PROGRESS ON MANUFACTURING AND TESTING OF THE SC MAGNETS FOR THE NICA BOOSTER SYNCHROTRON

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Abstract

NICA is a new accelerator collider complex under construction at the Joint Institute for Nuclear Research in Dubna. The facility is aimed at providing collider experiments with heavy ions up to Gold in the centre of mass energy from 4 to 11 GeV/u and an average luminosity up to $1 \cdot 10^{27}$ cm^{-2} s^{-1} for Au^{79+}. The collisions of polarized deuterons are also foreseen. The facility includes two injector chains, a new superconducting booster synchrotron, the existing 6 AGeV superconducting synchrotron Nuclotron, and a new superconducting collider consisting of two rings, each 503 m in circumference. The booster synchrotron is based on an iron-dominated "window frame"- type magnet with a hollow superconductor winding analogous to the Nuclotron magnet. The design of superconducting magnets for the NICA booster synchrotron is described. The progress of work on the manufacturing and testing of the magnets is discussed. The calculated and measured values of the characteristics of the magnets are presented. The status of the facility for serial test of superconducting magnets for the NICA and FAIR projects is described.

INTRODUCTION

The NICA project [1], [2] started at the Joint Institute for Nuclear Research (JINR) in Dubna in 2007. The main goal of the project is to study hot and dense strongly interacting matter in heavy-ion (up to Au) collisions at the centre-of-mass energies up to 11 GeV/u. A study of spin physics is also foreseen with extracted and colliding beams of polarized deuterons and protons at the energies up to 27 GeV for protons. The NICA accelerator complex will consist of two injector chains, the new 600 MeV/u superconducting (SC) booster synchrotron, the upgraded SC synchrotron Nuclotron [3], and the new SC collider having two storage rings each about 503 m in circumference with luminosity up to $1 \cdot 10^{27}$ cm^{-2} s^{-1} for Au^{79+} and two interaction points. The Nuclotron-type design [4] – [6] based on a cold iron yoke and a saddle-shaped SC coil has been chosen for the booster and the collider magnet. The magnet includes a window frame yoke at 4.5 K and a SC coil made of a hollow Nb-Ti composite SC cable cooled with a two-phase helium flow. The yoke supports Lorentz forces in the coil.

DESIGN OF THE MAGNETS

The designs of the magnets for the NICA booster are given in [7] – [12]. The iron yoke of the magnet consists of two symmetric parts bolted together. The half-yokes are fabricated of the laminated isotropic 0.65 mm thick electrical steel M 530. The laminations are compressed with pressure of 5 MPa in the direction of the longitudinal axis of the magnet. The side plates 10 mm thick are welded with laminations and stainless steel end plates 20 mm thick. The magnet is 2.2 m long and has a radius of the curvature of about 14 m. Fig. 1 shows the dipole magnet for the NICA booster.

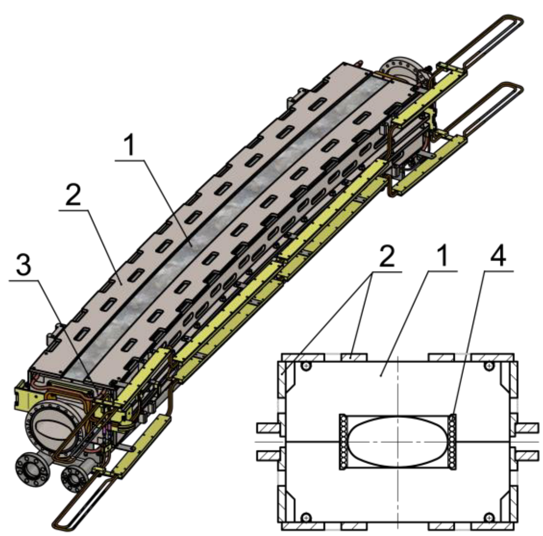

Figure 1: View of the dipole magnet. 1 – lamination, 2 - side plate, 3 - end plate, 4 – SC coil.

Each pair of lattice lenses is connected using the intermediate cylinder and form a doublet (see Fig. 2). The doublet of about 1.8 m length has a rigid mechanical design. It has a demountable construction that allows splitting the doublet into two horizontal parts to install the beam pipe. The doublet is fixed in a cryostat by means of eight suspension rods and adjusted in space as a unit.

Table 1: Main Characteristics of the Magnets

Characteristic	Dipole	Lens
Number of magnets	40	48
Max. magnetic field (gradient)	1.8 T	21.5 T/m
Effective magnetic length	2.2 m	0.47 m
Beam pipe aperture (h/v)	128 mm/ 65 mm	
Radius of curvature	14.09 m	-
Overall weight	1030 kg	110 kg

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There will 32 corrector magnets of 0.32 m long in the ring of booster synchrotron. 24 corrector magnets will have two coils each (horizontal and vertical dipole coils) and 8 corrector magnets will contain four coils each (normal and screw quadrupole and sextupole coils). The characteristics of the NICA booster lattice magnet are given in Table 1.

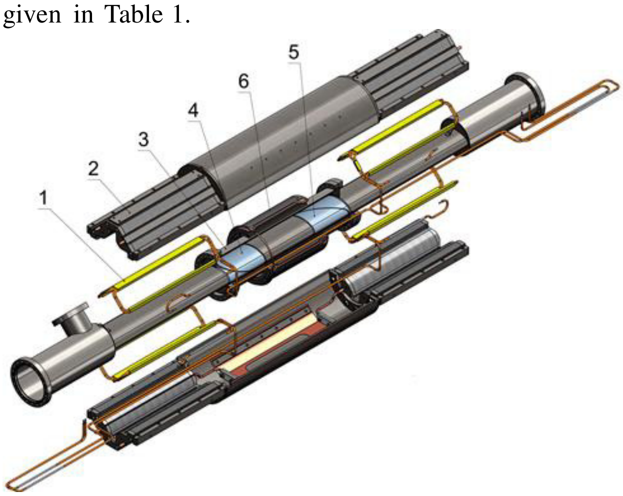

Figure 2: View of the doublet of the lenses. 1 – half-coil, 2 – half-yoke, 3 – beam pipe, 4, 5 – beam position monitors, corrector magnet.

STATUS OF MANUFACTURING THE MAGNETS

The iron yokes for the NICA booster dipole and quadrupole magnets are manufactured at SMZ (new name SSZ) plant in Savelovo town. Production of all 24 yokes for doublet of the lenses and 28 of 40 yokes for dipole magnets has been completed in this month (see Fig. 3). Production of the 32 yokes for corrector magnets is carried out at the company ATOM in Dubna. Completion of this work is scheduled for the second quarter of 2017. The vacuum shells for all booster magnets were manufactured at the company FRAKO-TERM from Poland. The thermal shields for cryostats will manufactured at the Laboratory of High Energy Physics (LHEP) of JINR. Supply of thin-walled curved beam chambers for dipole magnets and straight elliptic pipes for doublets of the lenses is scheduled for March - July 2017. The supplier of the beam pipes is FRAKO-TERM Company.

Figure 3: The yokes and vacuum shells for the magnets.

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The Nuclotron-type superconducting cable and all coils for dipole and quadrupole magnets will manufacture at the Laboratory of High Energy Physics. 16 dipole and 38 quadrupole coils have been manufactured up to now. Completion of SC coils manufacturing is scheduled for mid-2017.

FACILITY FOR CRYOGENIC TESTS

A special facility [13], commissioning of which at LHEP is scheduled for the next week, is designed for assembly and cryogenic test of superconducting magnets for NICA and FAIR projects (see Fig. 4-5). JINR and FAIR / GSI participate together in funding the facility. In the period of 4 to 6 years 40 dipoles, 48 quadrupoles and 32 corrector magnets for the NICA booster, 80 twin bore dipoles, 86 twin bore quadrupoles, 12 final focus quadrupoles, 8 dipoles for bring together and separate the beams, and 48 pairs of corrector magnets for the NICA collider, as well as 170 quadrupoles and 140 corrector magnets for the FAIR project, will be assembled and tested at this facility. The total number of the superconducting magnets to be assembled and tested at this facility is 664, without spare magnets. Six cryogenic benches in parallel operating a round the clock are provided to achieve operating rate of testing two magnets per week. One of the satellite-type helium refrigerators serves each pair of benches. The Dewar vessels with liquid helium for their operation are delivered from the Nuclotron central liquefier. Two pulse power converters of 15 kA and 25 V have been designed to test the magnets. Electrical connection of the magnet to the power converter is carried out by means of current leads having a high-temperature superconductor, cooled with liquid nitrogen. The original cable machine was designed and manufactured for the production of the Nuclotron-type superconducting cable.

Figure 4: The facility for assembly and cryogenic test of superconducting magnets for the NICA and FAIR projects.

More detailed information about the results of the latest tests of the magnets is given in [14] – [19].

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Figure 5: Series dipole magnet (left) and doublet (center) for NICA booster, and pre series dipole magnet for NICA collider (right).

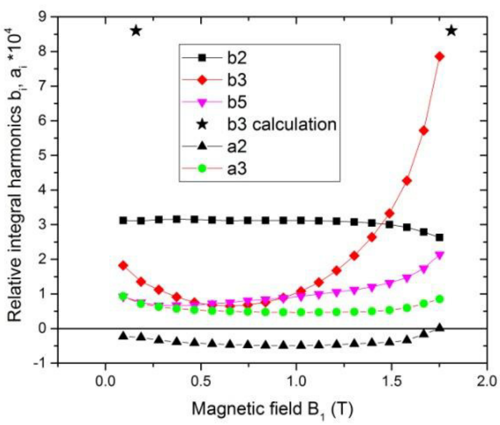

Figure 6: Relative integral harmonics of the magnetic field in the aperture of the NICA booster magnet at the radius of 30 mm as a function of the magnetic field in the magnet centre.

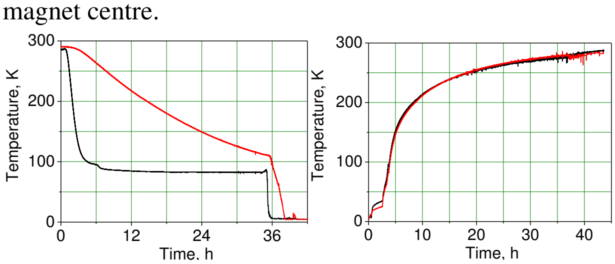

Figure 7: Cooling-down (left) and warm-up (right) of the dipole magnet for the NICA booster. Black line is inlet and red line – outlet of the magnet.

Some test results are shown in Fig. 6 and Fig. 7.

CONCLUSION

Serial production of the magnets for the NICA booster at the Laboratory of High Energy Physics of JINR has passed the halfway. Completion of manufacturing the magnets for the NICA booster synchrotron is planned for the middle of 2017. Facility for assembling and cryogenic tests of the SC magnets for the NICA and FAIR projects is prepared for commissioning in full configuration at Dubna in next week. Facility for assembling and cryogenic tests of the SC magnets for the NICA and FAIR projects is prepared for commissioning in full configuration at Dubna in next week. Serial cryogenic tests of the magnets successfully started at new test facility. Completing the cold tests of the magnets is scheduled for the end of 2017.

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