from the Hall probe (three measurements and the mean value) and from the 2D FEM calculation for the fifth group of corrector magnets are shown in Figure 5 and Table 2. Individual power supplies and operating currents of the coils were used according to the technical specification. As it can be seen, a correlation was observed between the measured and the calculated results. It should be emphasized, that the offset of the the axis of

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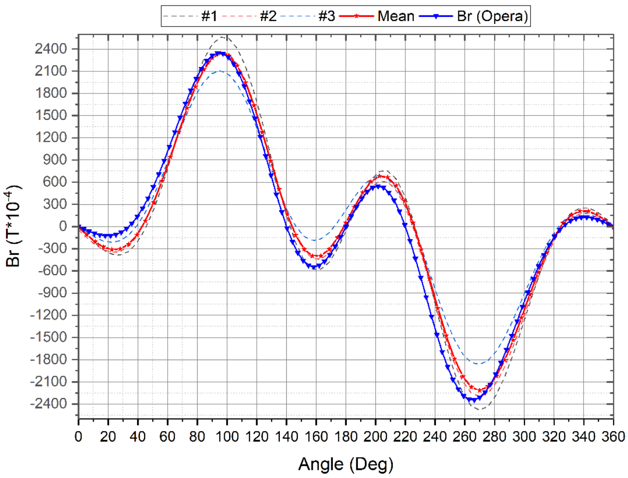

Figure 5: Radial component of the magnetic field vs. angular position.

the magnetic measurement probe to the magnetic axis and the difference between the designed and actual turns in the coils are the main sources of discrepancy between the 2D FEM calculation and the measurement results. Thus, based on the data of magnetic measurements, the offset between the corrector and quadrupole magnet axes can be calculated.

At present time, 100 % of the dipole (including reserves) and 34.8 % of the quadrupole magnets for the NICA Collider have passed the magnetic measurement procedure [8]. The search for a tuning mode of the magnetic field correction system based on these data is made our plans.

CONCLUSION

At the moment, the development of the NICA Collider magnetic field correction system has been completed. This system of the NICA Collider allows to reach the design parameters. The random and systematic errors should be compensated by the correction system. The development and serial production of the Collider corrector magnets has been started at JINR. The analytical and 2D FEM calculations were performed in the magnet centre. The FEM calculation tacking into account all sources of systematic errors, the 3D analytical and FEM models are made our plans. Magnetic measurements were carried out for 68.9 % of the Collider corrector magnets with a system based on the Hall probe. The experience of establishing the Booster corrector was taken into account when developing the design and technology of the collider correctors.

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