Magnet design, field calculations

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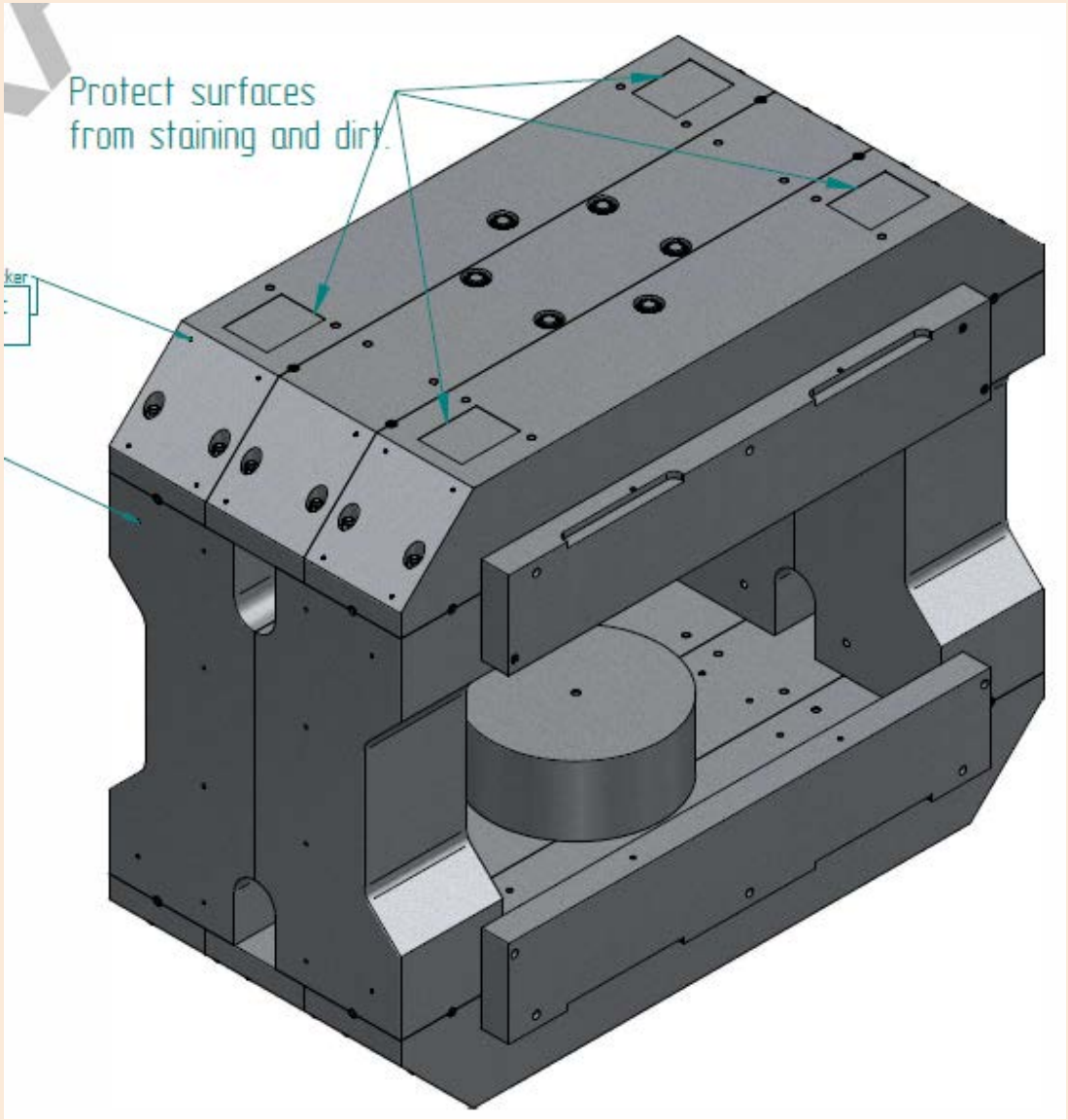
Outline

- Magnet design. Dimension.
- Calculation of the 3D model in Mermaid code
- ANSYS 3D calculations
- ANSYS 2D model for checking any inconsistencies in 3D calculations
- Discussion of the results

Total view of the magnet



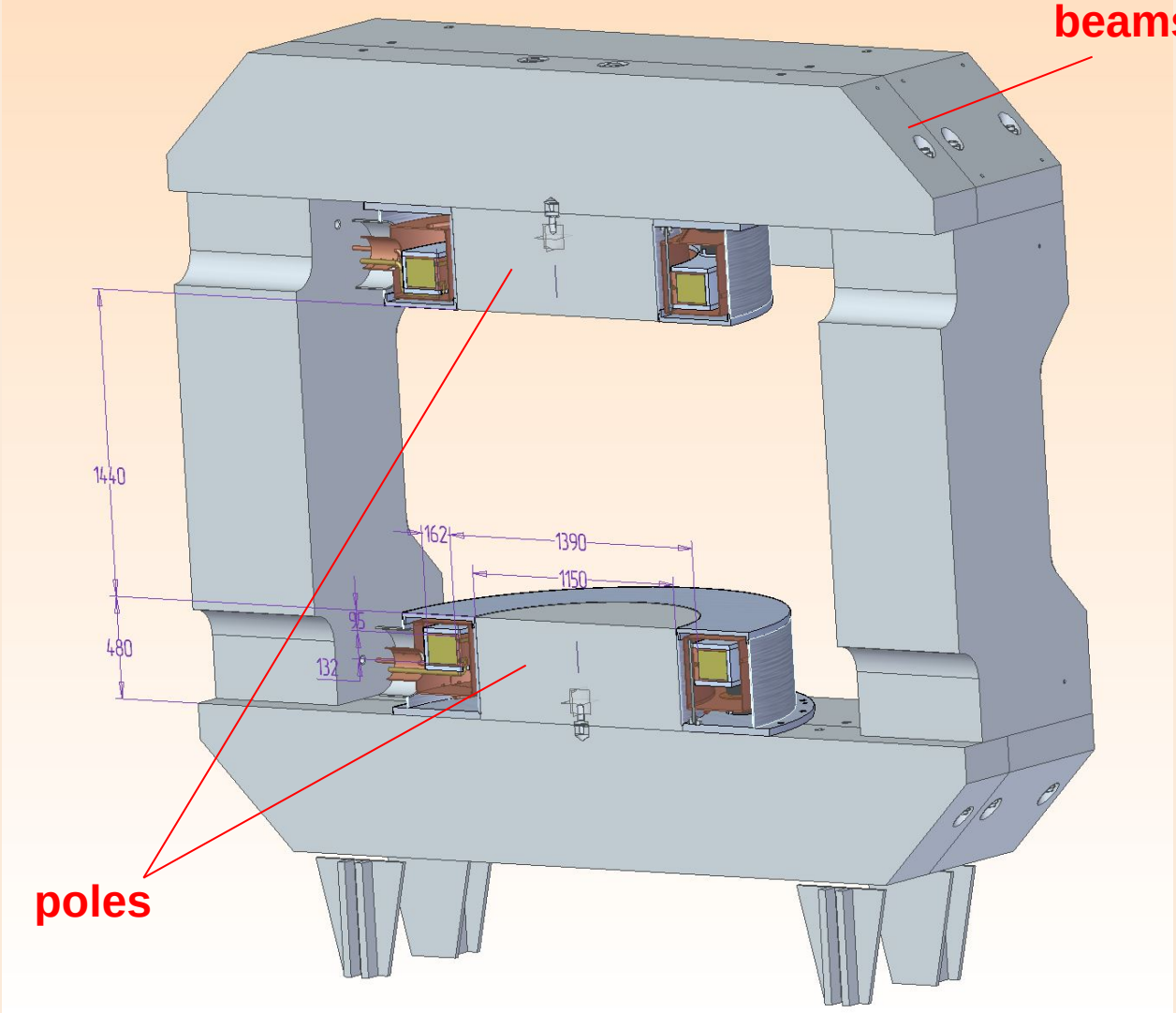
Magnet design: iron yoke

The yoke is of

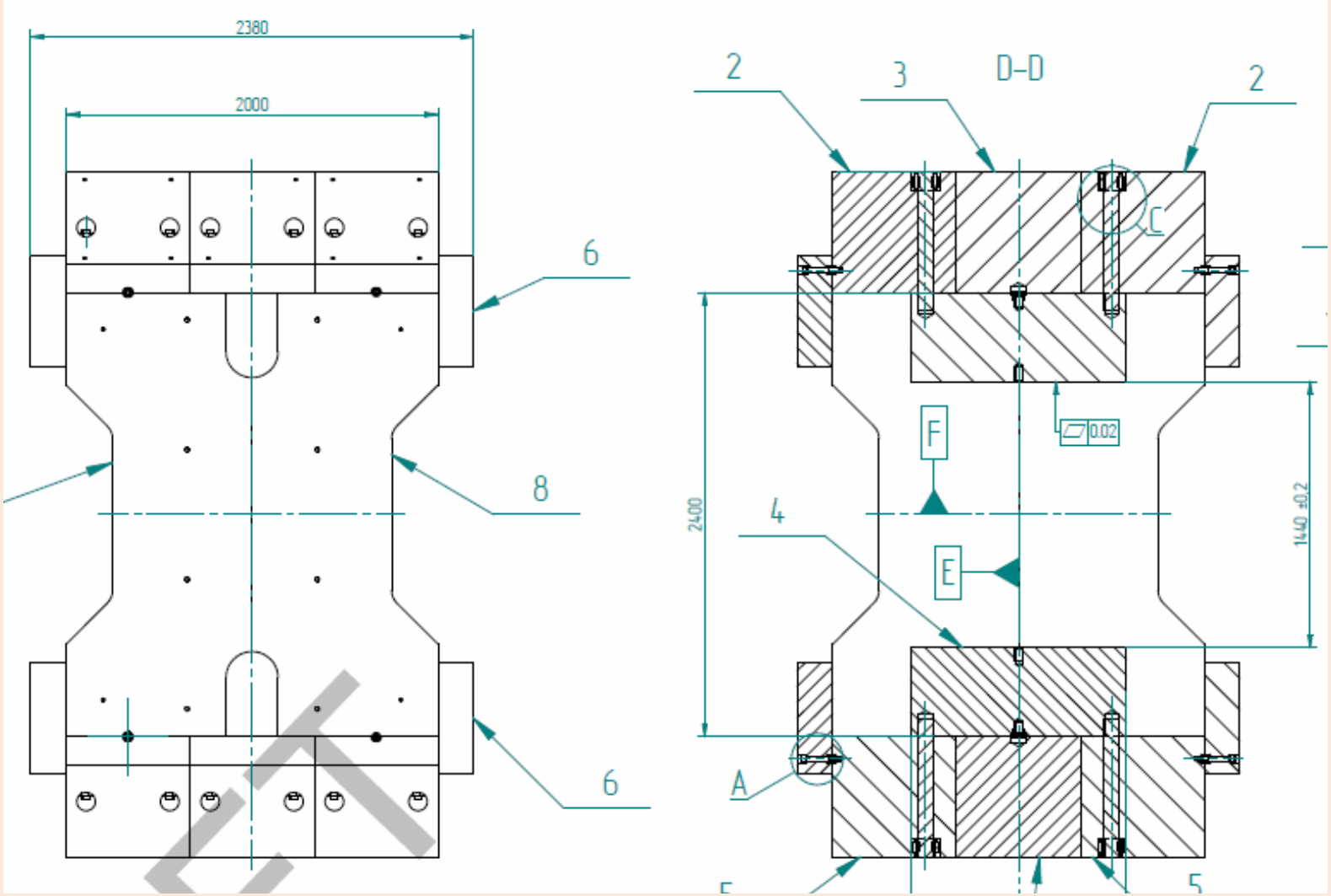
Steel 1010,

the pole of the yoke is a kind of ARMCO (08kp)

Total mass of the yoke is ~ 144 tones.



Dimensions now



Calculation codes and models

In the magnetic field analysis the results of the following calculations were used:

-ANSYS 3D code performed by Y. Goussakov and S. Farinon;

-MERMAID 3D code S. Khrushchev

-ANSYS 2D code A. Bragin

The main results of the ANSYS 3D of Y. Goussakov and MERMAID 3D are close, so the next slides will be referred to the MERMAID 3D only.

The ANSYS 3D calculations by Stefania were very helpful to pay more close attention to non uniform distribution of vertical force on the coils.

Mermaid 3D model

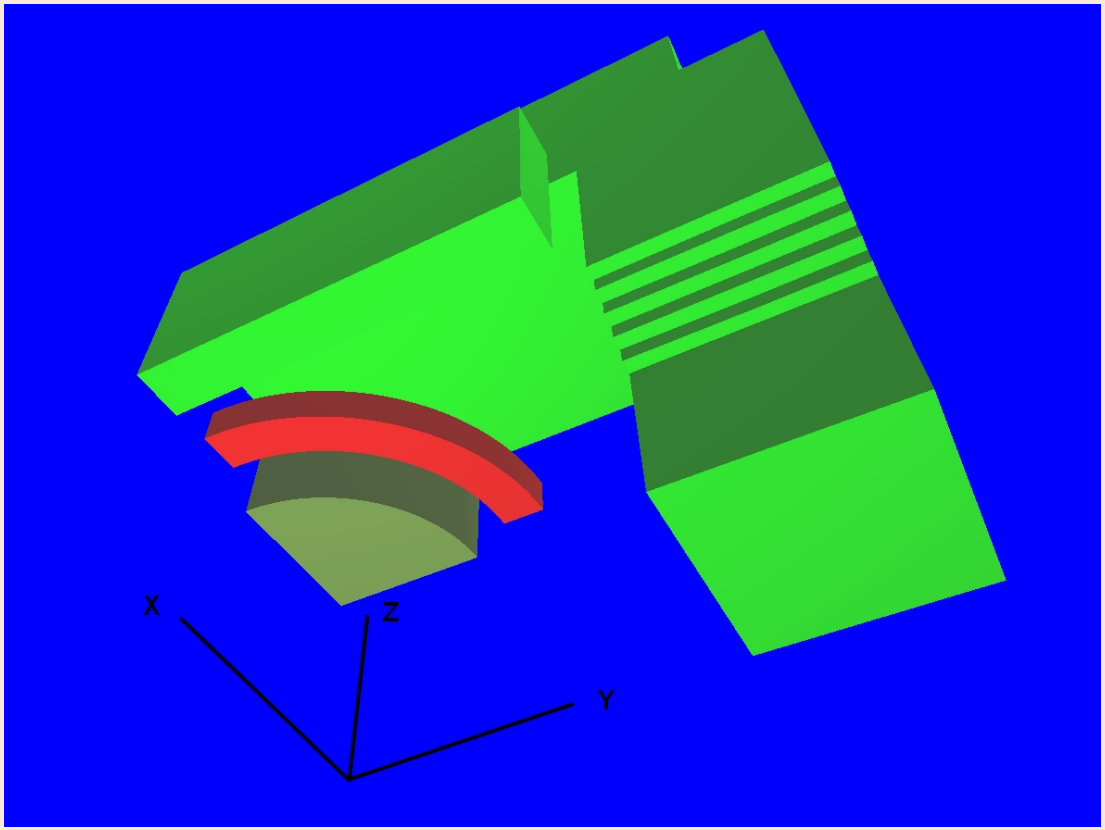
The total current in the coil is 1.2 MA (686 A of operating current).

Inner diameter of the winding is 1390 mm,

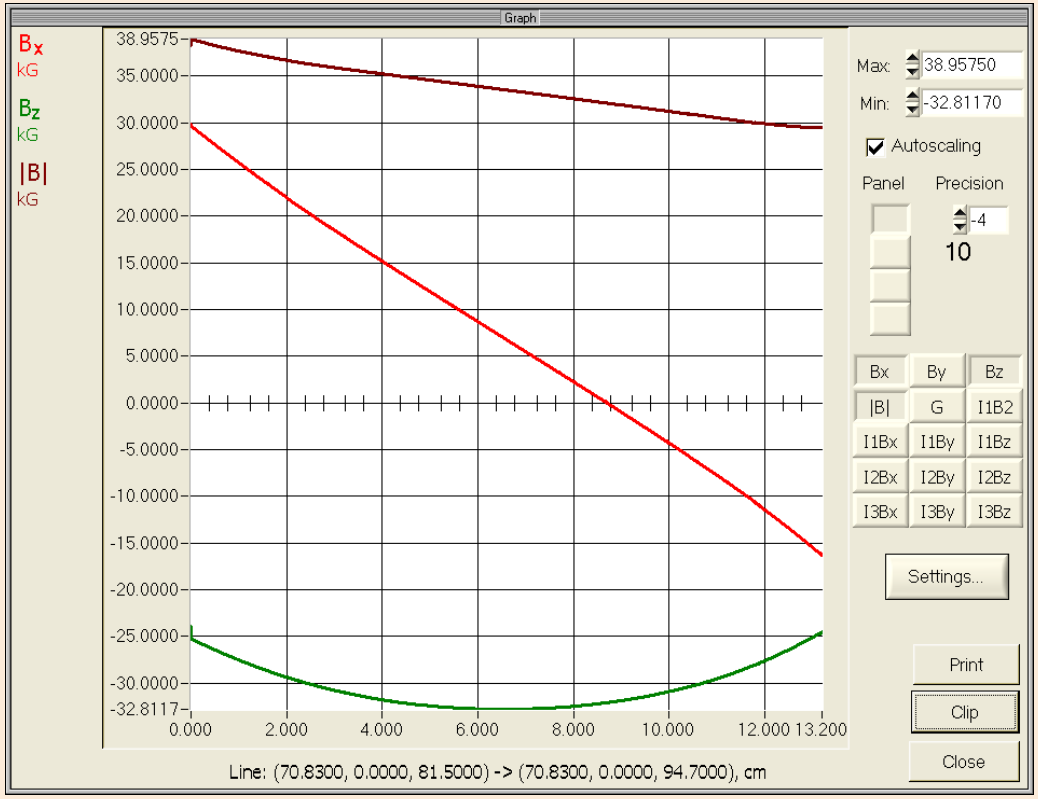
axial thickness is 131 mm,

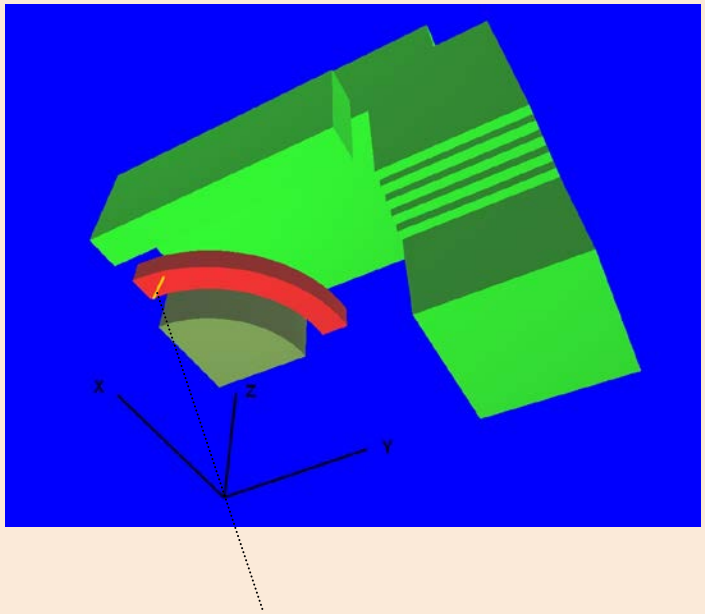
radial thickness is 160 mm

Vertical distance between the poles is 1440 mm.



Magnetic field in the coil





The presented graph is along this yellow line.

The magnetic field values inside the SC winding as Mermaid result. The magnetic filed values are in kG, the distances are in cm. These filed values are highest in the coil as this winding part is closest to the iron field clamps.

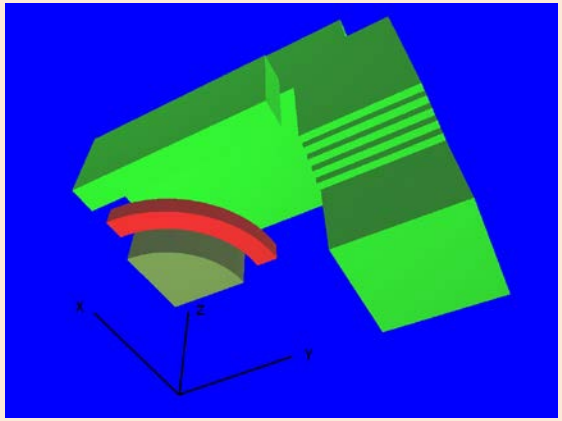
Forces in the coil

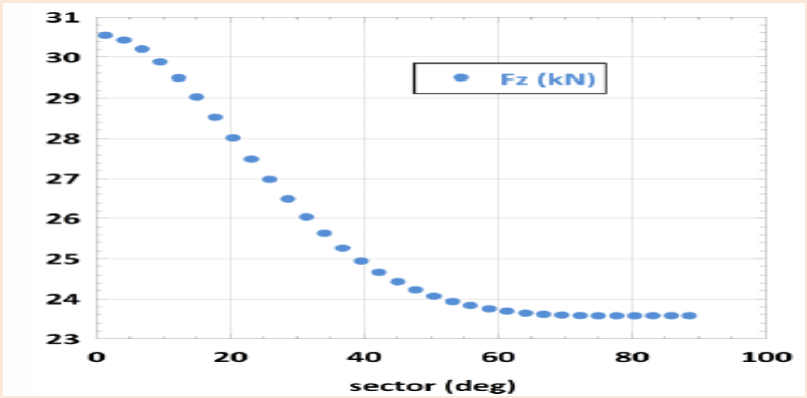
Lorentz forces in the coil

Inner pressure as p = I*Bz/(ax. thick.) ~ 5 MPa.

Vertical force Fz = I*Br*(πD) ~ 3.1-3.4 MN.

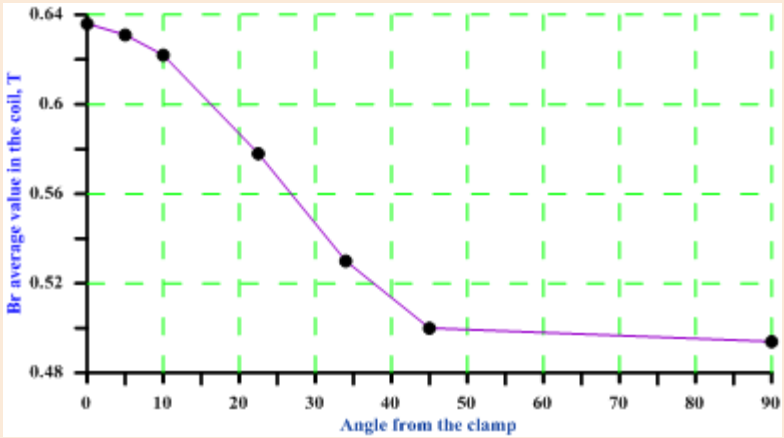
The vertical force is not uniformly distributed around the coil, the difference is ~ 22.5%. The highest value is by the field clamps.





The azimuthal distribution of vertical force along the sector of 90 grades. ANSYS 3D by Stefania.

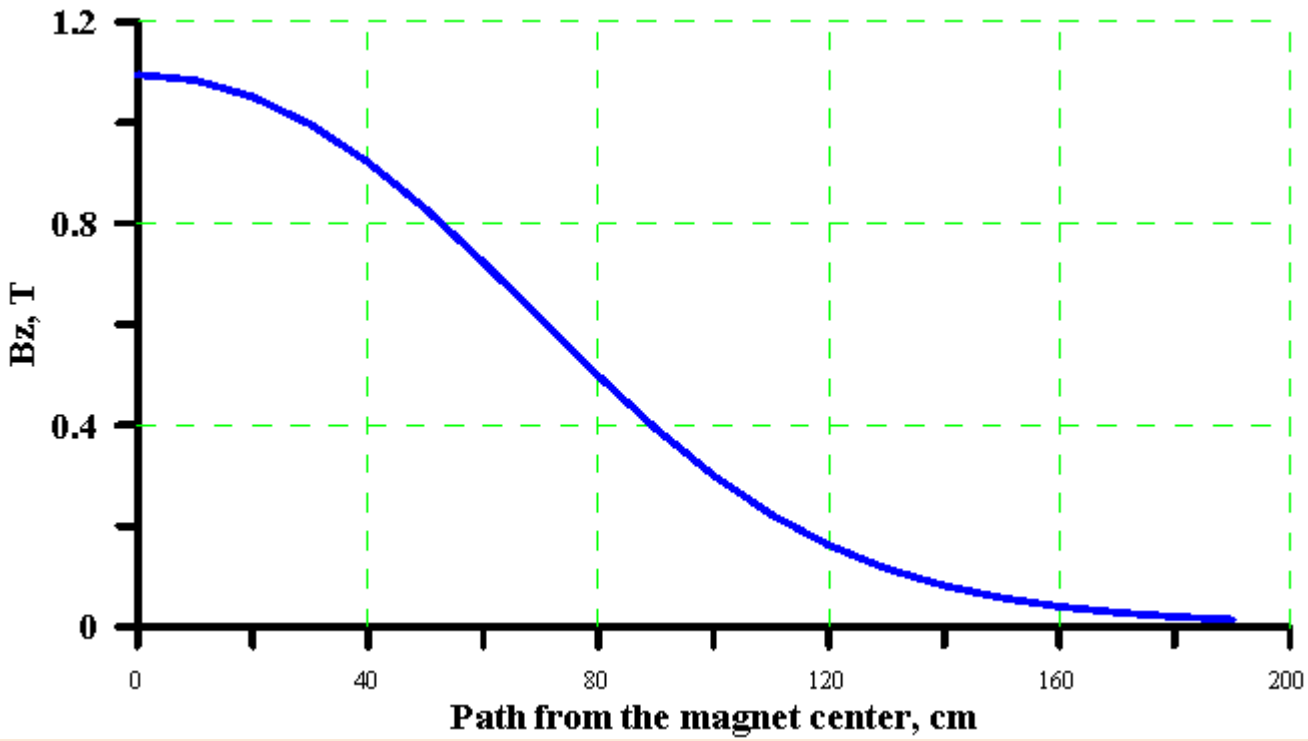
Fz = 3.4 MN.



The azimuthal distribution of average radial magnetic field along the sector of 90 grades. Mermaid 3D in BINP.

Fz = 3.1 MN.

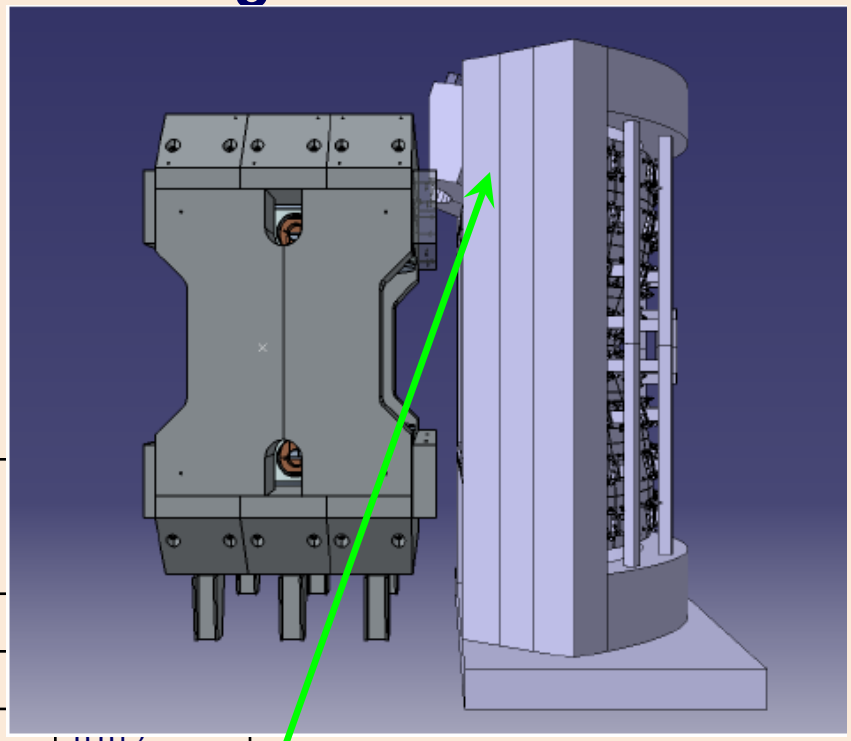
Magnetic field distribution



Magnetic field integral is 1.004 T*m about the center of the magnet on the length of 1 m.

Magnetic field around the RICH detector region

The field in the region of the RICH detector should be less than 0.01 T.



Z, cm / X, cm	110	120	130	140	
100	1.39	1.37	0.033	0.028	
110	1.38	1.37	0.021	0.019	
120	1.38	1,31	0.015	0.014	0.012
130	1.16	0.87	0.012	0.010	0.009
140	1.09	0.040	0.009	0.008	0.007
150	0.0044	0.0054	0.0063	0.0061	0.0056
160	0.0051	0.0051	0.0051	0.0049	0.0046
170	0.0052	0.0048	0.0045	**0.0042**	**0.0039**
180	0.0054	0.0045	0.0040	**0.0036**	**0.0033**
190	0.0047	0.0039	0.0034	**0.0031**	**0.0029**
200	0.0035	0.0032	0.0029	**0.0027**	**0.0025**

ANSYS 2D calculations

ANSYS 2D model of axial symmetry was used to check the calculations performed by ANSYS 3D and MERMAID 3D.

It was useful in:

-determining maximal field on the coil;

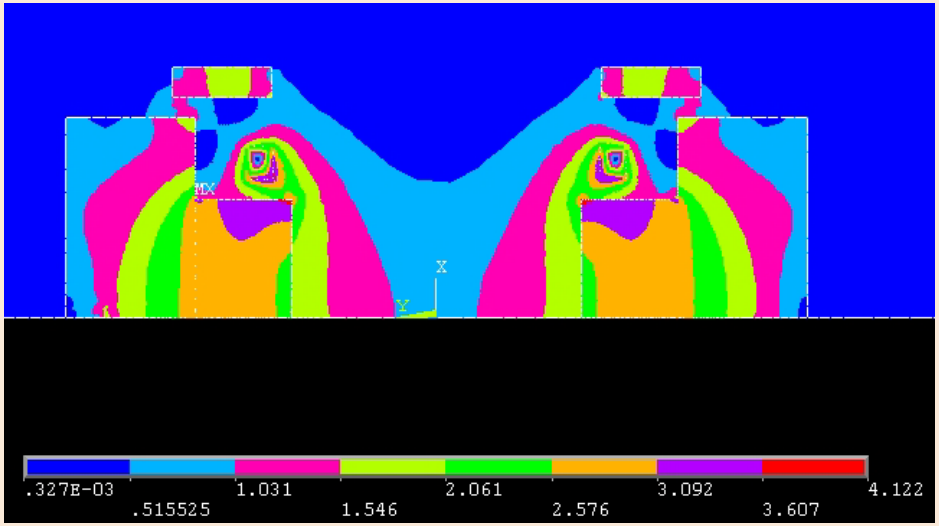
- poles shape evaluation;

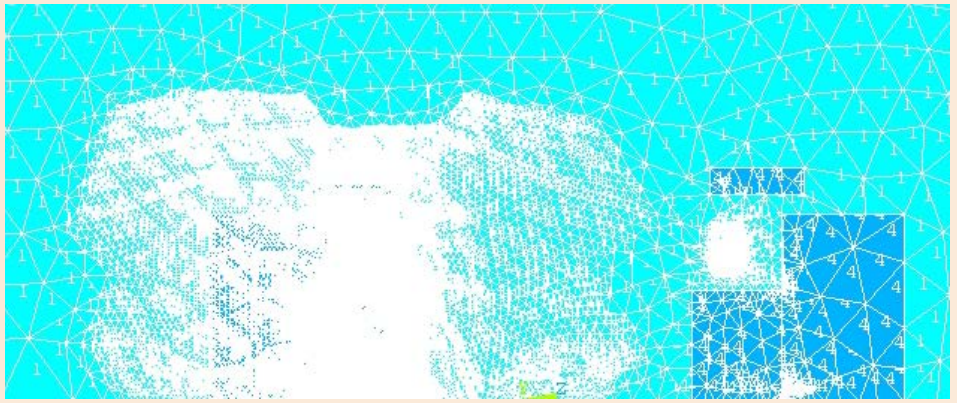
- forces calculations, especially on the poles;

-inductances evaluation.

The discrepancy with 3D models is about 5-10%.

It gives the stored energy value ~ 4.9 MJ while 3D models gives 5.04 MJ (MERMAID) and 5.2 MJ (ANSYS SF).





Conditions	Pole, Fy in MN	Iron2, Fy in MN	Total Fy iron, in MN
Step 1	-2.47	-0.49	-2.96
Step 2	+0.74	-3.82	-3.08
Step 3	+0.70	-3.80	-3.10
Only one charged	+0.015	-0.033	-0.018

Forces, inductances

- The forces on the coils are:

- 3.3 MN (highest) in vertical direction to the nearest horizontal yoke beams. It is not uniform azimuthally with 22% of difference.

- 5 MPa of internal pressure.

- Force on the pole iron attractive toward the nearest horizontal yoke beams ~ 0.7 MN (70 tones).

- Mutual inductance between the coils is 0.21 H – very low. Calculated from stored energies of separately charged coils in ANSYS 2D.

Results

- The magnetic field was calculated in different codes: ANSYS 3D, MERMAID 3D.
- The field integral is satisfying to be 1 T*m – the main parameter.
- Maximal magnetic field on the winding is 3.9 T
- Coil support struts should be placed properly with respect to the non uniform distribution of vertical force around azimuth.
- The number of struts will be reconsidered to be 8.
- Force on the pole is attractive to the nearest horizontal beams of the yoke, about 70 tones.
- The stray field by the RICH detector is not high.