SERIES MAGNETIC MEASUREMENTS OF NICA BOOSTER DIPOLES

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Abstract

NICA booster magnetic system consists of 40 dipole and 48 quadrupole superconducting (SC) magnets. Measurement of magnetic field parameters is assumed for each booster magnets. At the moment six series dipole magnets are assembled and have passed all tests. Booster dipole magnets are 2.14 m-long, 128 /65 mm (h/v) aperture magnets with design similar to Nuclotron dipole magnet but with curved (14.1 m radius) yoke. They will produce fields up to 1.8 T. The magnetic field parameters will be measured at "warm" (300 K) and "cold" (4.5 K) conditions. The obtained results of magnetic measurements of first five magnets are summarized here.

INTRODUCTION

At the Laboratory of High Energy Physics (LHEP) the technical complex [1] for assembly and testing of SC magnets for the NICA and FAIR project is lunched for pass whole cycle operating at assembling and series testing mode. Five magnets were done. The testing program of magnets includes “warm” and cold magnetic measurements (MM).

DIPOLE MAGNET FOR THE NICA BOOSTER

The Nuclotron-type design based on a window frame iron yoke and a saddle-shaped SC winding has been chosen for the NICA booster and collider magnetic system. A cross-section view of the booster dipole magnets with installed magnetic measuring system (MMS) is shown on Fig. 1.

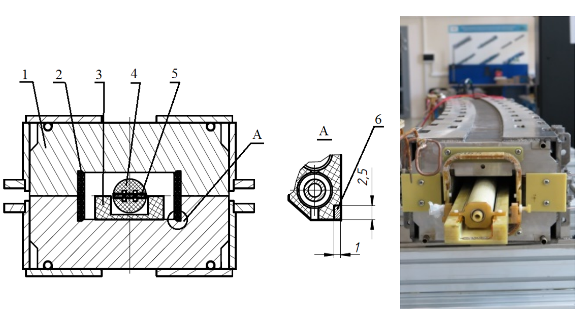

Figure 1: Cross-section view of the bent dipole magnet for the NICA booster with magnetic measurement system. 1. Yoke, 2. Main coil, 3. Base of MMS frame, 4. MMS frame, 5. PCB with harmonic coils, 6. Reference coil.

The NICA Booster operating cycle consists of stages of linear field ramping up and down with a ramp rate of 1.2 T/s and two stages with a constant field. Injection magnetic field is 0.11 T, at electron cooling is 0.56 T.

SPECIFICATION FOR MAGNETIC MEASUREMENTS

According to the specification following parameters of Booster dipole magnets have to be measured:

- Relative variation of effective lengths

$$L_{eff} = \frac{\int_{-\infty}^{\infty} B_y ds}{B_y(0)} \qquad \delta L_{eff} = \frac{\Delta L_{eff}}{< L_{eff} >} \le 5\cdot 10^{-4}$$

- Angle between the magnetic and mechanical median plane (Dipole angle)

$$\alpha_1 = -arctg(\frac{a_1}{b_1}) \quad \delta(\alpha_1) \le 0.1\,\text{mrad}$$

- Relative integrated harmonics up to the 5th

b_2^*	$5\cdot 10^{-4}$
a_2^*	$5\cdot 10^{-4}$
b_3^*	10^{-3}
b_n^* , a_n^* , $n>3$	10^{-4}

THE MAGNETIC MEASUREMENT SYSTEM

Magnetic measurements were carried out by means of the rotating harmonic coils probes. Detailed description of magnetic measurement system and methods was done in papers [2], [3].

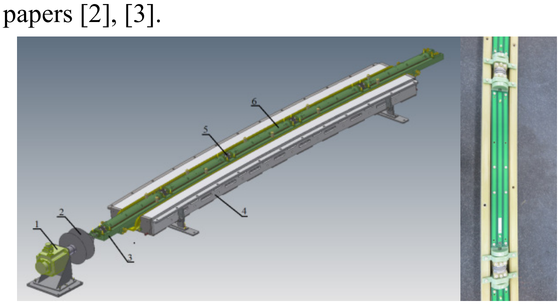

Figure 2: Layout of bottom part of magnets yoke with installed MMS: 1. Servomotor, 2. Bobbin for the cable, 3. Base of frame, 4. Bottom part of yoke, 5. Flexible coupling, 6. Measuring section.

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The measuring system (Fig. 2) consists of five identical sections connected by bellow couplings. Each section has inside three measuring coils made as multilayered printed-circuit board. The base frame is fixed on the bottom pole of a magnet yoke. Coils consist of 400 turns created from 20 layers, each of which contains 20 turns. Dipole component suppression

$$\frac{cmp_{\Psi_1}}{ncmp_{\Psi_1}} \cdot 10^4 = 2.6 \div 11$$

THERMAL CONTRACTION OF PCB

Temperature of magnetic measurement probe is controlled by TVO sensors (Fig. 3). If measuring time from start of cooling differs for magnets, probe temperature will be too various in range 100-70 K and the calculated effective length should be corrected on a thermal contraction. Magnetic measurement probe contraction by cooling was measured in CERN (Fig. 4). Typical value of the contraction is 2.6-3.2 mm/m.

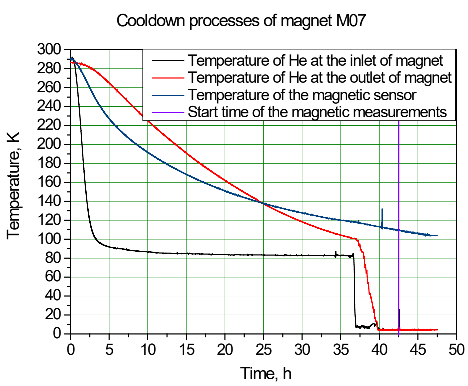

Figure 3: Cooling down processes of NICA Booster dipole magnet.

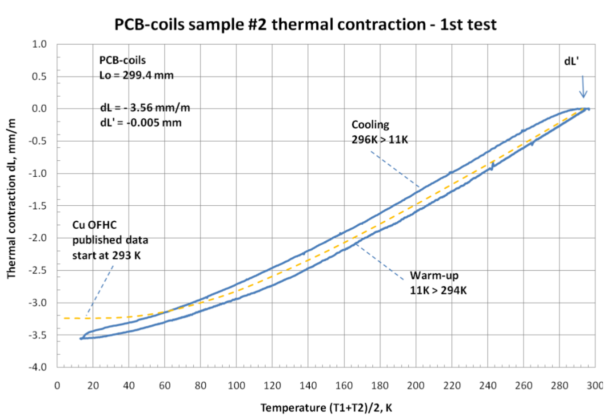

Figure 4: Thermal contraction of PCB.

MAGNETIC MEASUREMENT RESULTS

At the moment five dipole magnets are assembled and have passed all tests, including “warm” and “cold” magnetic measurements. Results are presented on Figures 5-11.

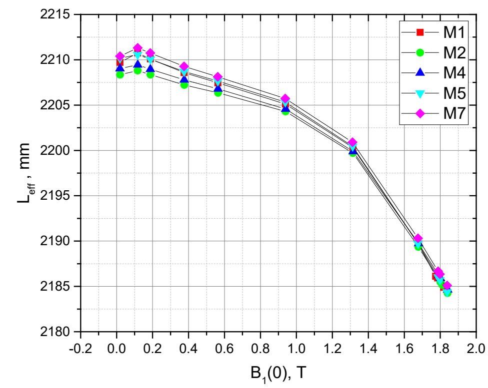

Figure 5: Effective lengths vs. the magnetic field intensity in the center of magnet.

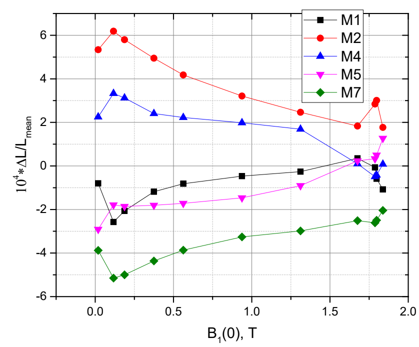

Figure 6: Relative variation of effective lengths vs. the magnetic field in the center.

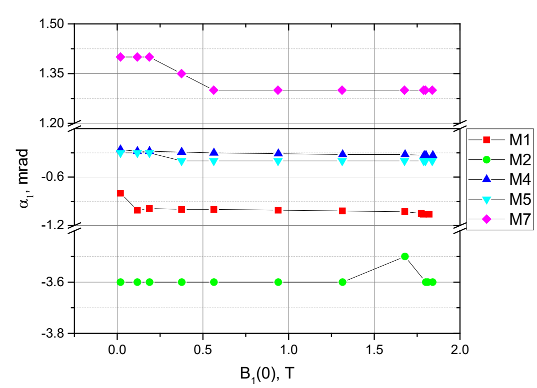

Figure 7: Dipole angle vs. the magnetic field intensity in the center. Accuracy of the measurements is equal 0.5 mrad.

Dipole angle doesn’t depend on a magnetic field Fig.7.

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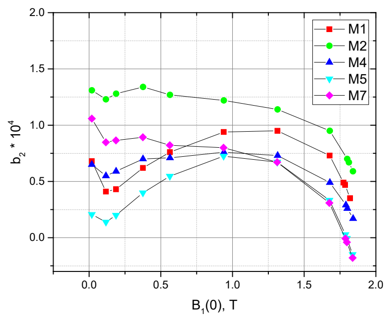

Figure 8: b_2 harmonic vs. the magnetic field intensity in the center.

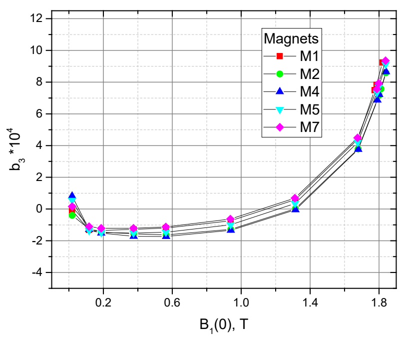

Figure 9: b_3 harmonic vs. the magnetic field intensity in the center.

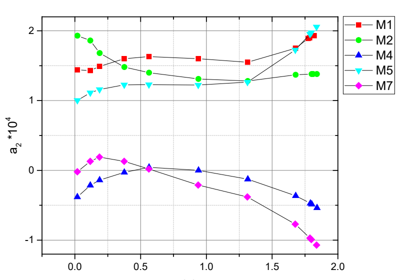

Figure 10: a_2 harmonic vs. the magnetic field intensity in the center.

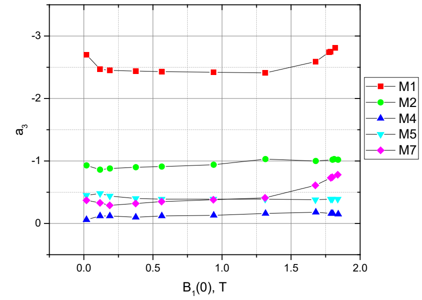

Figure 11: a_3 harmonic vs. the magnetic field intensity in the center.

CONCLUSION

First magnets are released on series testing. Magnetic measurements showed good agreement with the specification.

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[2] V. Borisov, et al., “Magnetic measurement system for the NICA booster magnets,” in Proceedings of the 5th International Particle Accelerator Conference IPAC 2014, Dresden, Germany, June 15–20, 2014, p. 2696, WEPRI088.

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