Magnetic Measurements of the NICA Booster superconducting magnets

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INTRODUCTION

NICA booster magnetic system consists of 40 dipole and 48 quadrupole superconducting magnets. The magnetic field parameters of each magnet must be measured at "warm" (300 K) and "cold" (4.5 K) conditions. . Now 26 series dipole magnets (65%) and 5 (10%) quadrupole doublets are assembled and have successfully passed all the tests, including "warm" and "cold" magnetic measurements.

DIPOLE MAGNET FOR THE NICA BOOSTER

The design of the NICA booster magnets is Nuclotron-type design based on a cold iron yoke and a saddle-shaped SC coil. Booster dipole magnets are 2.14 m-long, 128 /65 mm (h/v) aperture magnets with curved (14.1 m radius) yoke. Two quadrupole magnets are connected together to form a dou-blet. Main characteristics of the NICA booster magnets are given in Table I. The booster dipole magnets with installed magnetic measuring system (MMS) is shown in Fig. 1 and 2.

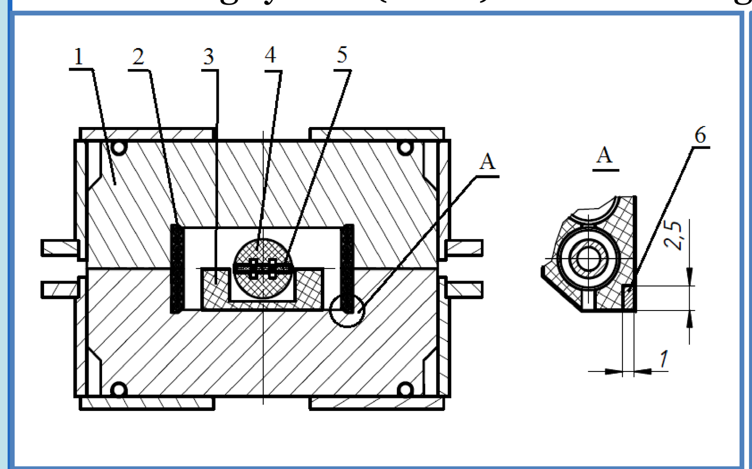


Figure 1: Cross-section view of the bent dipole magnet for the NICA booster with MMS. 1. Yoke, 2. Main coil, 3. Base of MMS frame, 4. MMS frame, 5. PCB with harmonic coils, 6. Reference coil.

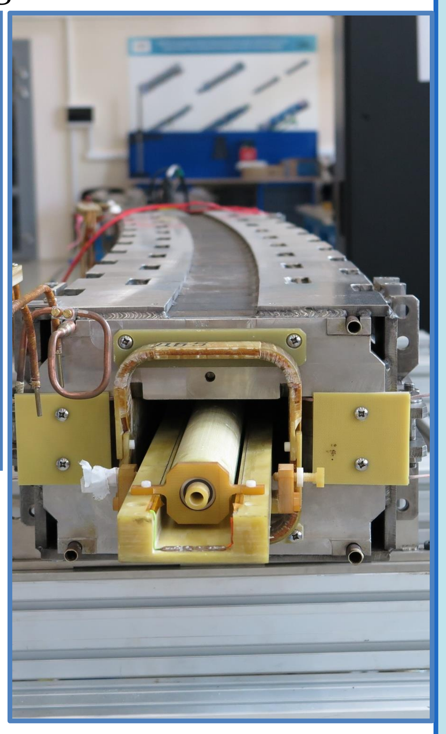


Figure 2: Photo of the bent dipole magnet for the NICA booster with installed magnetic measurement system.

Main Parameters of the NICA Booster Magnets

Parameter	Dipoles	Quadrupoles
Number of magnets	40	48
Maximum magnetic field	1.8 T	21.5 T/m
Magnetic field at injection	0.11 T	1.3 T/m
Effective magnetic length	2.2 m	0.47 m
Beam pipe aperture (h/v)	128 /65 mm	128 /65 mm
Radius of curvature	14.01 m	
Operating current	9.68 kA	9.68 kA

SPECIFICATION ON MAGNETIC MEASUREMENTS

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

- Relative standard deviation of effective lengths

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

- Magnetic field direction (dipole angle), angle between the magnetic and mechanical median plane

$$\alpha_1 = -arctg(\frac{A_1^*}{B_1^*}) \quad \sigma(\alpha_1) \le 0.1\ mrad$$

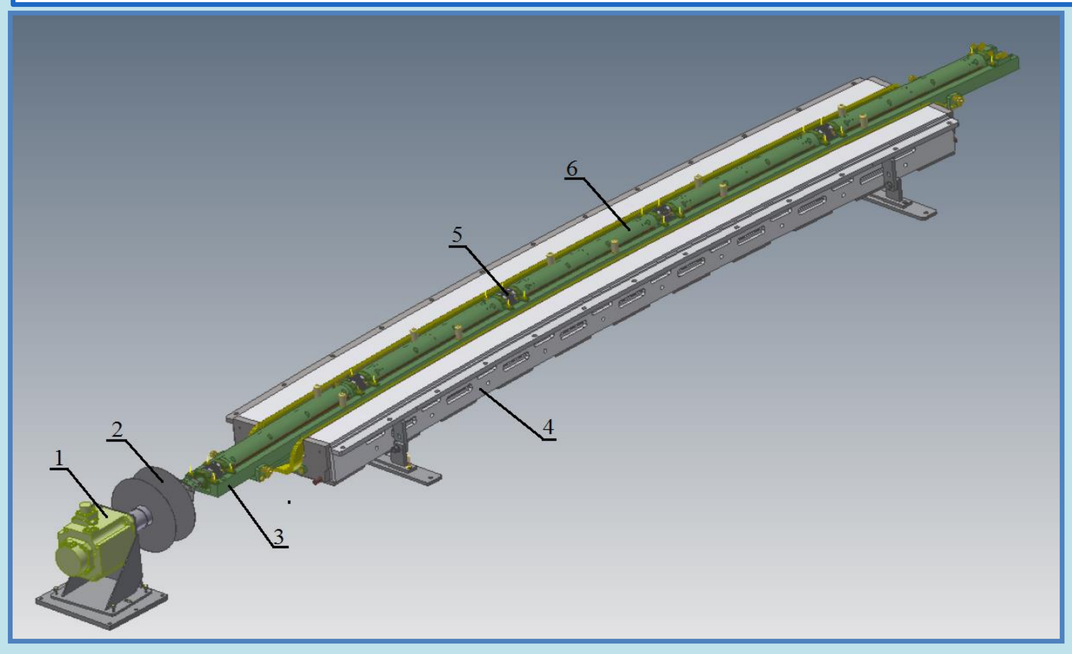
- Relative integrated harmonics up to the 5th

b_2^*, a_2^*, a_3^*	$\le 5\cdot 10^{-4}$
b_3^*	$\le 10^{-3}$
b_3^* an injection field	$\le 10^{-4}$
b_n^*, a_n^*, n>3	$\le 10^{-4}$

* - integrated harmonics

ROTATING COILS SYSTEM

The measuring system (Fig. 3) consists of five identical sections connected among themselves by bellow couplings. Each section consists of two glass epoxy parts, the frame and the covers. On the frame three measuring coils made as multilayered printed-circuit board are installed (Fig.4). The base frame is fixed on the bottom pole of a magnet yoke. Precision fabrication of a yoke pole surface and base frame determines the accuracy of positioning of measuring system in a magnet aperture. Further the system via the coupling connects to servomotor shaft.



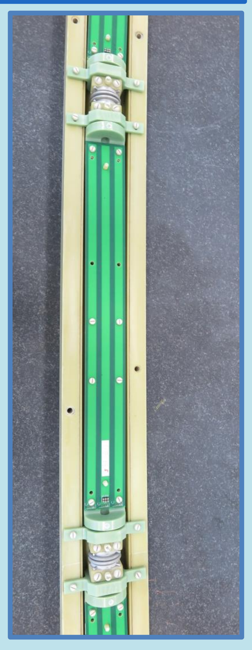


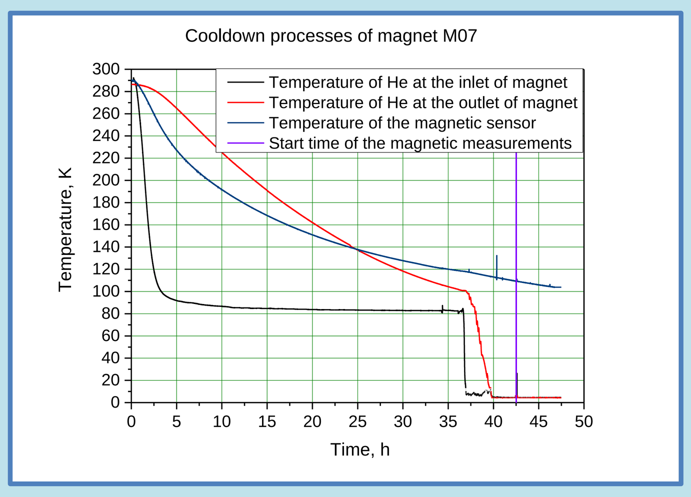
Fig. 3: Layout of bottom part of magnets yoke with installed MMS: 1. Servomotor, 2. Bobbin for cable, 3. Base of frame, 4. Bottom part of yoke, 5. Flexible coupling 6. Measuring section.

Fig. 4: View of one section without cover part. Multilayered printed-circuit board.

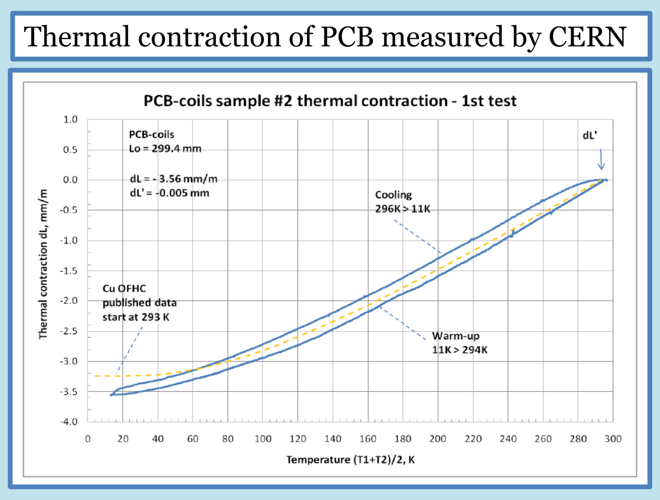
Coils consist of 400 turns created from 20 layers, each of which contains 20 turns.

Dipole component suppression $\frac{\Psi_1^{cmp}}{\Psi_1^{ncmp}} \cdot 10^4 = 0.5 \div 5$

Flux dependences are measured by step-driving method. Shaft is rotated by servo at 64 angular equidistant positions. The magnet is excited by a triangular current pulses. Inducted signals are digitized by ADC modules and written at hard drive. All data are analyzed offline.

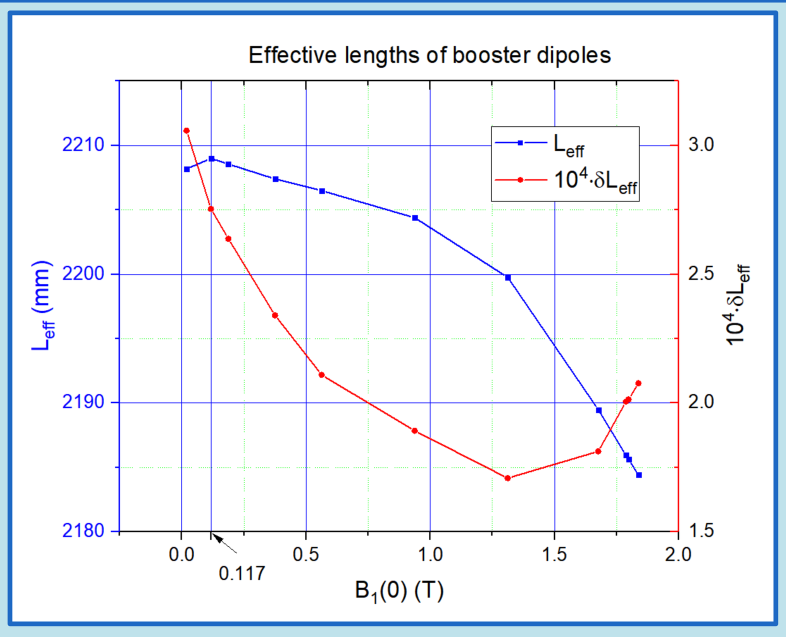


Thermal contraction of PCB measured by CERN

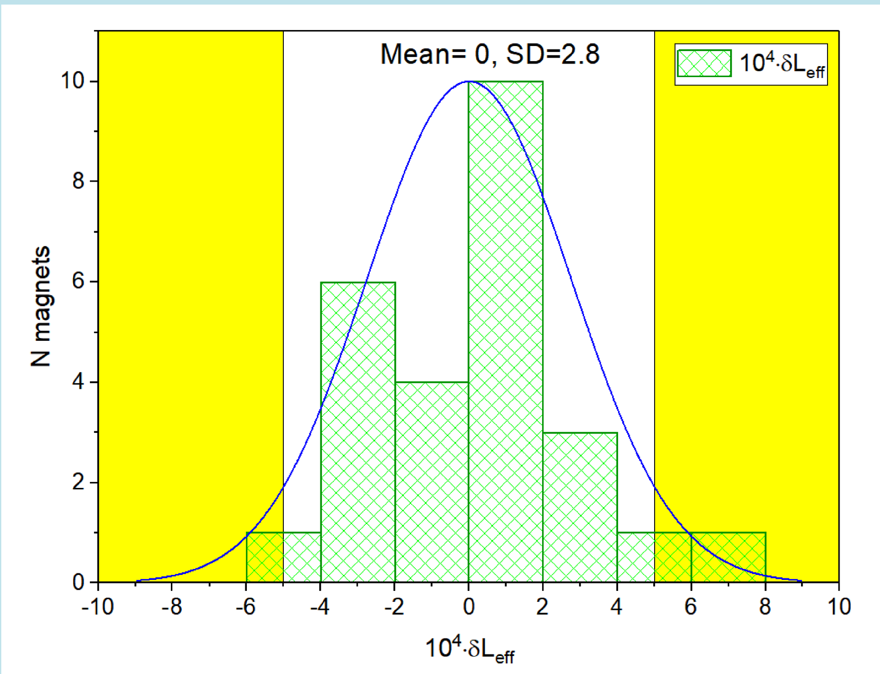


Magnetic measurement probe contracts by cooling. If measuring time from start of cooling differ for magnets, temperature will be various and the calculated effective length should be corrected on thermal contraction. Typical value of contraction is 2.6-2.9 mm/m.

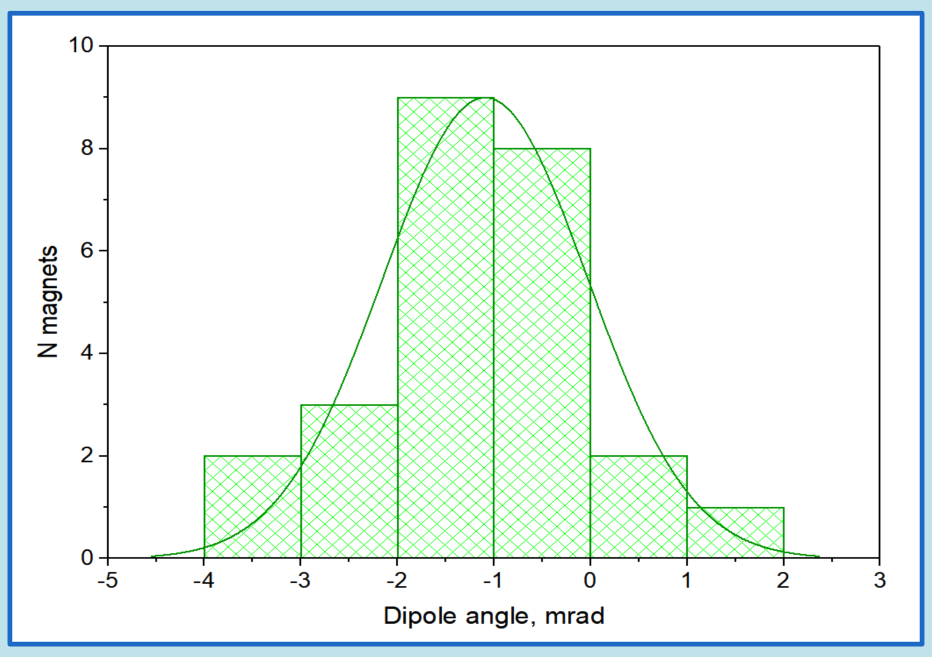
RESULTS

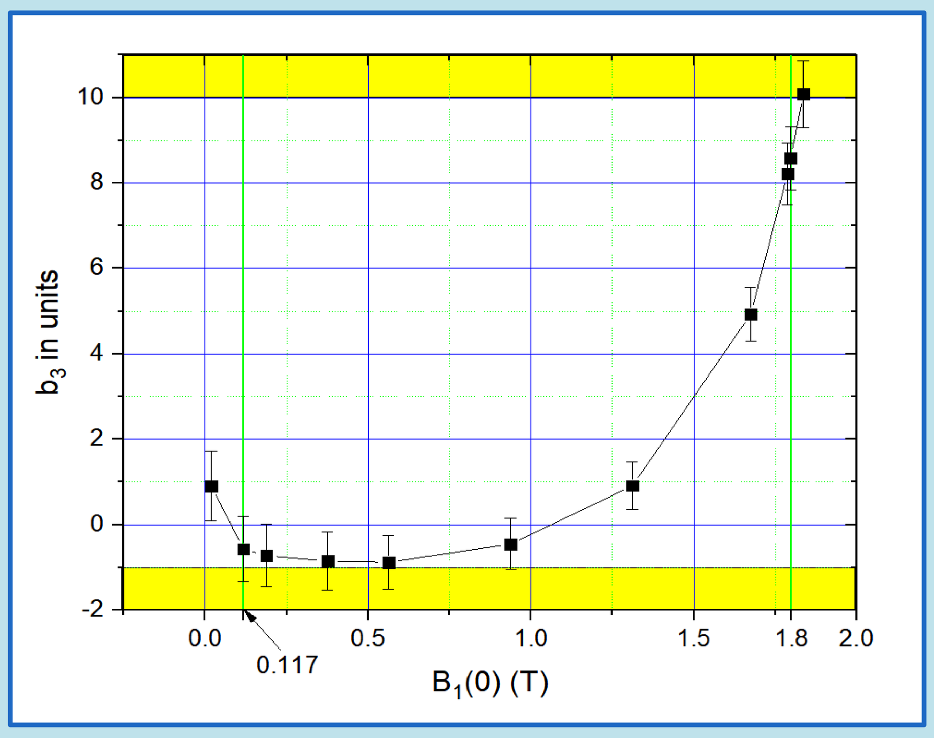


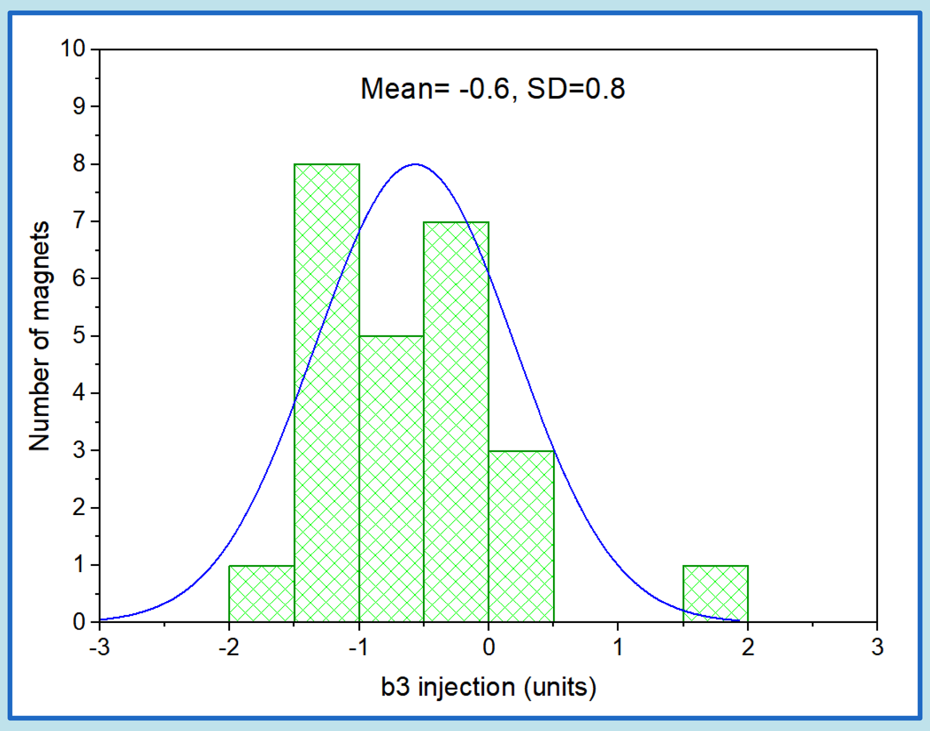
Mean value and relative standard deviation of effective lengths vs. the magnetic field induction in the center. 0.117 T is injection field.

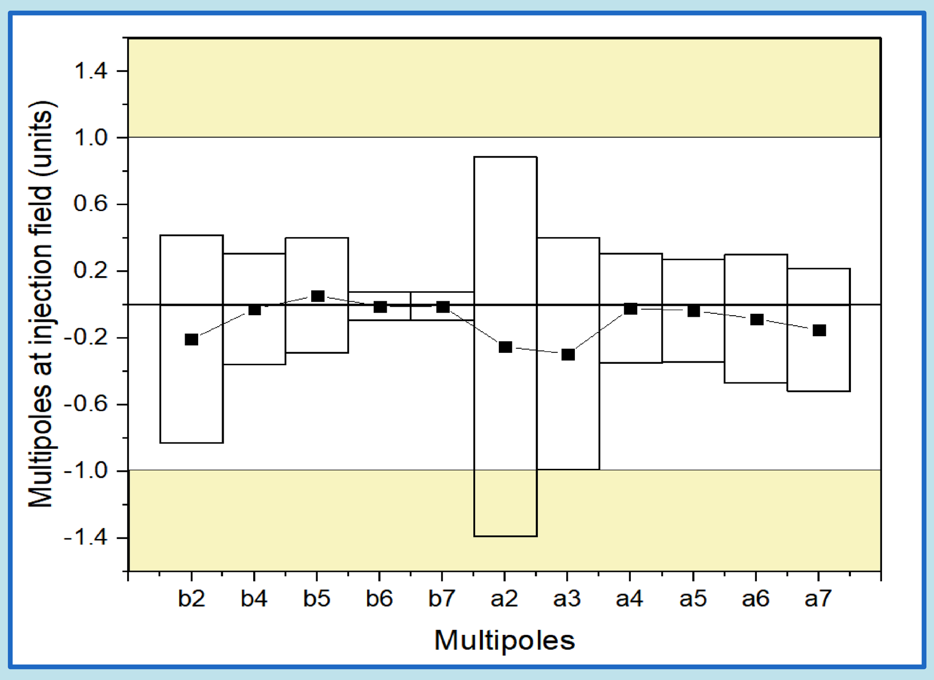


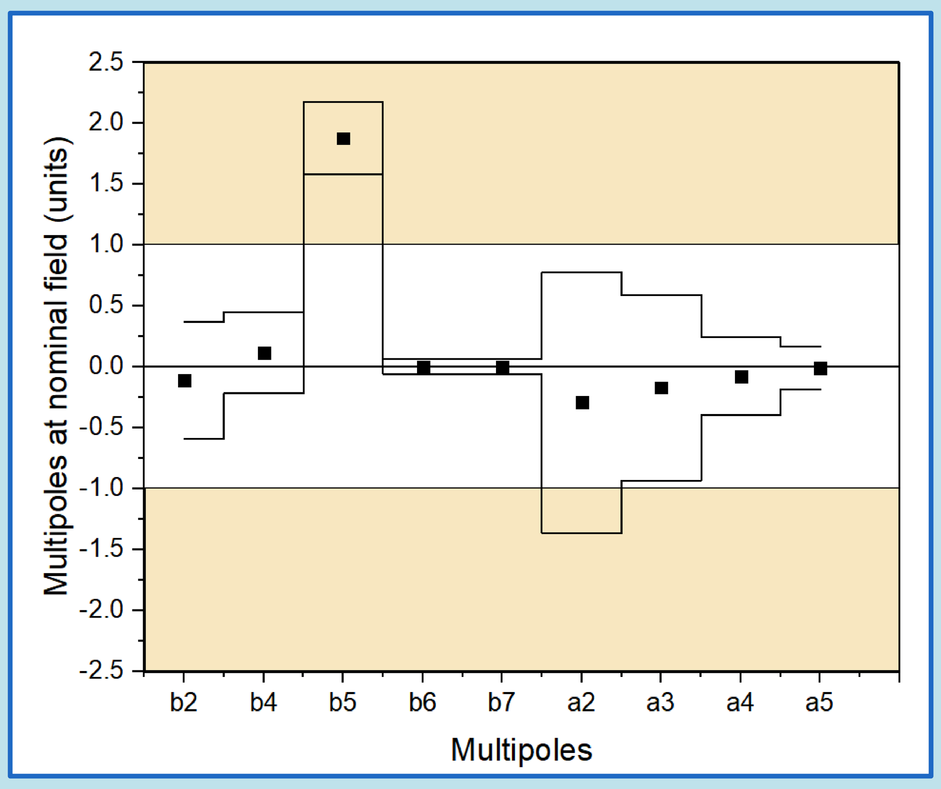
Distribution of effective lengths relative variations for 0.117 T











CONCLUSION

60% of the dipole magnets for the NICA booster synchrotron was successfully passed cryogenic test and can be installed in the tunnel of the accelerator. Magnetic measurements showed good agreement with the specification.

ACKNOWLEDGMENT

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