Magnetic calculations of the SPD detector solenoid

VII SPD Collaboration Meeting

E. ANTOKHIN, T. DERBYSHEVA

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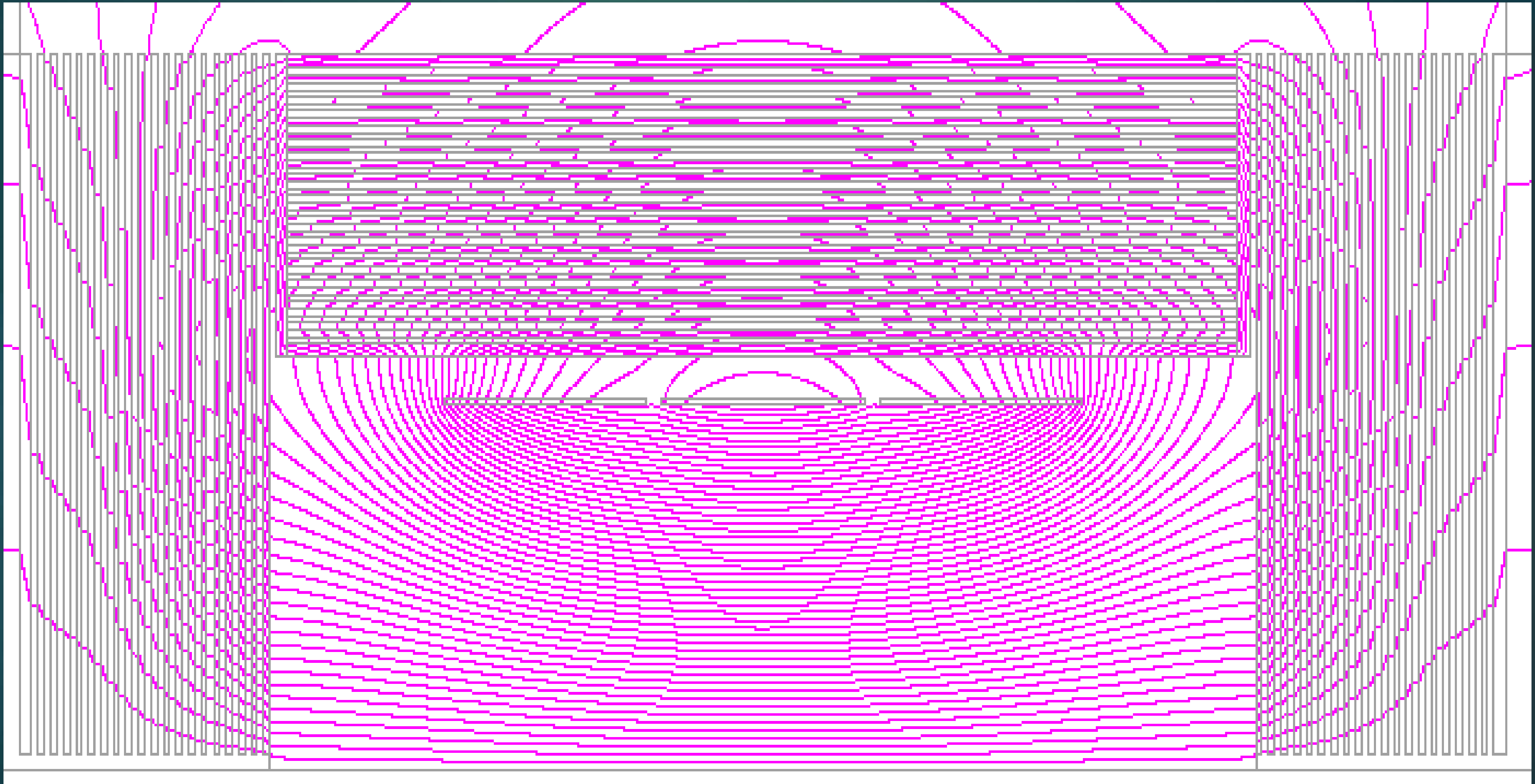
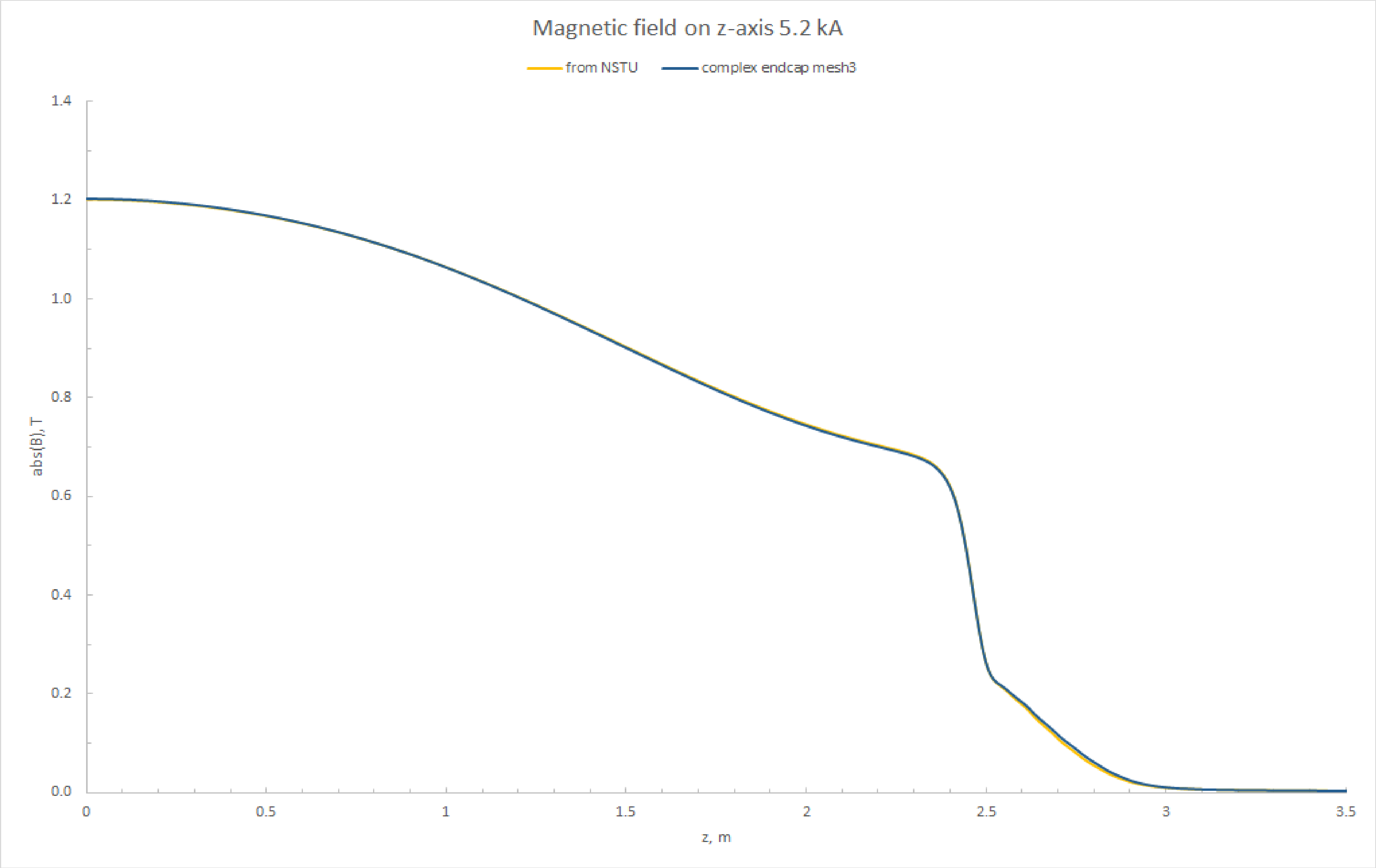
Basic conditions

- Software - TELMA
- Number of detector coils – 3
- 150 turns in the central coil and 300 turns in the side coils (+30 in latest version)
- Magnetic core material – Steel 3
- Current 5200 A

General view of a magnet with power lines



The longitudinal component of the field on the axis

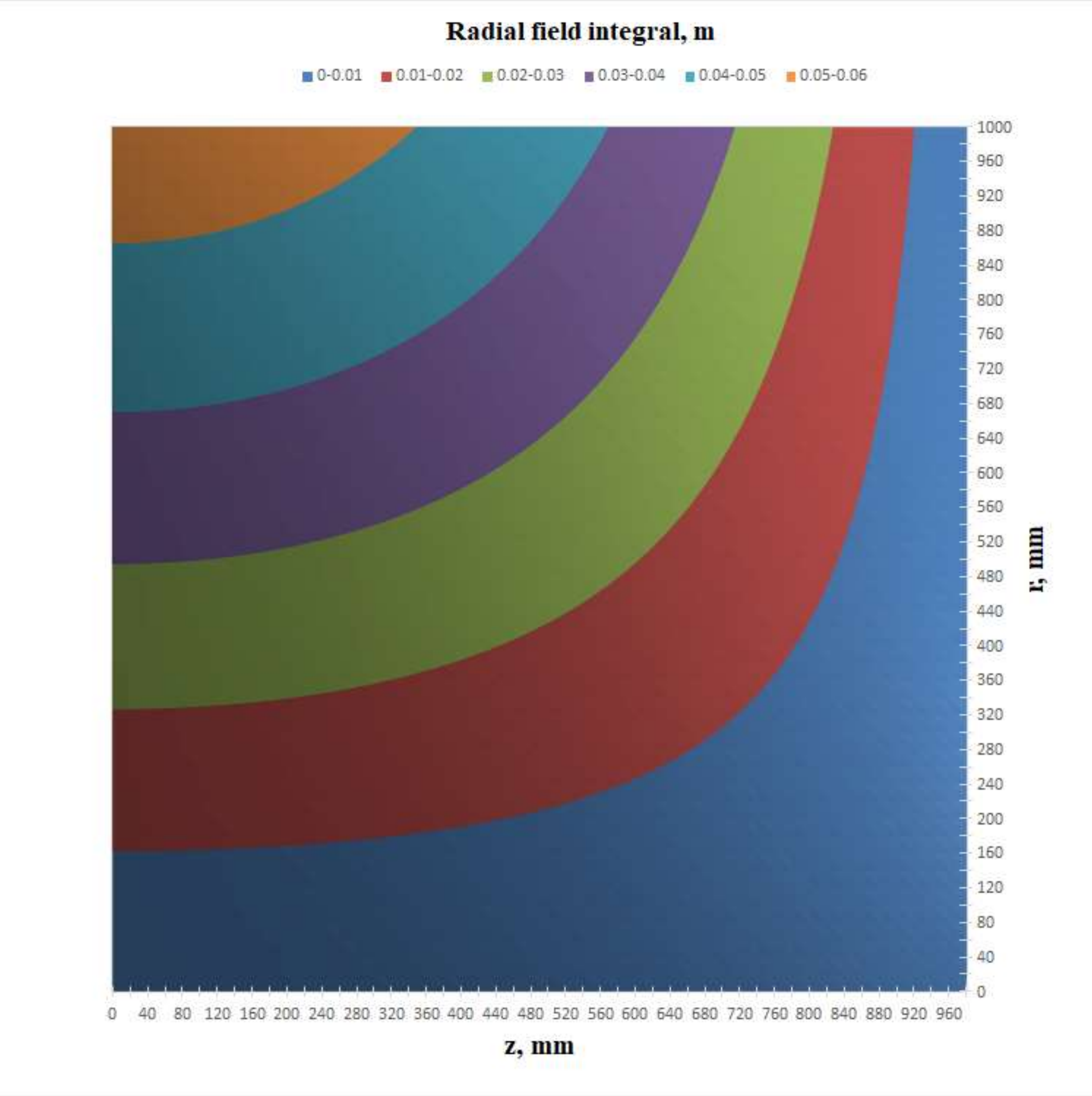


Radial integral

Coils turns
300-150-300

The integral is calculated using the formula from the current Z to Z=100 cm at different radii r

$$Int = \left\{ \left| \int_{z}^{100} \frac{Br(r,z)}{Bz(r,z)} dz \right| \right\}$$



Improving uniformity with correction coils

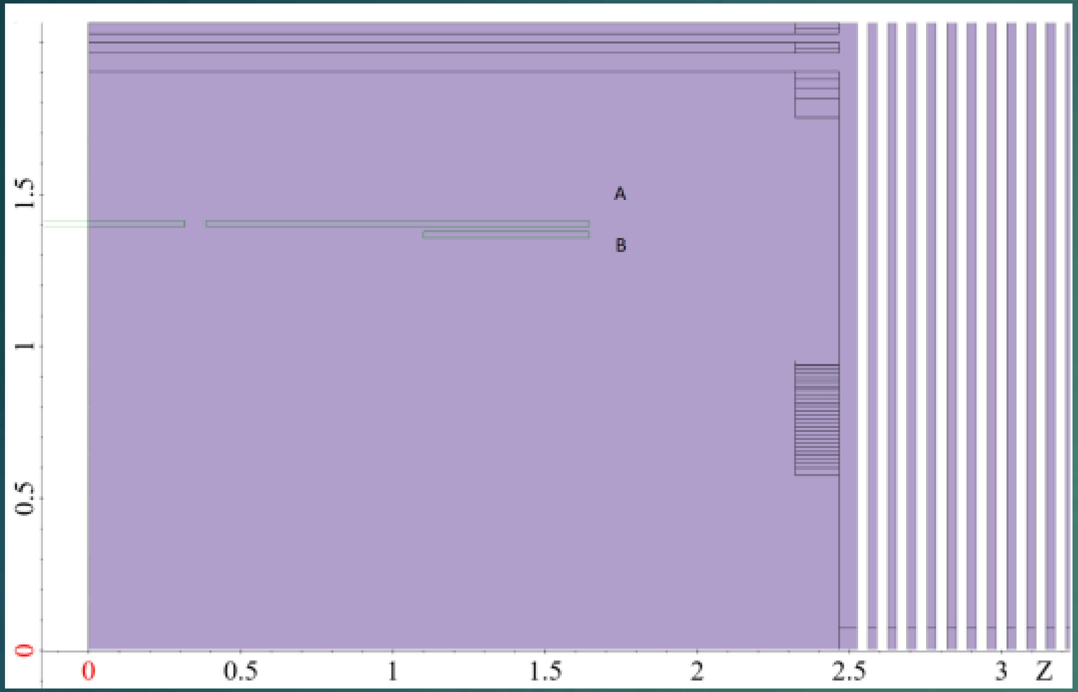
Aim of the work:

Find the configuration of additional correction coils on the edge of the main superconducting coil to improve the homogeneity of the longitudinal field component Bz on the axis and radius of 1 m of the solenoid. It is necessary to provide homogeneity of Bz not worse than 7-8% in the region Z=0-140 cm and R=0-100 cm.

Boundary conditions:

- Additional superconducting correction coils should have two layers.
- The correction coils cannot be located in the area between the main superconducting coils and the closing vertical magnetic core and go beyond the dimensions of the main coils.
- It is necessary to minimize the number of layers along the radius to simplify the design of the cryostat.
- The current in the main coils is equal to the current in the correction coils.

Improving uniformity with correction coils



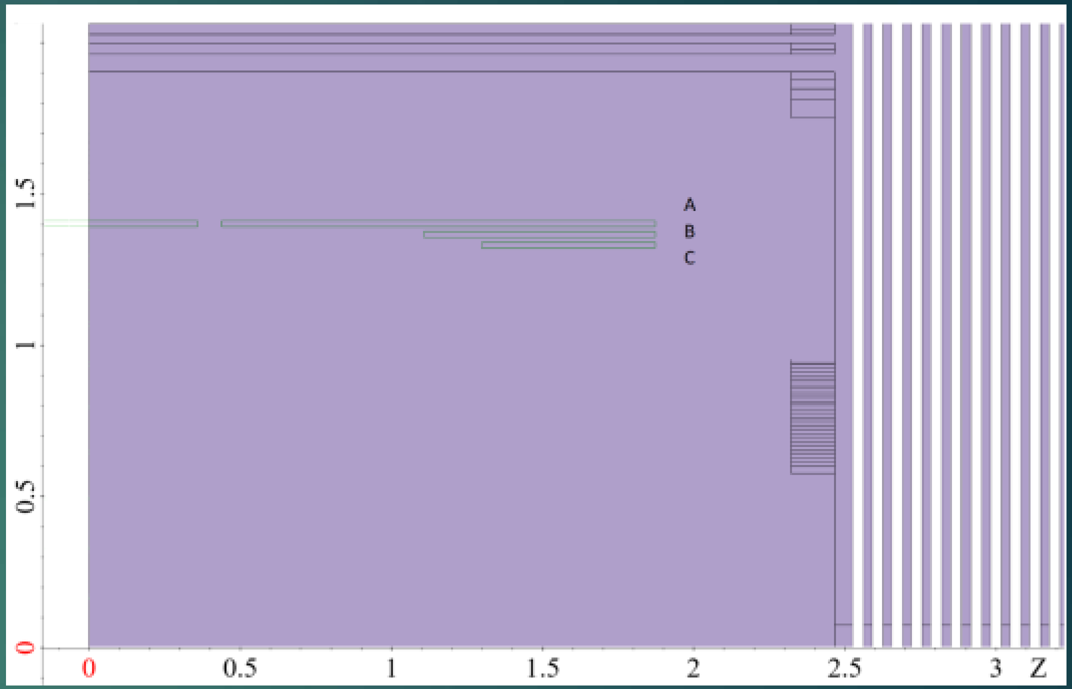


Table 1. Setting options for the case with two correction coils

	Coil B	Coil C
1	2 layers of 60 turns	2 layers of 60 turns
2	2 layers of 20 turns	2 layers of 50 turns
3	2 layers of 50 turns	2 layers of 50 turns
4	2 layers of 40 turns	2 layers of 40 turns

Improving uniformity with correction coils

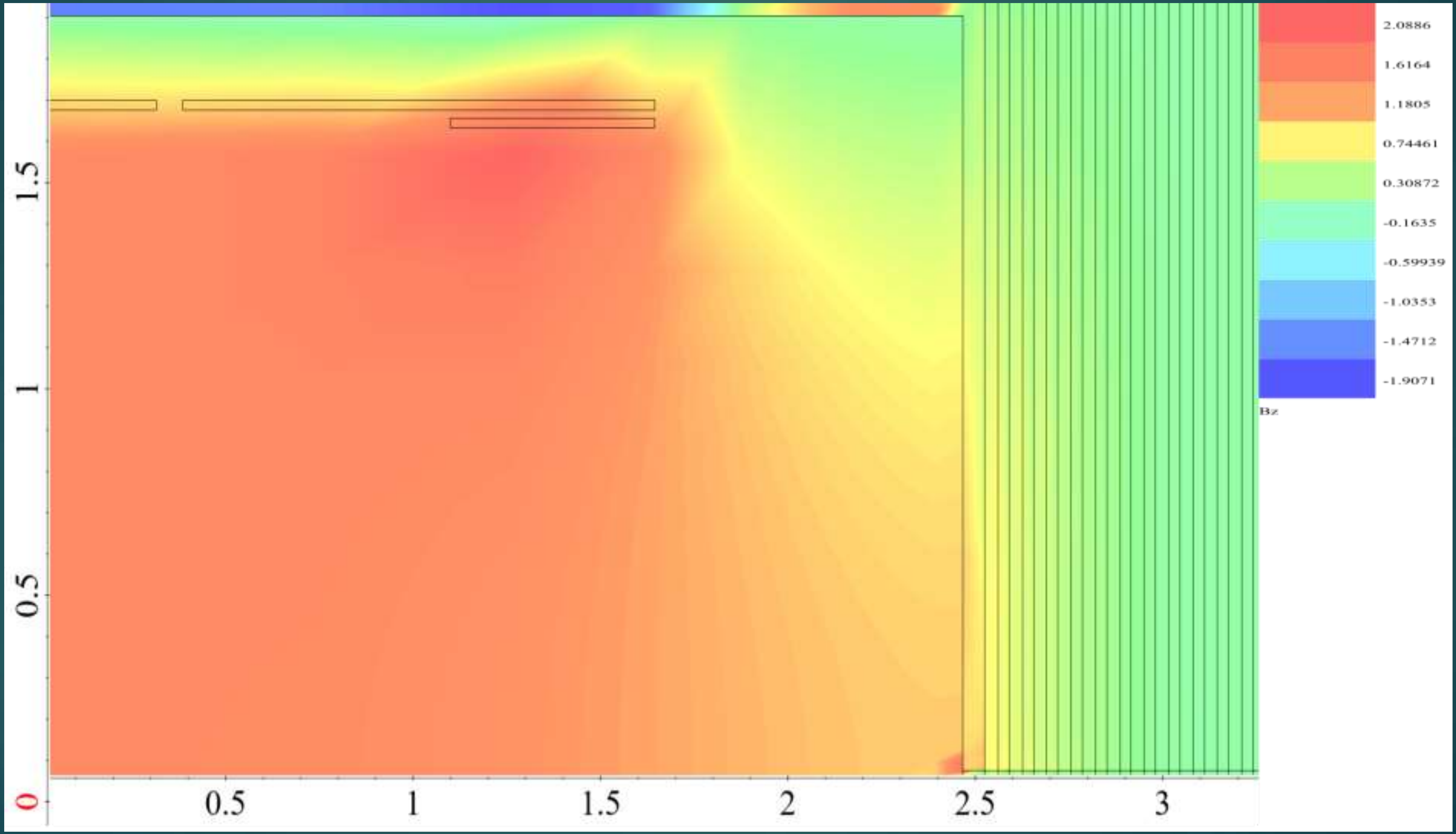


Figure 1. Distribution of Bz in the YZ section at x = 0 for a 65x2 coil

Improving uniformity with correction coils

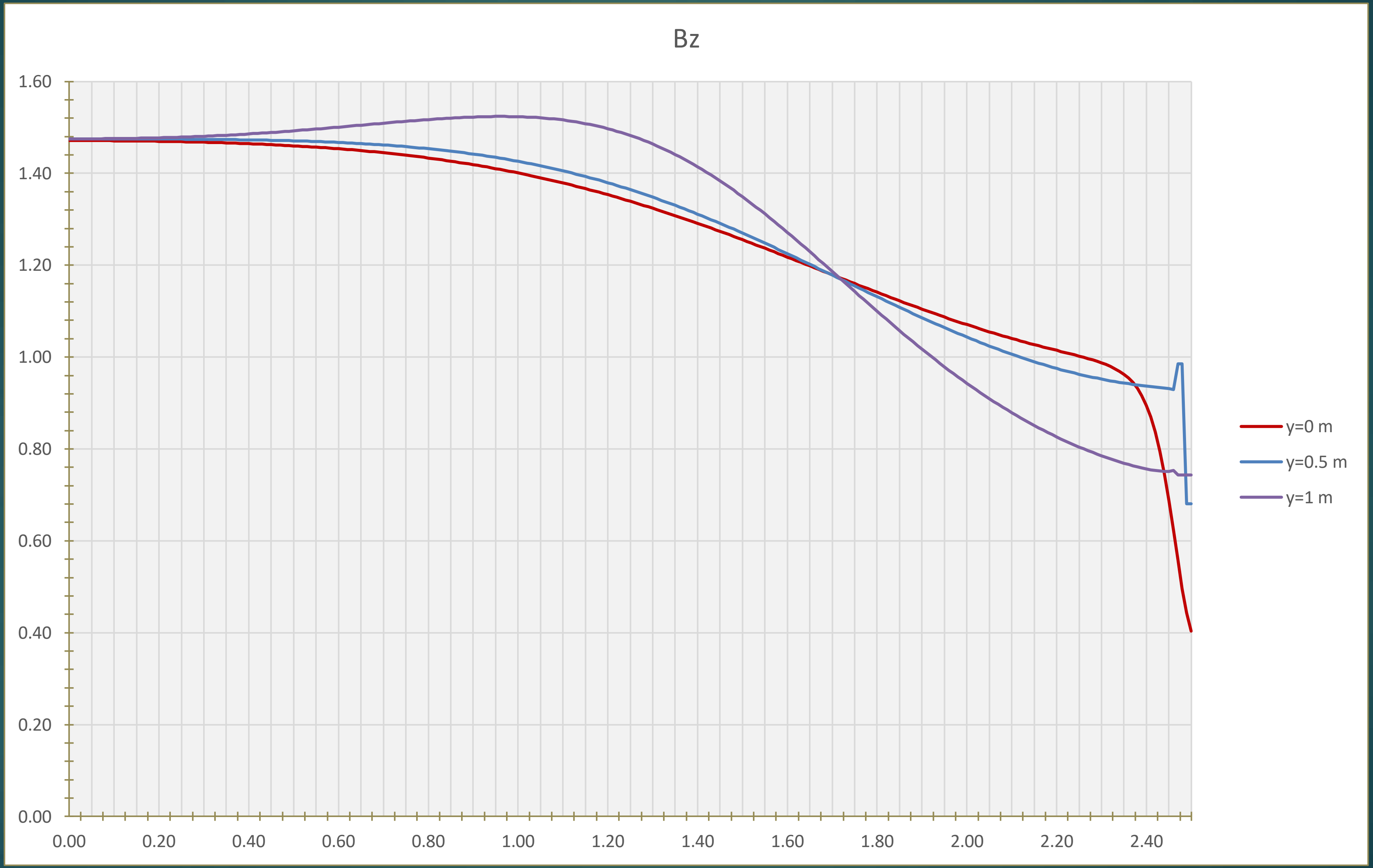


Figure 2: Graph of Bz(z) for a 65x2 coil

Improving uniformity with correction coils

Table 2. Maximum deviations of Bz(z) values from Bz(0) in %

	Y=0	Y=0.5	Y=1
65x2	12.2	10.8	3.74
60x2+60x2	5.67	2.87	13.7
20x2+50x2	9.7	8	3.94
50x2+50x2	6.63	4.22	10.1
40x2+40x2	8.25	6.31	5.77
80x2+30x2+30x2	3.87	3.38	15.8

Improve uniformity by turning off the center coil

Turning off the central coil to reduce its contribution to the central region of the solenoid is considered as a potential option for improving field uniformity without the use of correction coils.

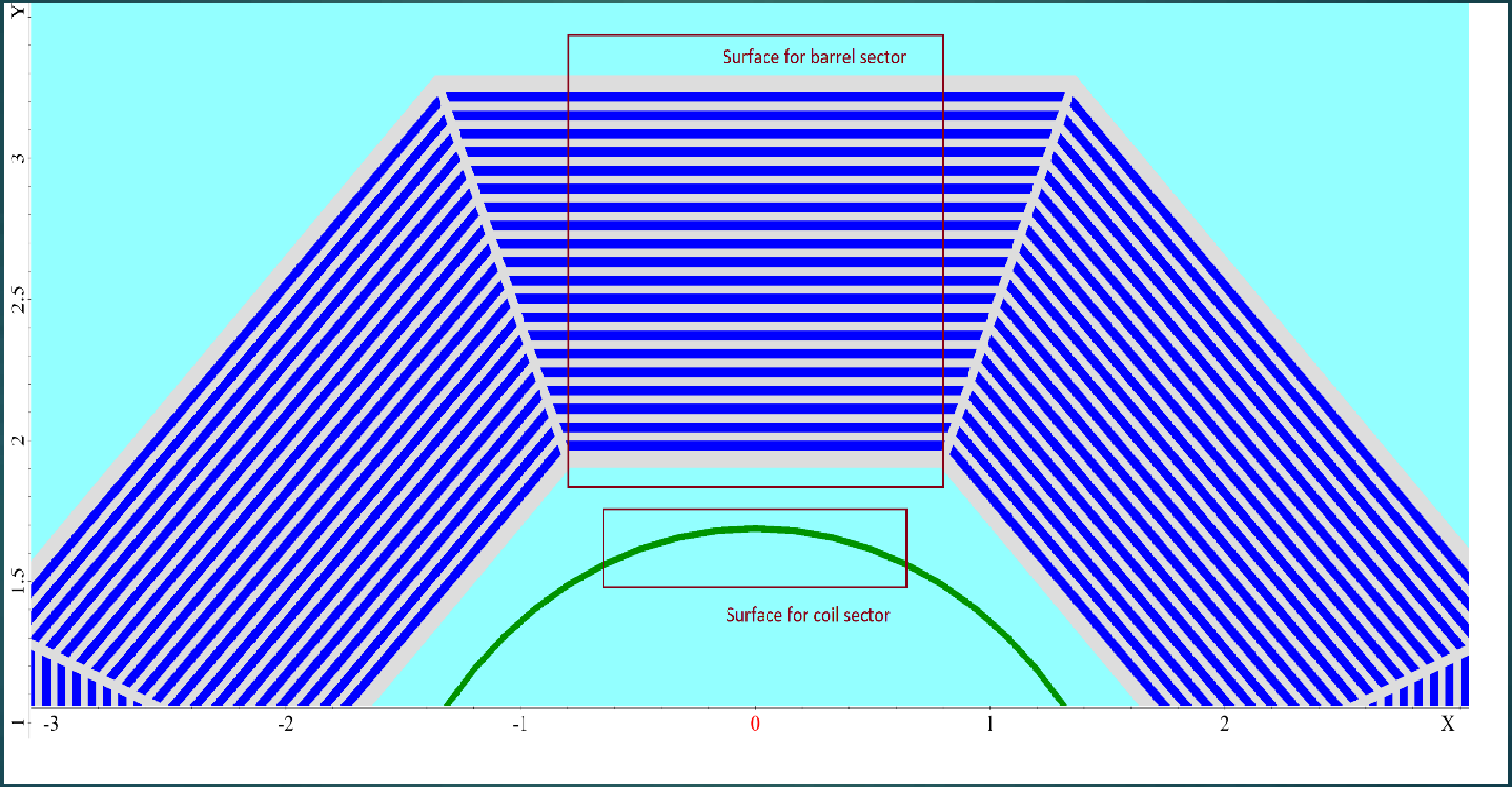
Despite the fact that the uniformity improves somewhat (up to 10%), its value is still insufficient.

A significant disadvantage of this method of uniformity improvement is the reduction of the solenoid field and, as a consequence, the need to increase the current from 5200 A to 6500 A. In this case, the critical current of the superconductor does not have the necessary reserve at this field.

Forces acting on doors and coils

Magnetic force, air gap 1 mm before endcaps, N							
	comp.	Barrel top sector (half along Z)	Barrel top sector	Endcaps (half)	Endcaps	Center coil (top sector 1/8)	Side coil (top sector 1/8)
F, kN	X (horiz.)	0	0	-12.4	0	0	0
	Y (vert.)	-143.8	-287.6	0	0	658.9	1185.9
	Z (long.)	67.5	0	-694.1	-1700	0	-594.1

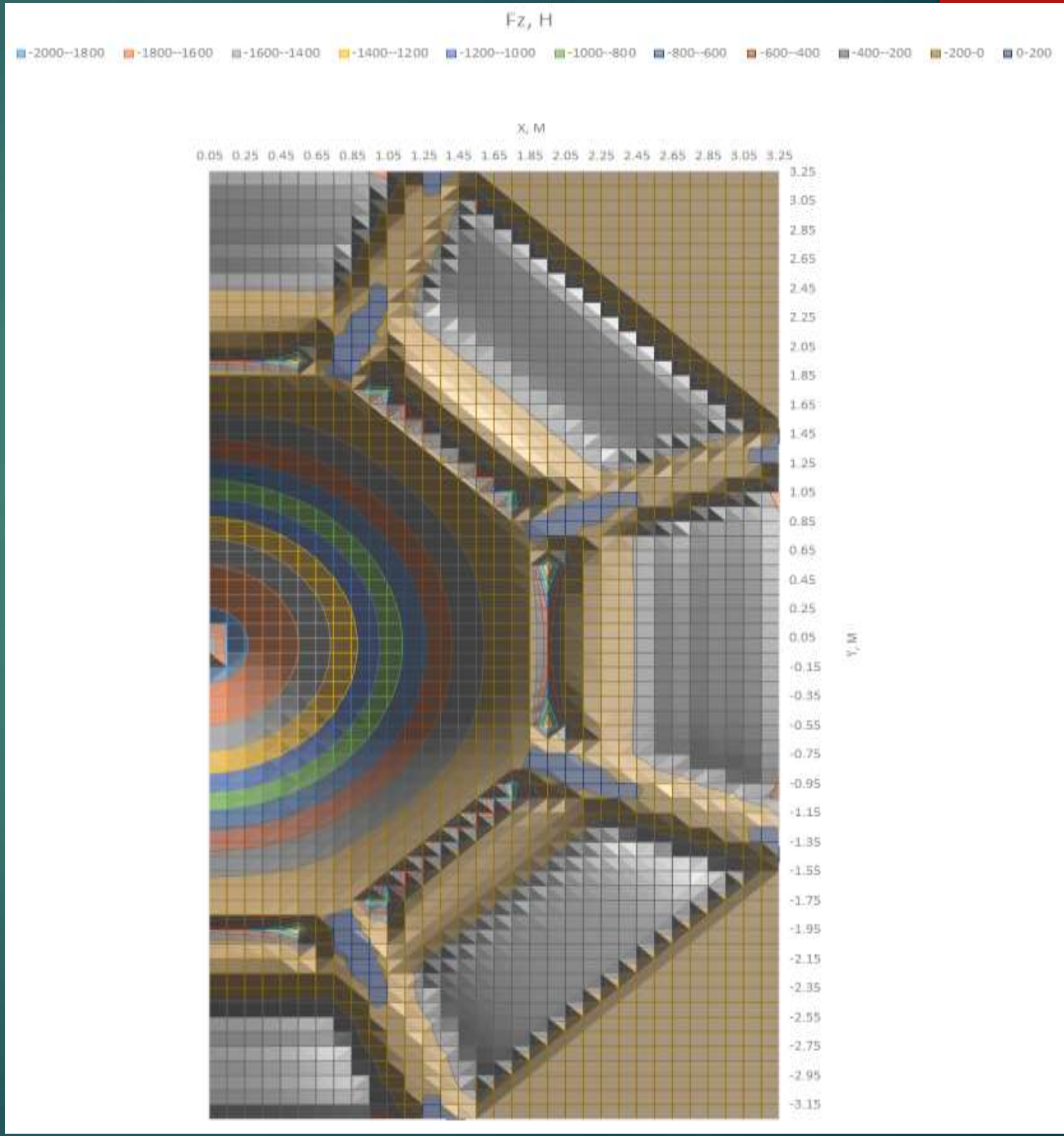
Forces acting on the barrel



Calculation of magnetic forces acting on the door. The grid step is 0.1 m.

The figure shows a map of the distribution of magnetic forces acting on one of the doors (end cap).

The force values were calculated for the centers of the corresponding 0.1 x 0.1 m grid elements and are shown in color ranges of 200 N each.



Calculation of magnetic forces distribution along endcup and barrel

The magnetic forces acting on endcap plates had been calculated.

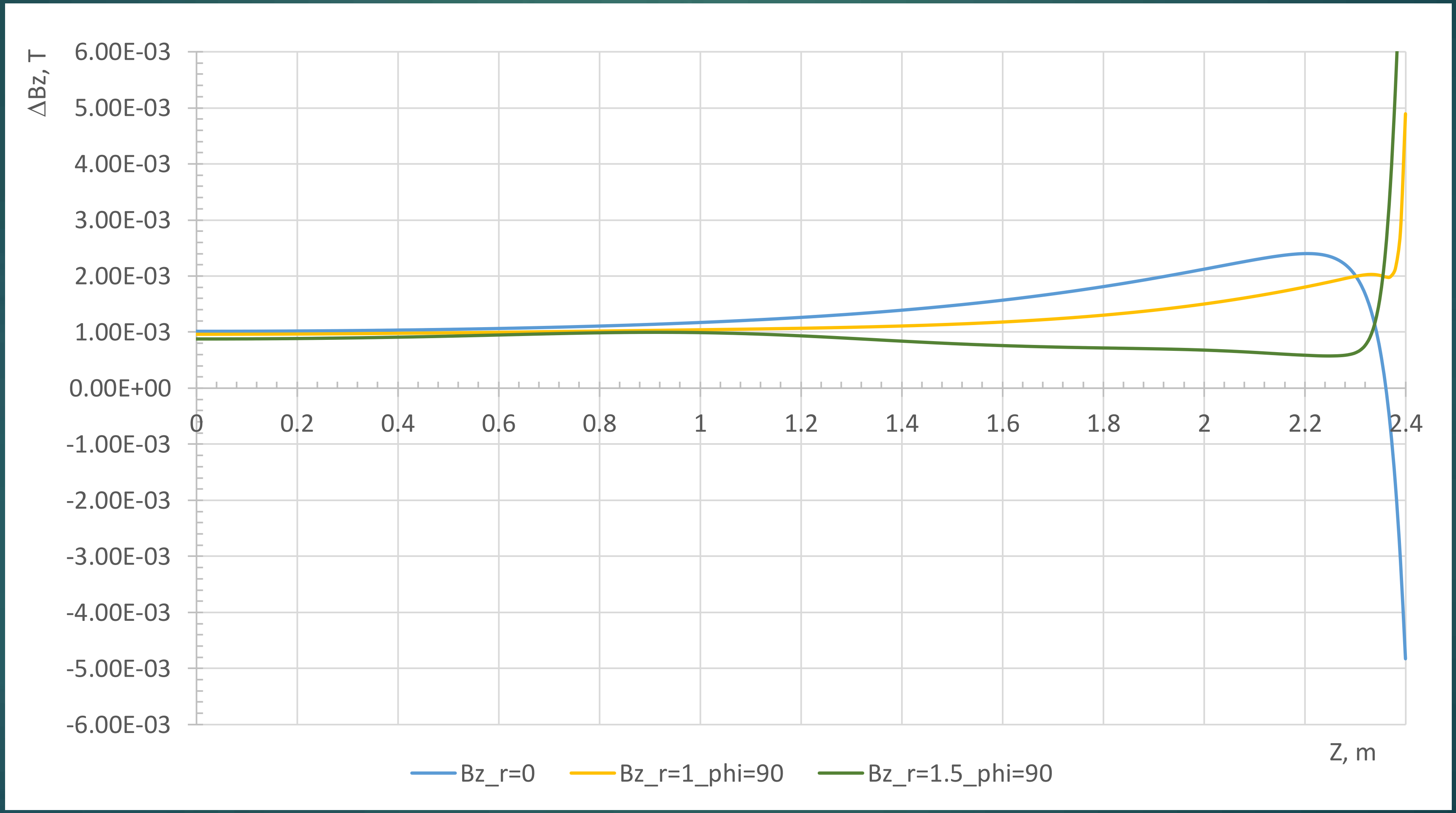
The magnetic forces acting on barrel plates are in process of calculation.

Calculation of magnetic forces acting on the coils during displacement

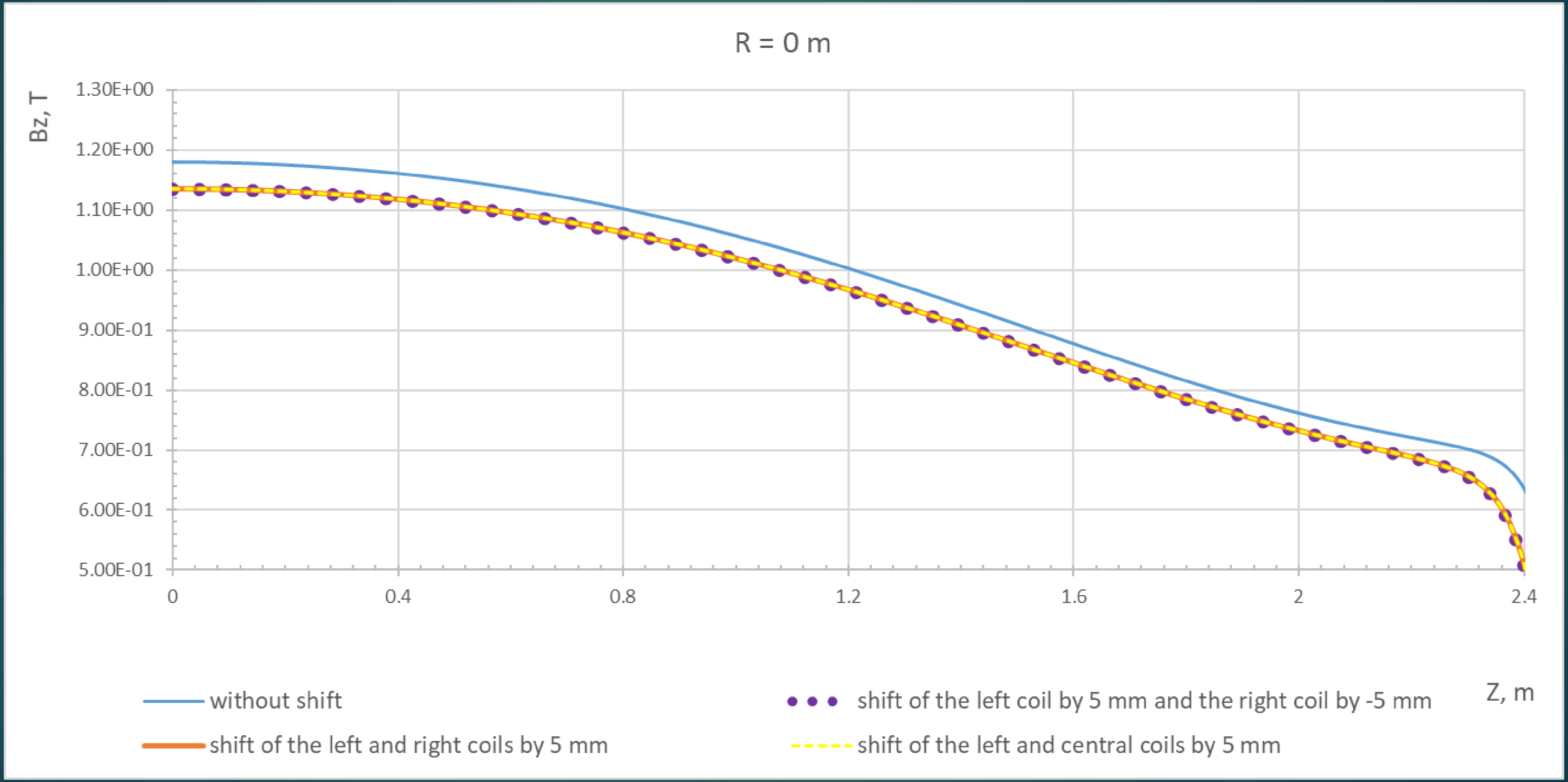
Magnetic force on coils				
	comp.	Left coil	Central coil	Right coil
F, kN	X (horiz.)	0	0	0
	Y (vert.)	0	0	0
	Z (long.)	4748.0	0	-4748.0
F, kN z +5 mm	X (horiz.)	0	0	0
	Y (vert.)	0	0	0
	Z (long.)	4521.4	-69.6	-4743.4
F, kN y +5 mm	X (horiz.)	0	0	0
	Y (vert.)	-2152.8	-1065.1	-2152.8
	Z (long.)	4752.8	-0.3	-4753.3

In the latest STEP model, the number of turns was increased by 30 (+12 in the side coils and +6 in the central one). Current reduced from 5200 A to 5000 A.

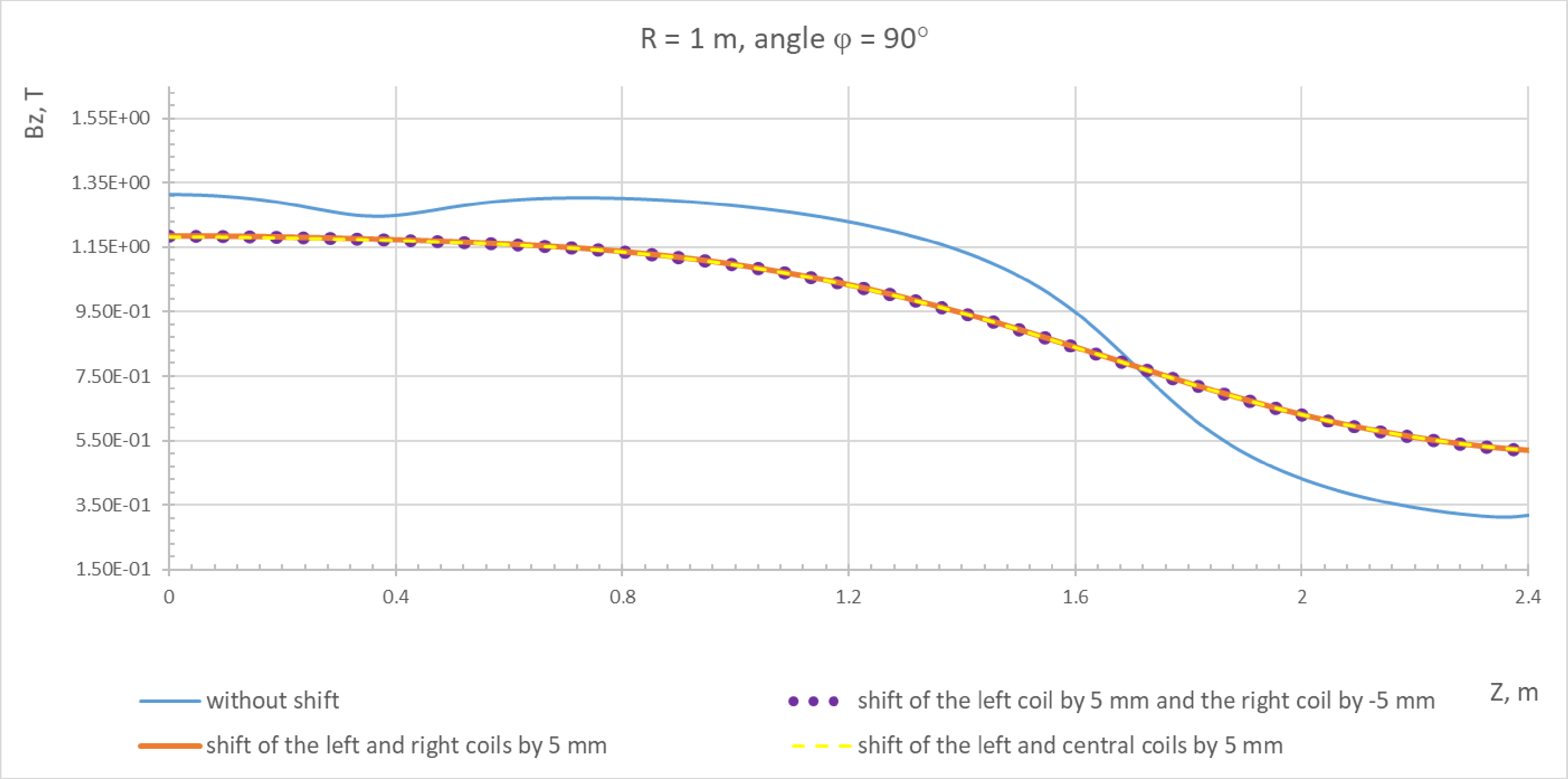
The difference between the distribution of the Bz component along Z with a 5 mm barrel-endcap gap and without a gap



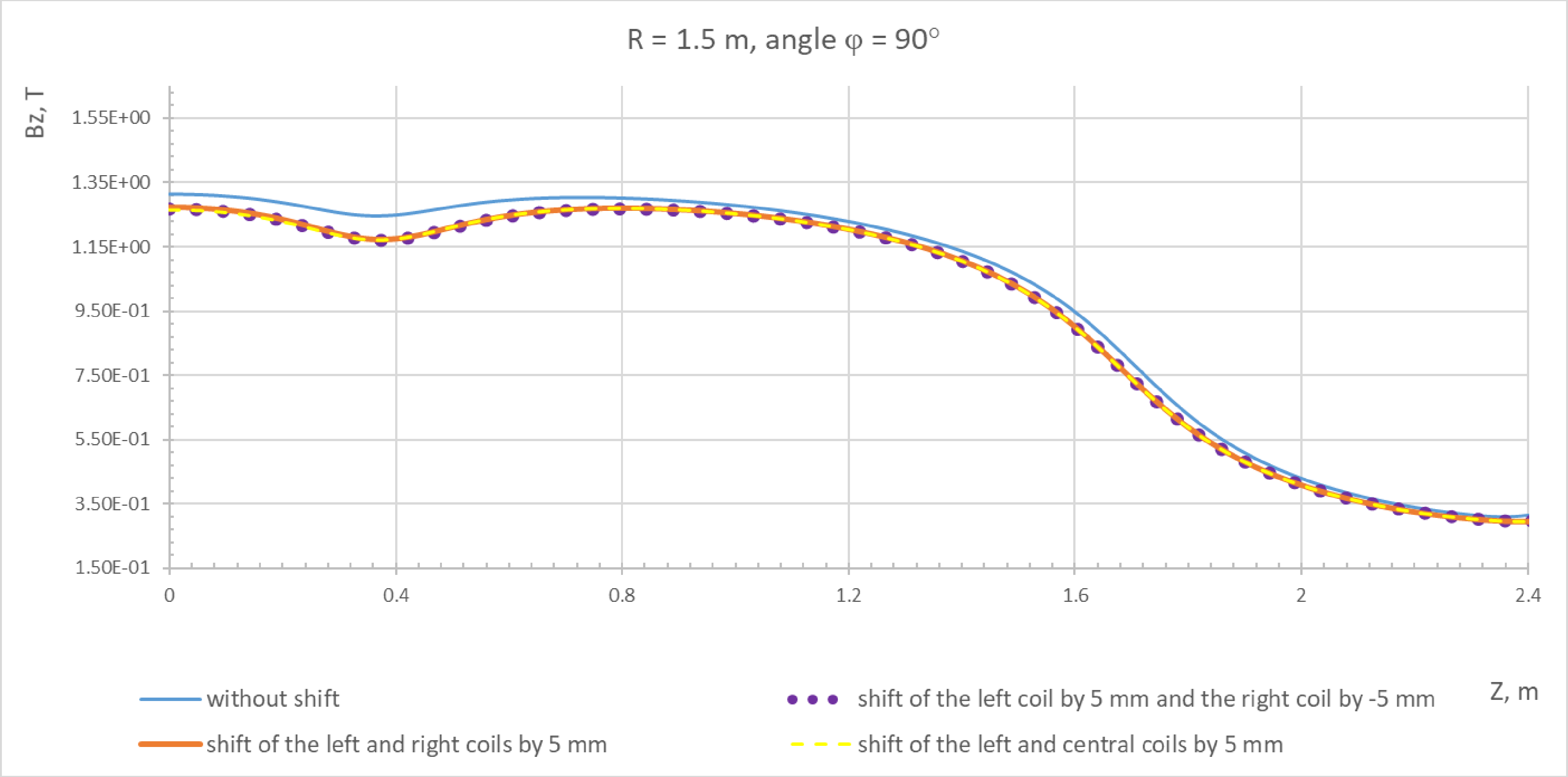
Comparison of the distribution of the Bz component along Z with a coil shift of 5 mm and without shift



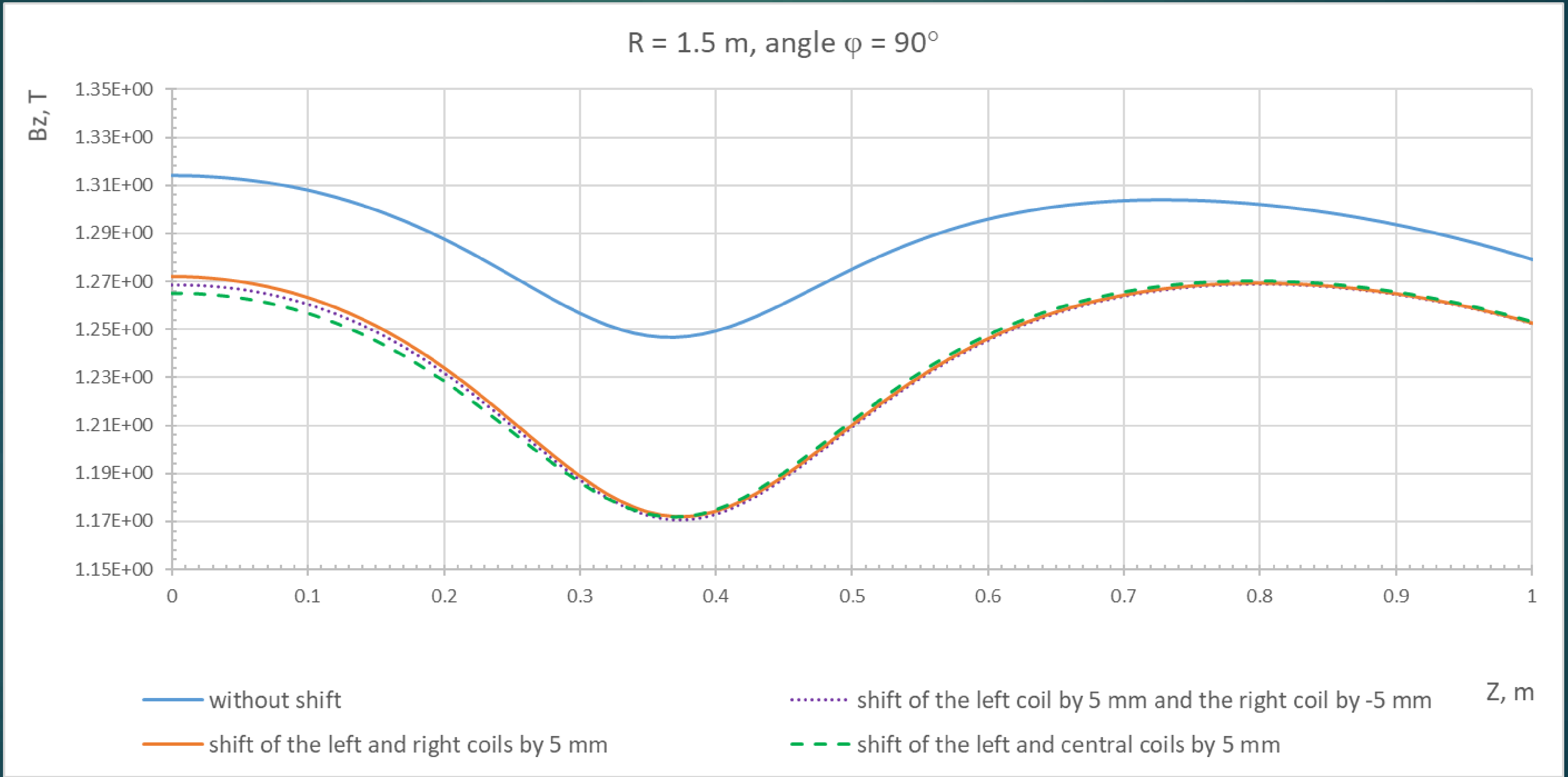
Comparison of the distribution of the Bz component along Z with a shift of the coils and without a shift



Comparison of the distribution of the Bz component along Z with a shift of the coils and without a shift



Comparison of the distribution of the Bz component along Z with a shift of the coils and without a shift



Thank you for attention