Design and main characteristics of the FRDM magnet

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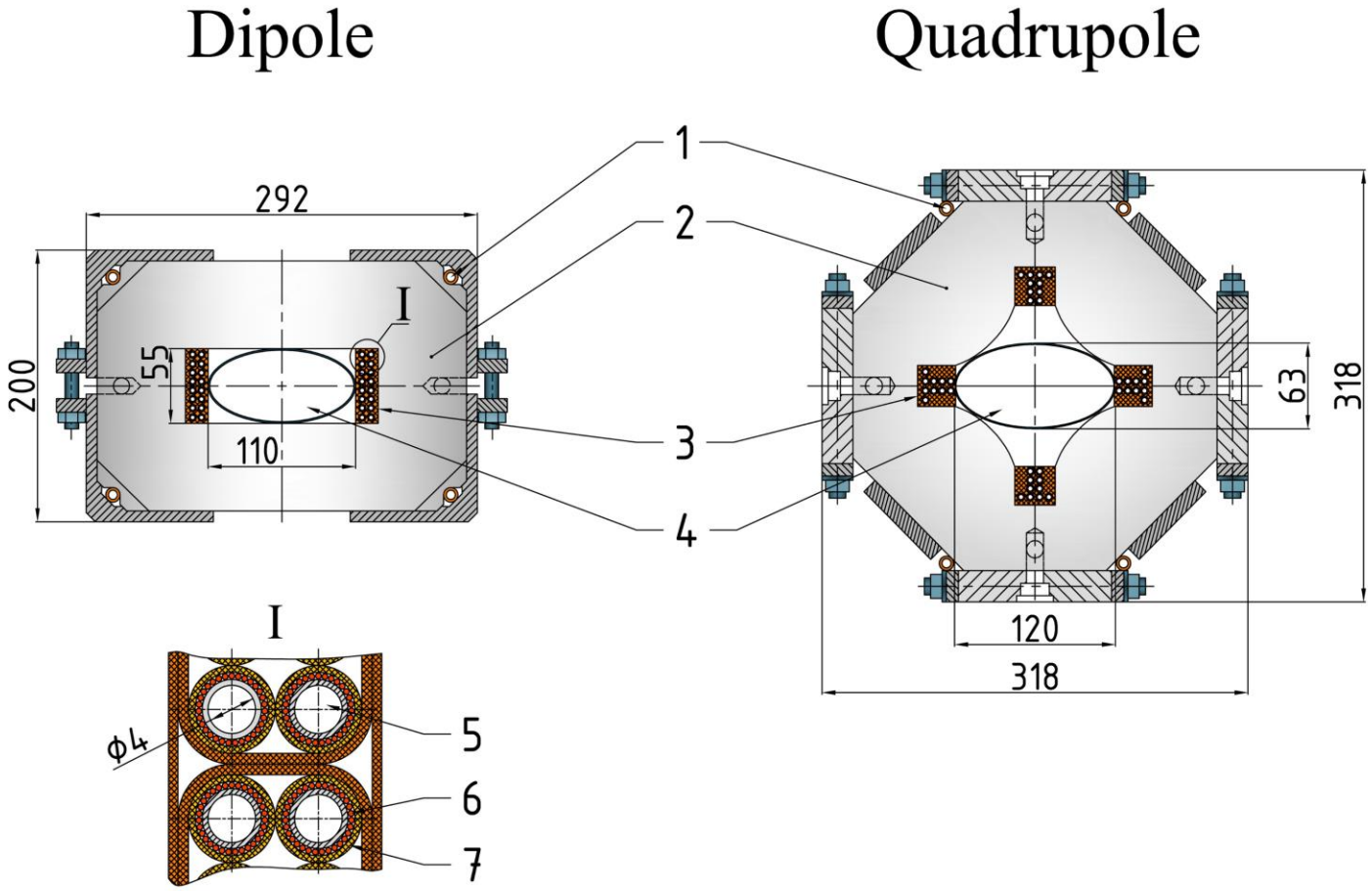
JINR – IMP seminar, Dubna, September 26

FRDM prototype

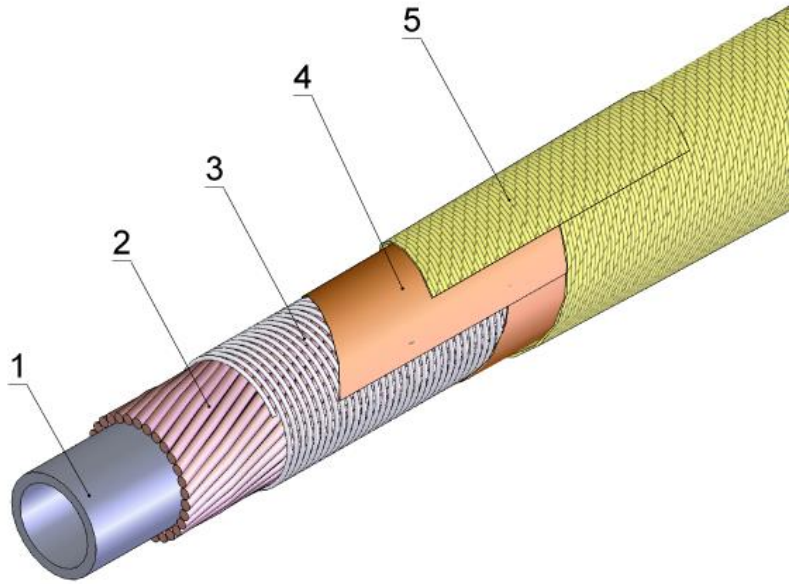
According to the demand for high beam intensities of the future high intensity heavy ion synchrotron accelerators including HIAF, fast ramping superconducting dipole magnets (FRDM) with a ramp rate of up to 10 T/s are required. A FRDM prototype was designed and fabricated based on Nuclotron type magnet, which is the world leader in field ramp rate of superconducting accelerator magnets.

Nuclotron magnets



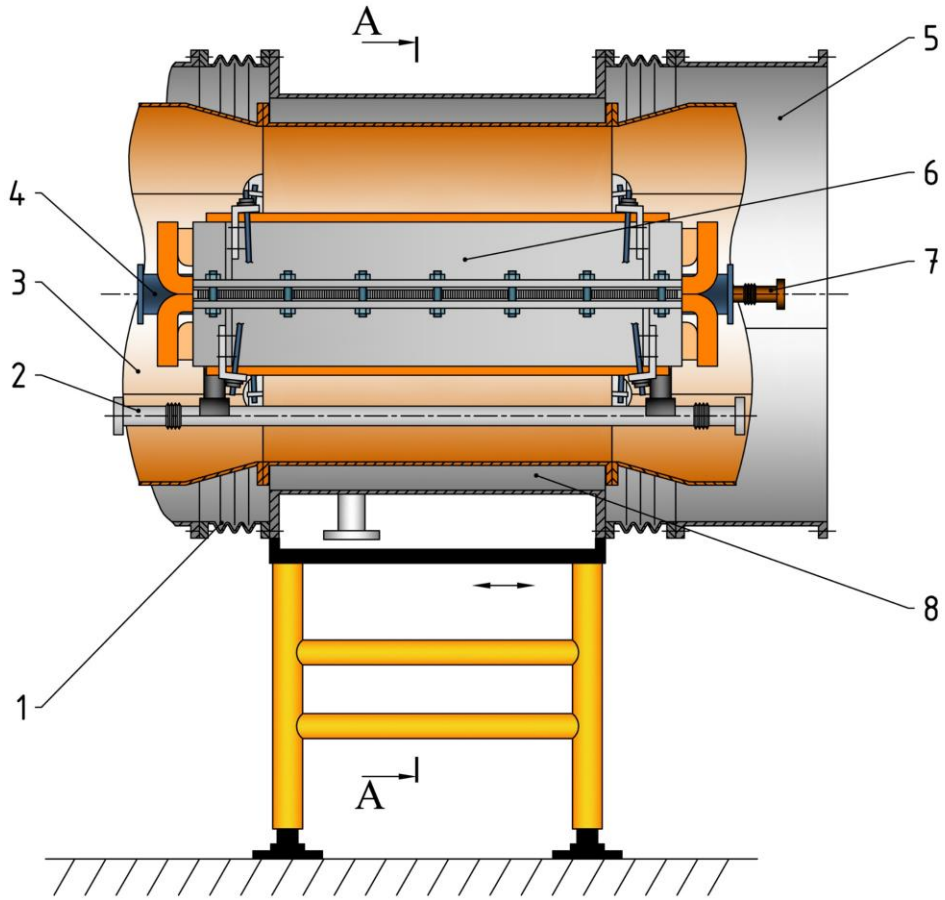
1 – tube for cooling the iron yoke; 2 – iron yoke; SC winding; 4 – beam pipe; 5 – cooling tube; 6 – SC wire; 7 – electrical insulation.

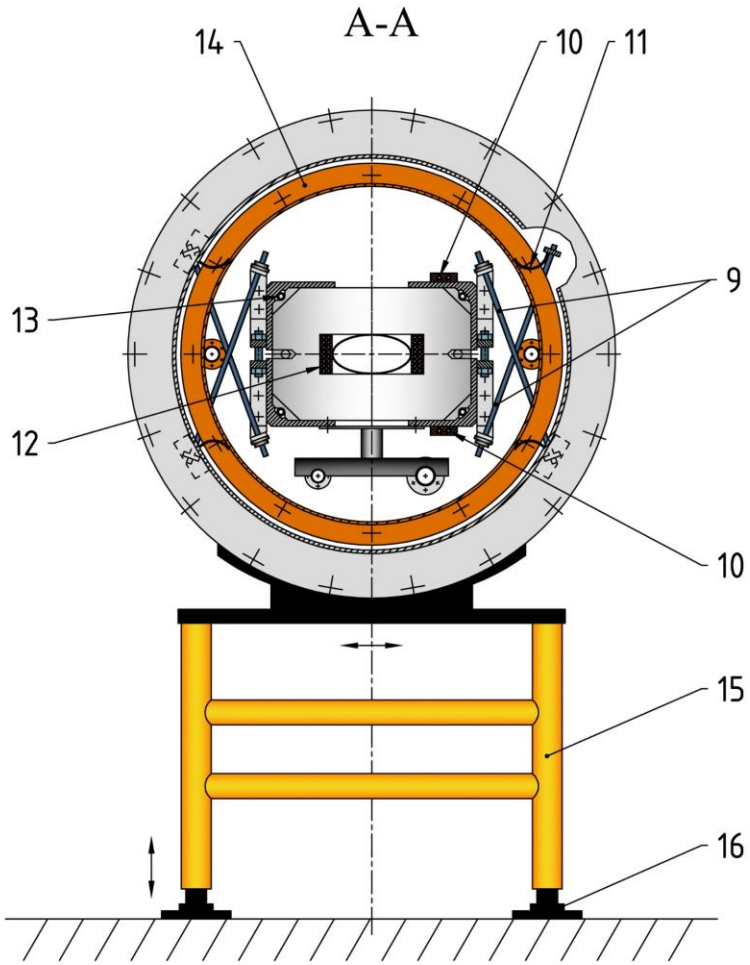
Nuclotron cable



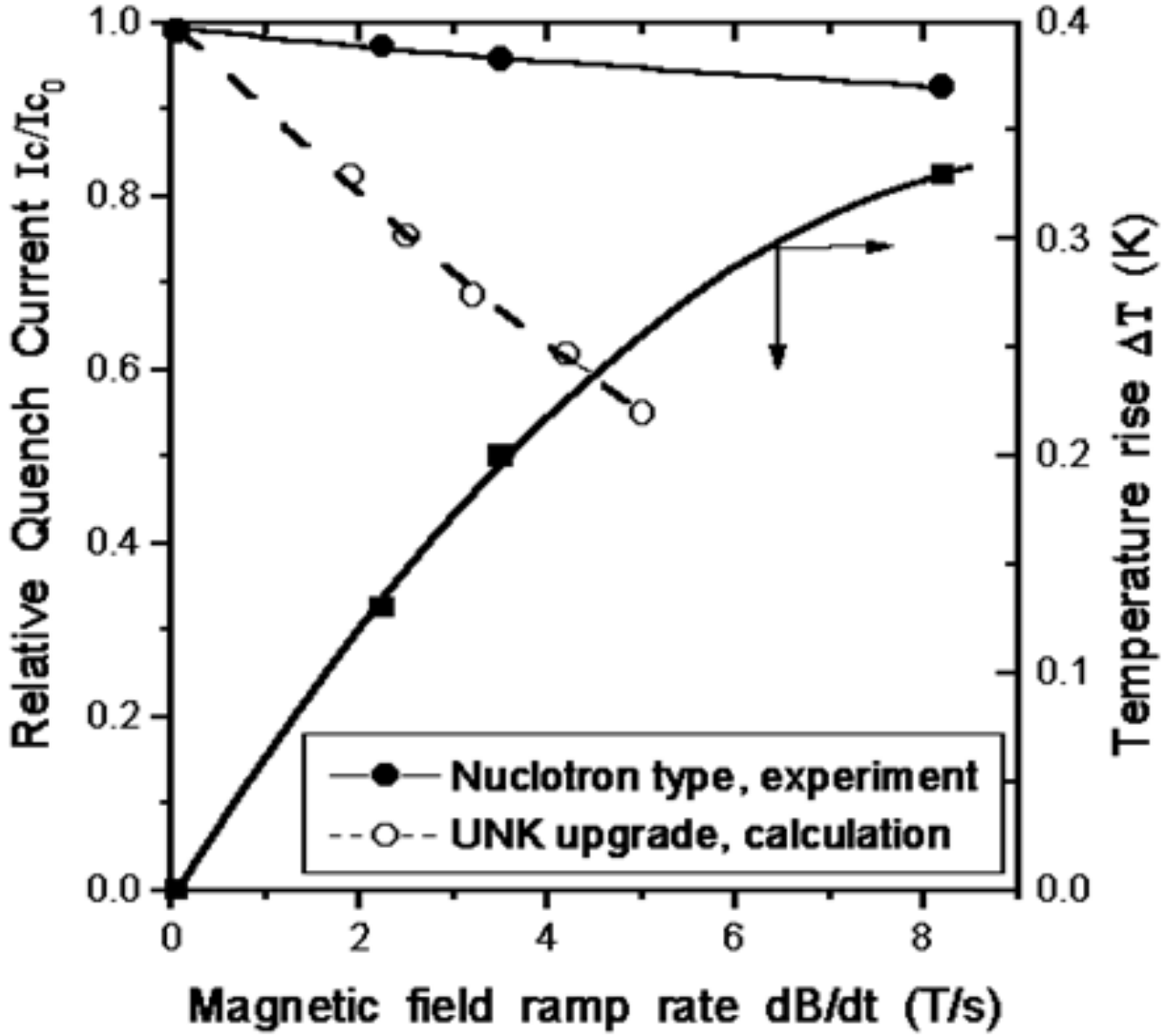
1 - Cu-Ni tube
2 - SC wire
3 - Bandage wire
4 - Kapton tape
5 - Glass fiber tape

Schematic view of the Nuclotron magnet in a cryostat





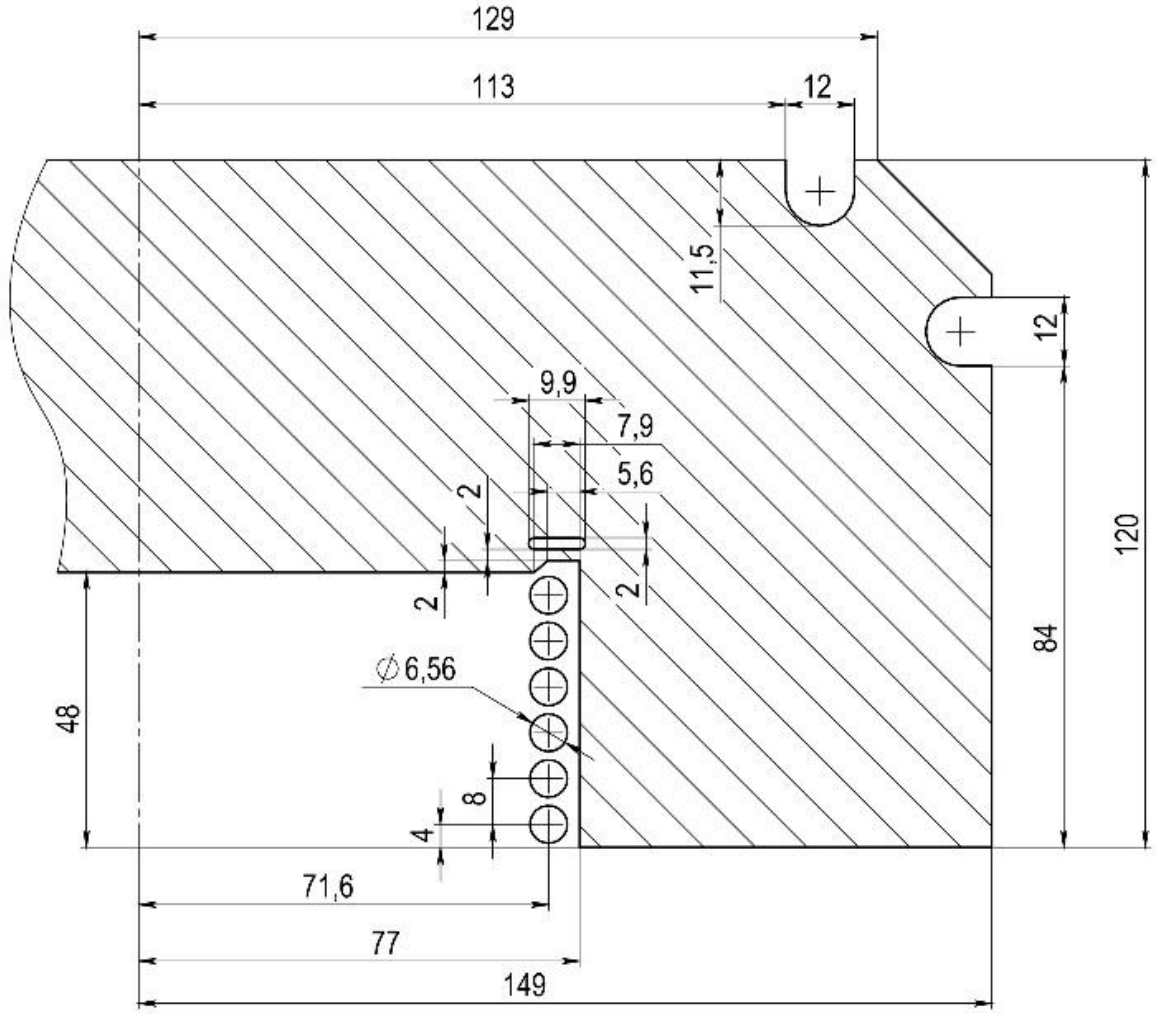
Cooling conditions of the Nuclotron magnet



FRDM Specifications

Parameter	Unit	Value
L_{eff}	m	1.0
B_{max}	T	1.6~1.8
SC strand diameter	mm	0.78
Nominal filament diameter	μm	6
Cu/SC ratio		1.38
Twist pitch	mm	7
Critical current I_c @ 2T, 4.2K	A	900
Cu-Ni cooling tube diameter	mm	5 x 0.5
Number of strands in the cable		22
Cable outer diameter	mm	7.5
Beam pipe aperture, h/v	mm	130/85
Iron yoke aperture, h/v	mm	154/96
Number of coil turns		12
Operating current	A	11750
Ramp rate	T/s	at least 6

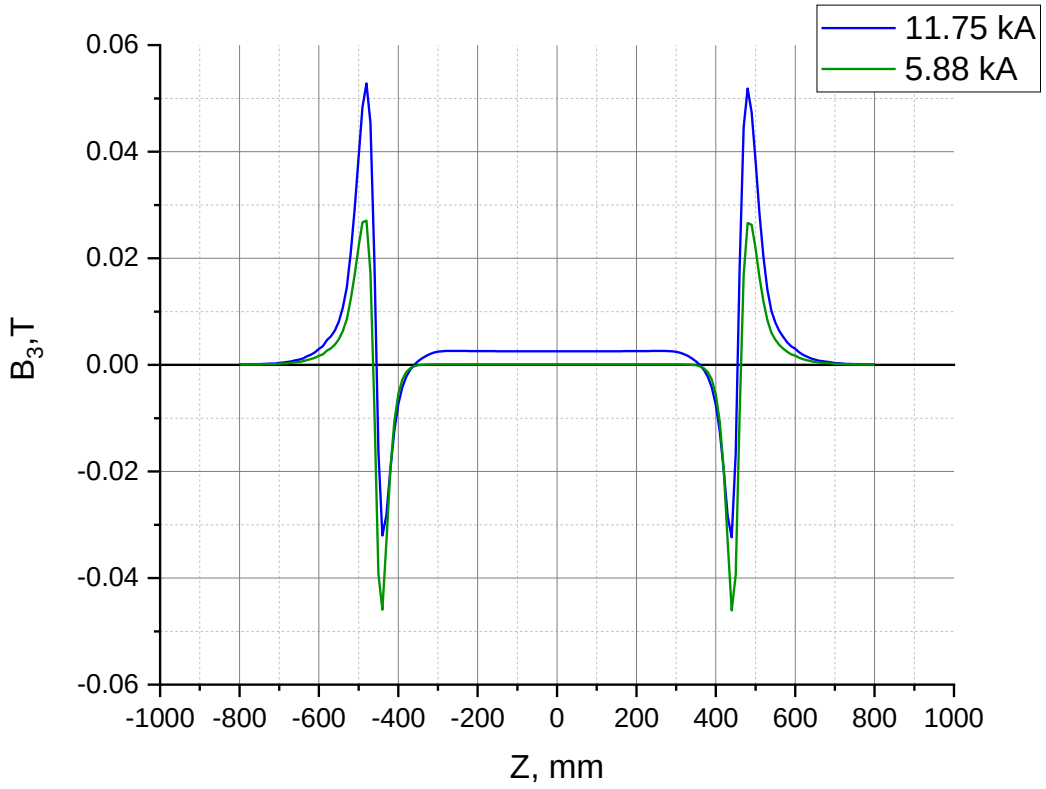
Cross section view of the FRDM



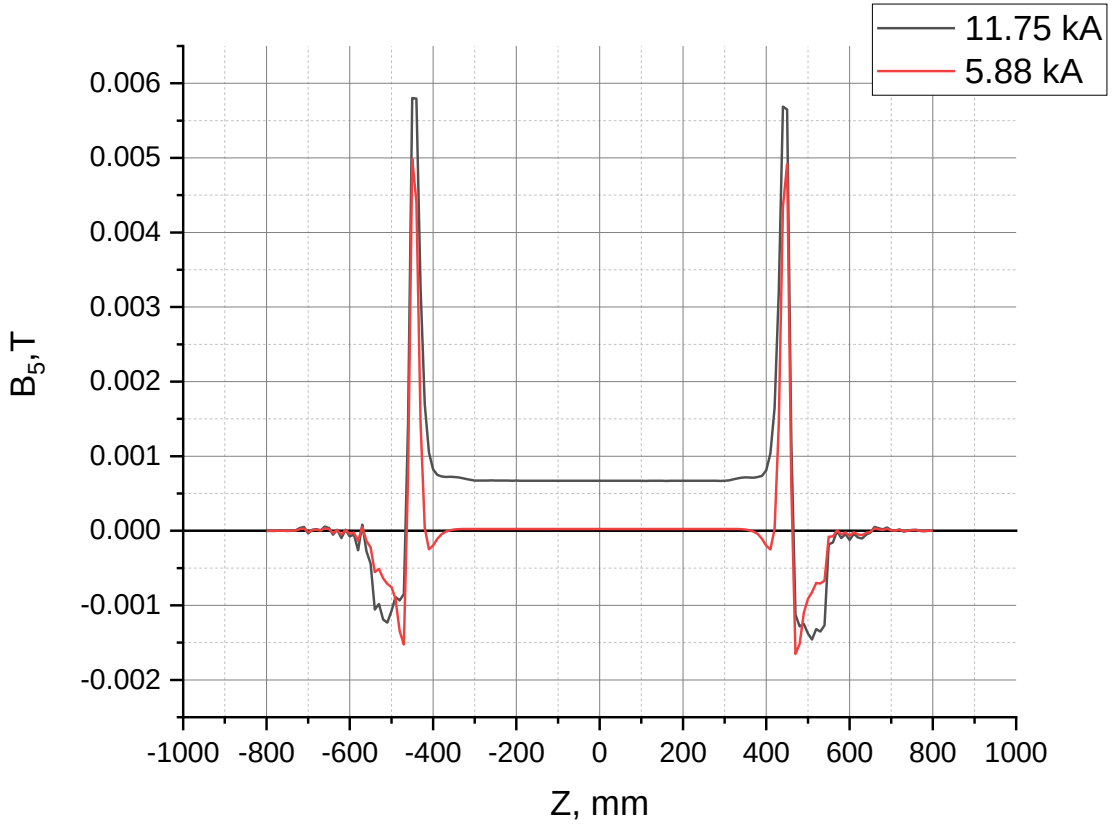
The magnetic field simulation results

	I=11754 A		I=11754 A	
Harmonic number	$\int B_n dl$, T·mm	$10^4 \frac{\int B_n dl}{\int B_1 dl}$	$\int B_n dl$, T·mm	$10^4 \frac{\int B_n dl}{\int B_1 dl}$
1	1714.51	10^4	918.67	10^4
2	-0.20	-1.2	-0.11	-1.1
3	5.64	32.9	-0.08	-0.9
4	-0.08	-0.5	-0.05	-0.6
5	0.73	4.2	0.08	0.8
6	-0.01	-0.11	-0.01	-0.1
7	-0.0	-0.0	-0.02	-0.2
8	0.0	0.0	0.0	0.0
9	-0.01	-0.1	-0.0	-0.0
10	-0.0	-0.0	-0.0	-0.0

The magnetic field simulation results

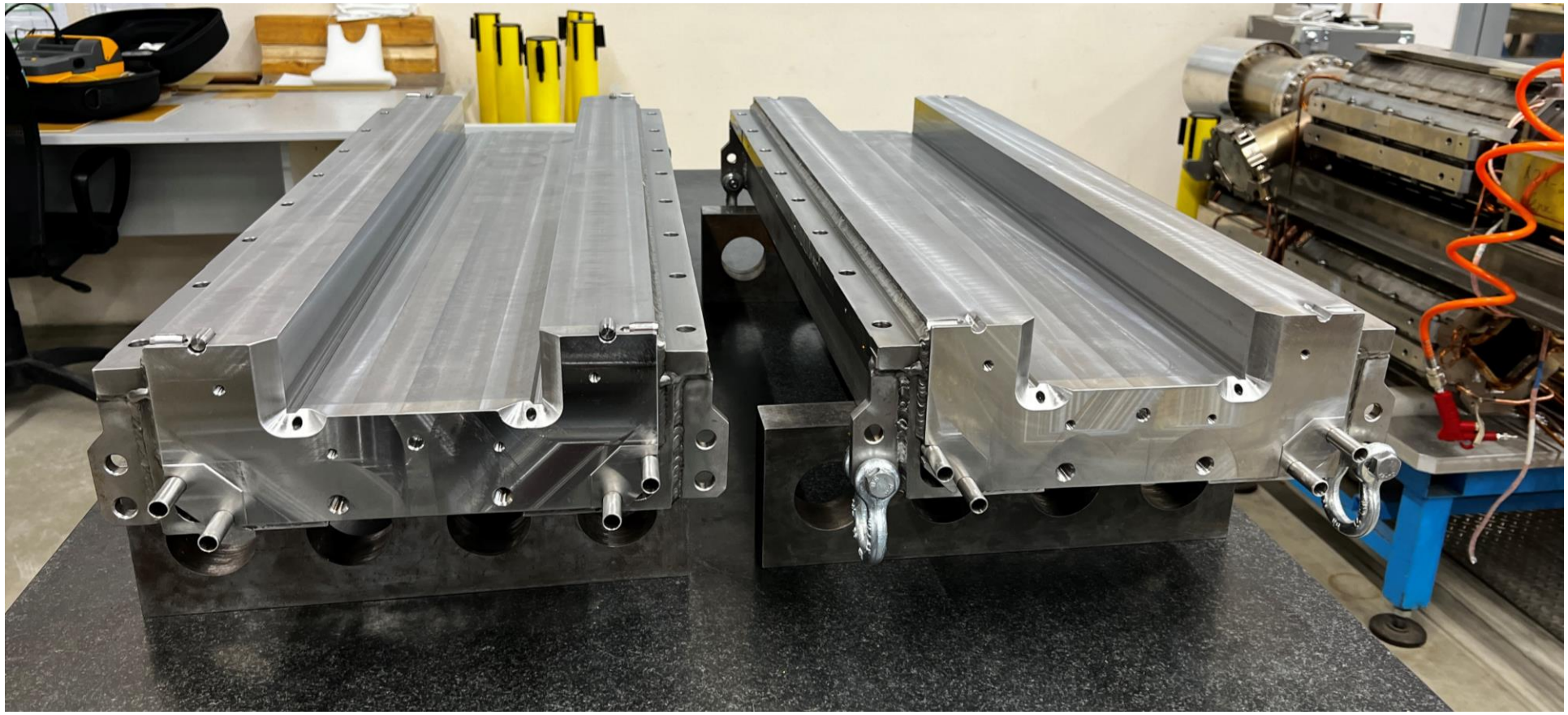


Distribution of the B_3 harmonic along the Z coordinate



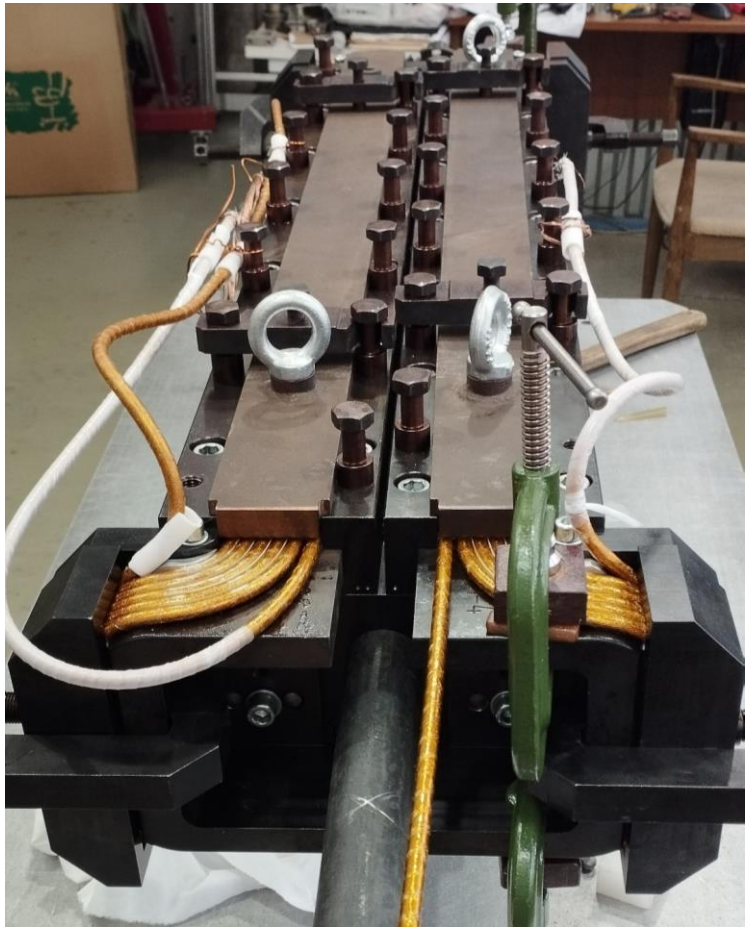
Distribution of the B_5 harmonic along the Z coordinate

Half yokes of the magnet



The FRDM yoke was manufactured at a plant in Minsk.

FRDM coil production

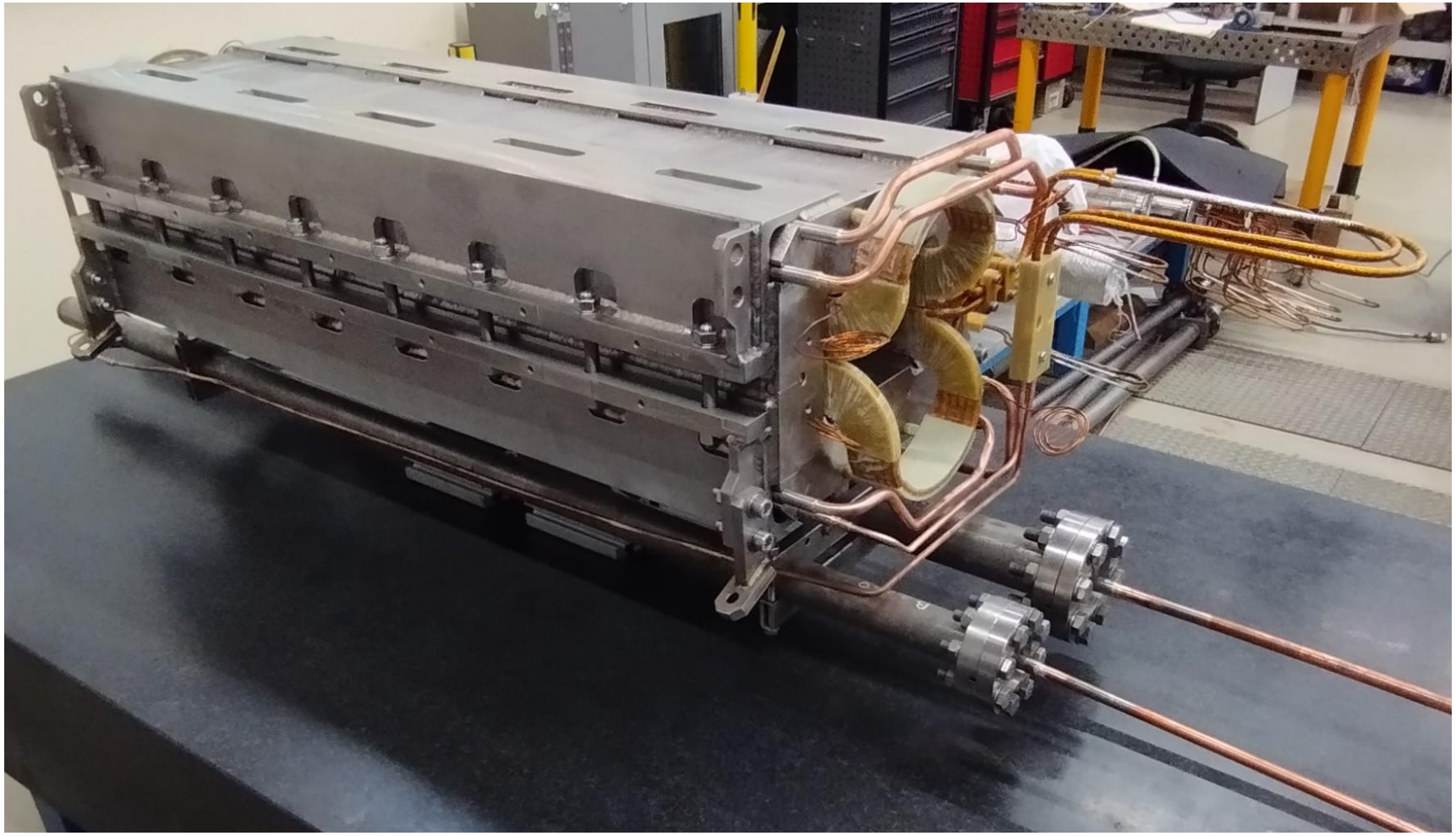


The FRDM winding was manufactured at JINR.

FRDM coil production

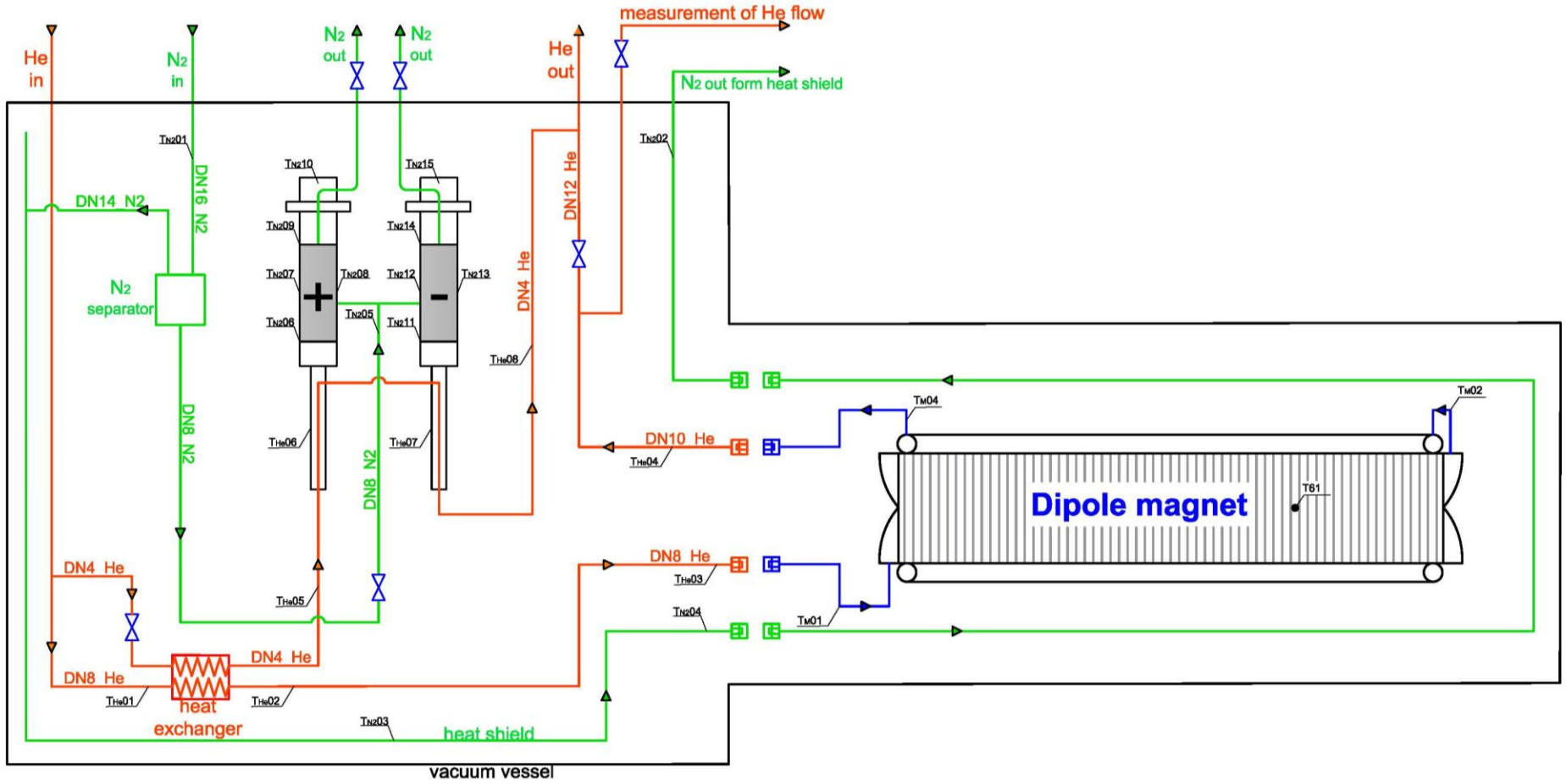
FRDM coil production

FRDM prototype



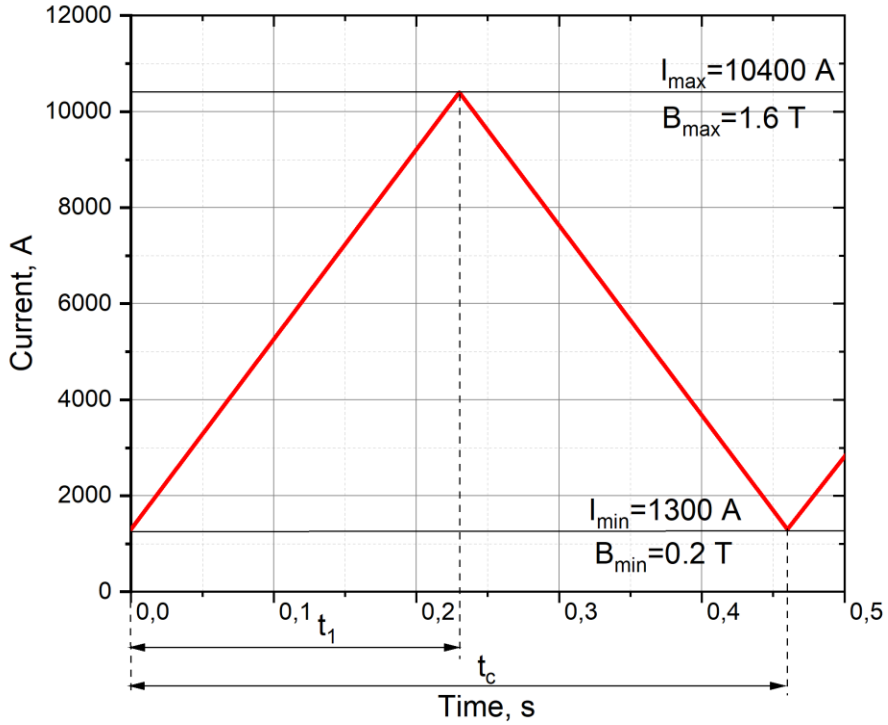
Magnet after installing the winding in the yoke.

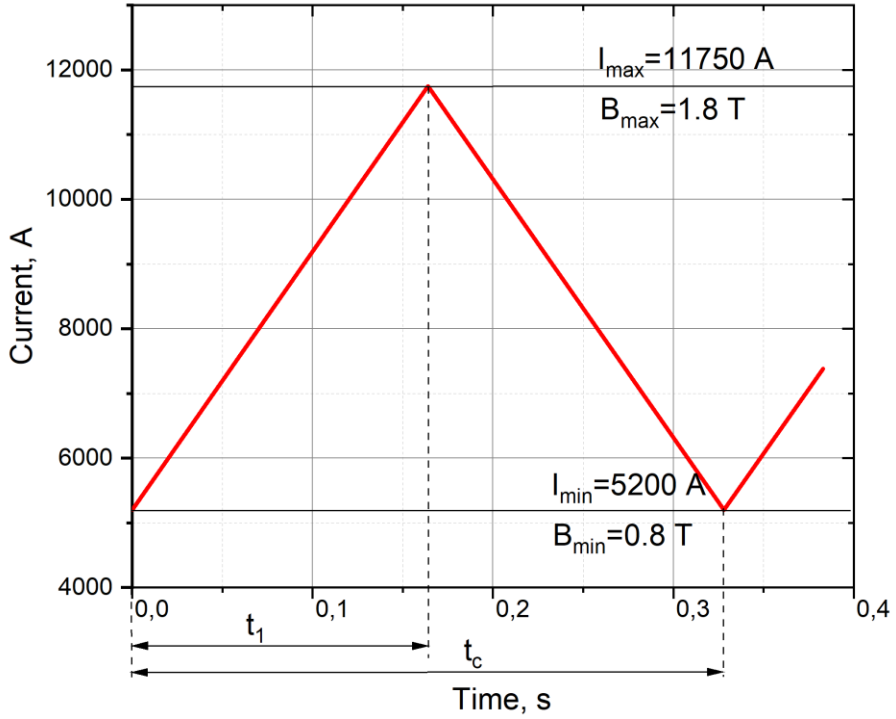
Preliminary results of magnet testing



Test bench layout

Preliminary results of magnet testing





The magnet was cooled to operating temperature, magnetic measurements were taken and the magnet's performance was checked at high ramp rates: 6.1 T/s; 7 T/s and 8 T/s. Operation at higher ramp rates is limited by the capabilities of the test bench's power supplies. Dynamic heat generation at 6.1 T/s was about 70 W.

Thank you for your attention