Joint Institute for Nuclear Research

PANDA solenoid design with laminated iron yoke

A.Vodopianov, E.Koshurnikov, Yu.Lobanov,
A.Efremov, A.Makarov

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Solenoid yoke dimensions

Dimensions are chosen in accordance with:

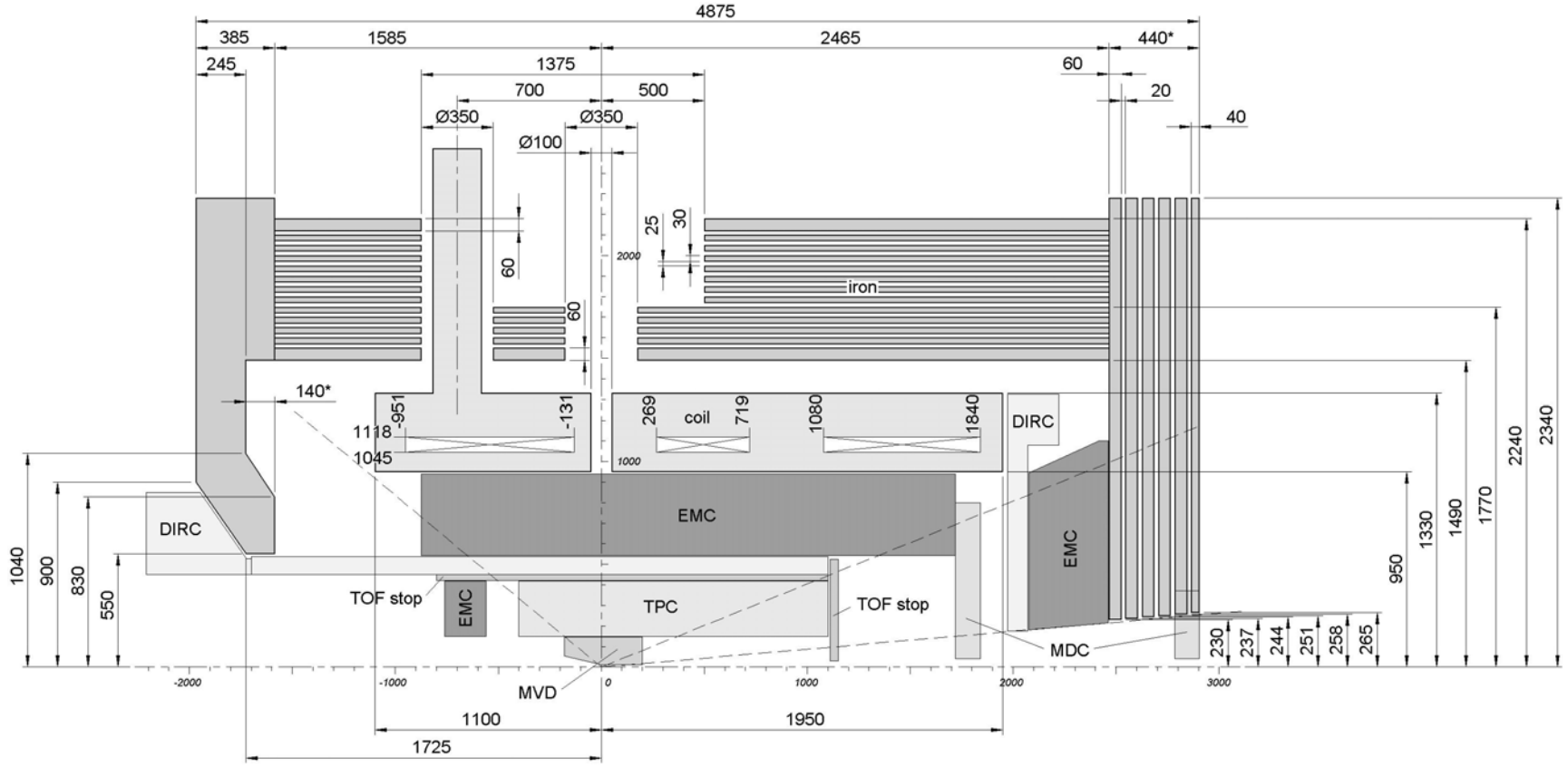
1. Design option proposed by Technical Board (Lars & Jost variant)
2. Decisions of the GSI November, 9th meeting and Dubna November, 14th magnet & muon meeting
3. Further discussions via e-mail
4. Our optimization with respect to magnet field parameters and for mechanical construction purposes

Solenoid yoke dimensions

The position of upstream end cap is chosen by taking into account the following factors:

- limitation of axial magnetic force (10 tons in our design);
- avoiding magnetic field saturation inside the end cap;
- tolerance in the coil adjustment precision of ±1 cm (strongly dependent on the proximity of the coil to the end caps);
- leaving the space inside the yoke between the coil and the upstream end cap for possibility of placing the upstream DIRC detector in case if it will be designed for working in magnetic field (like downstream one).

Solenoid cross-section



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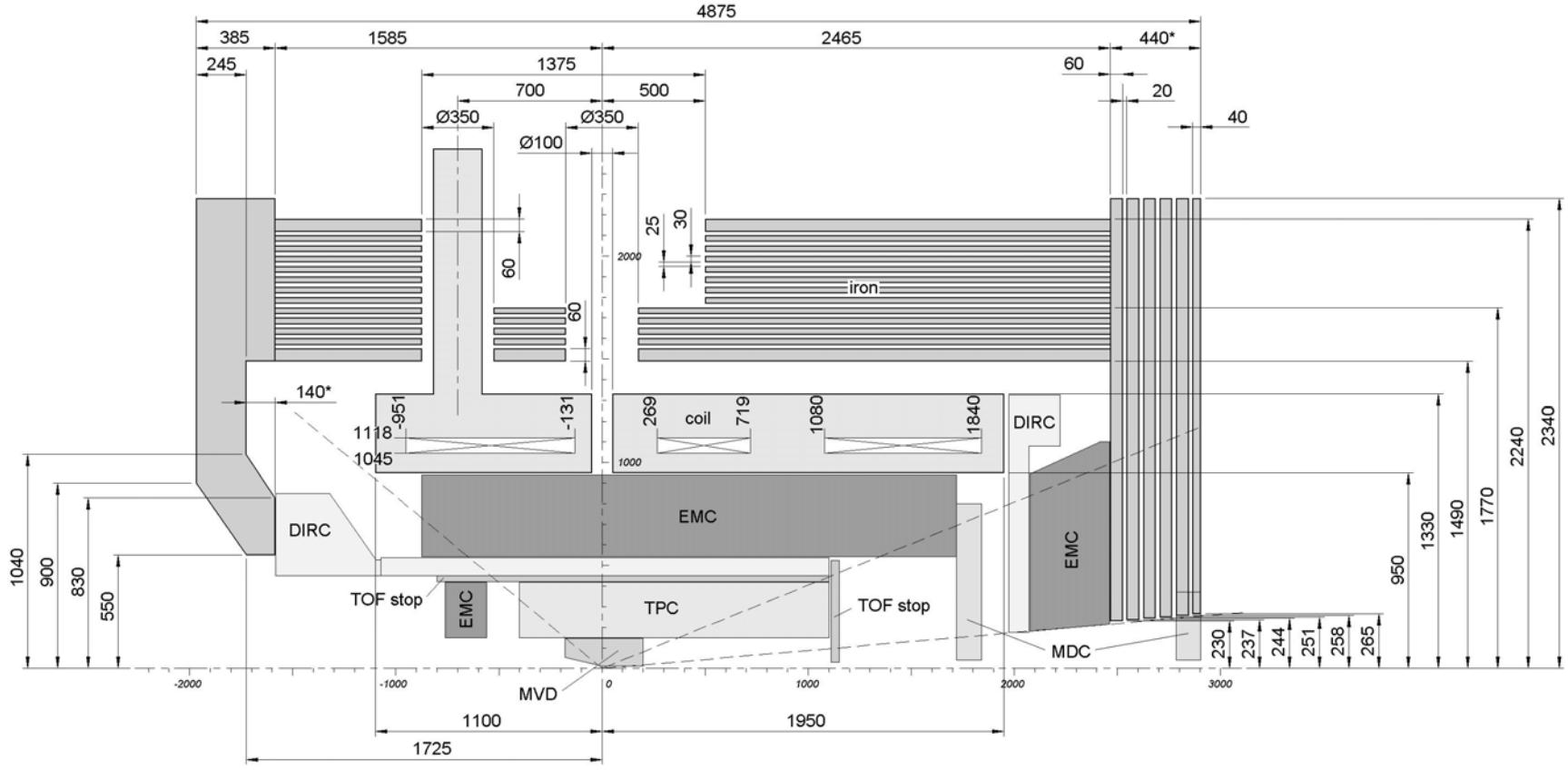

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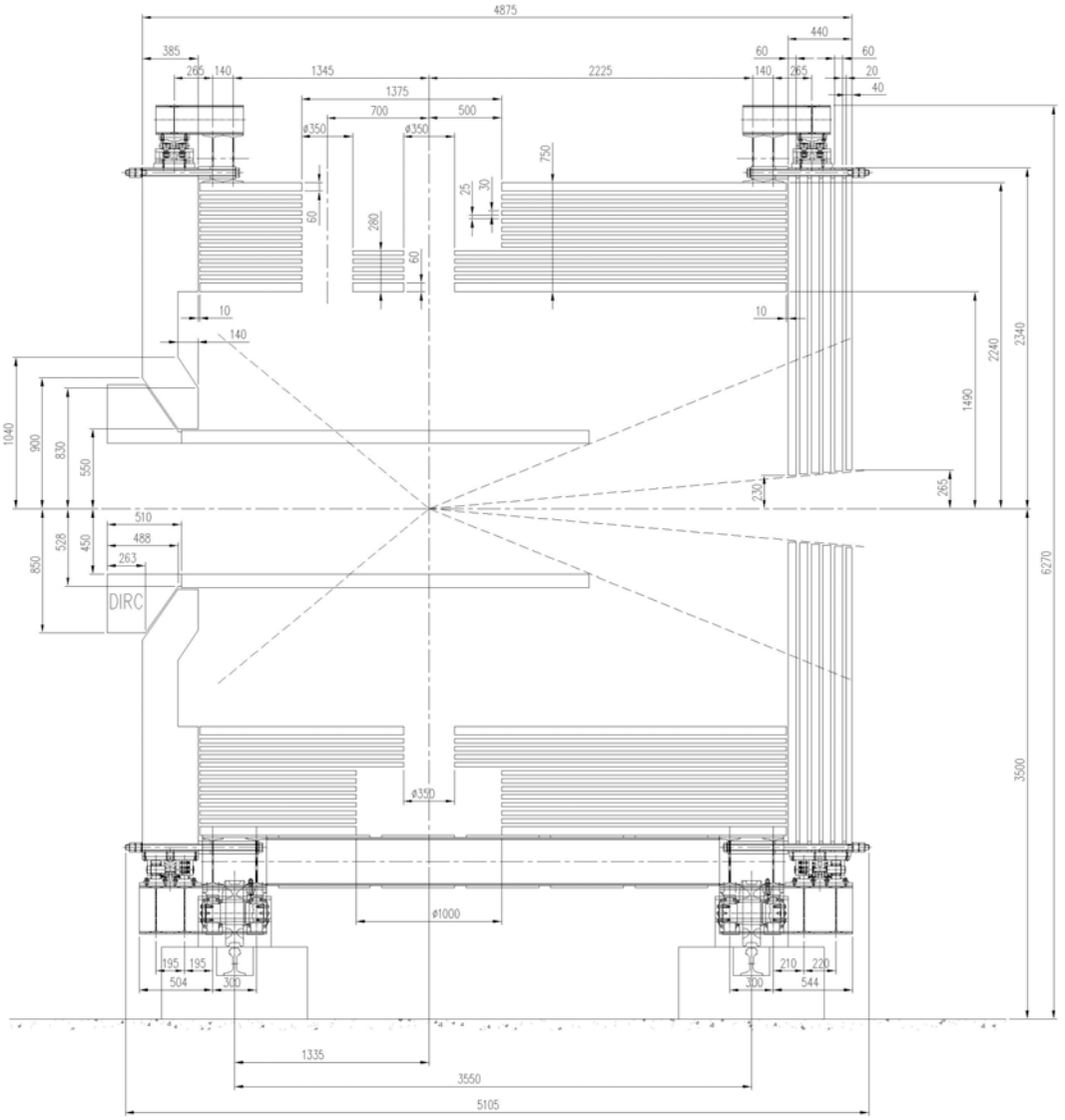
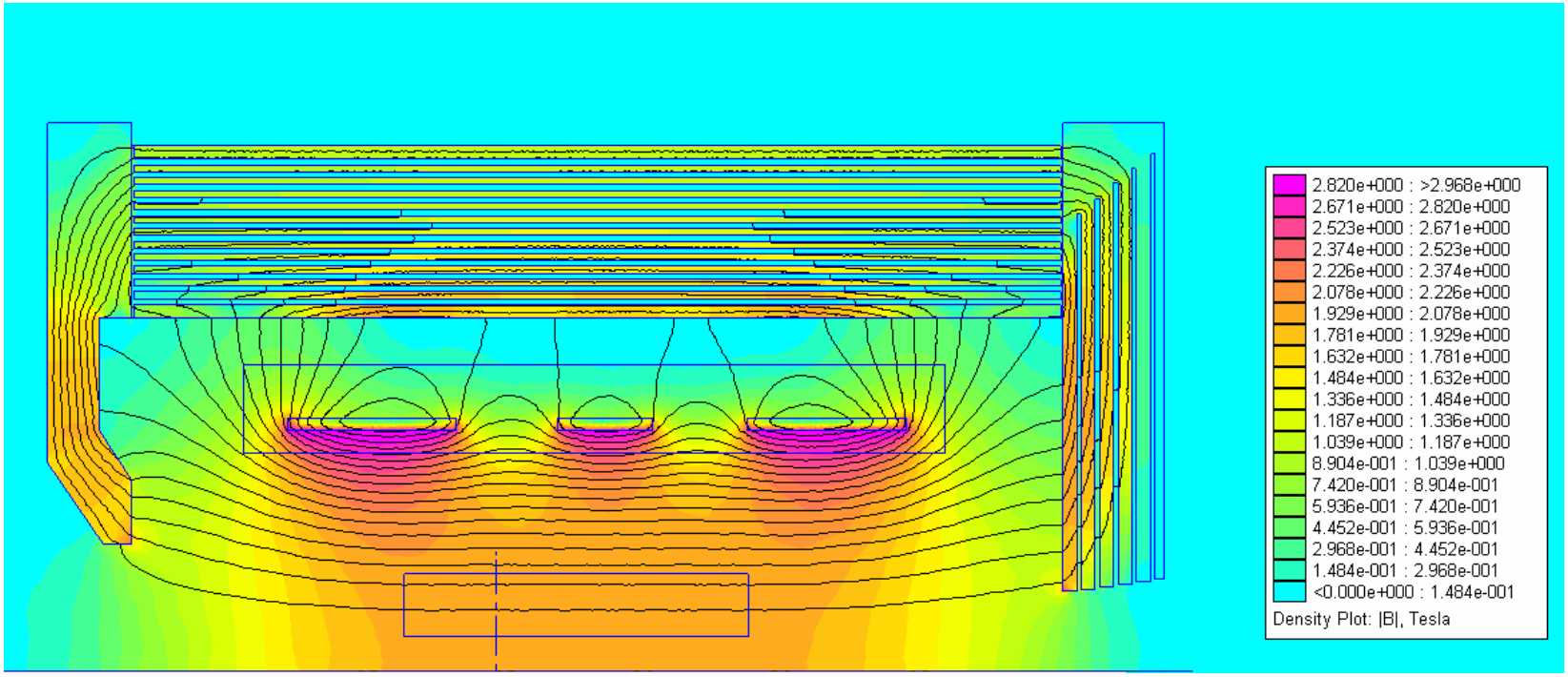


Magnetic flux density distribution



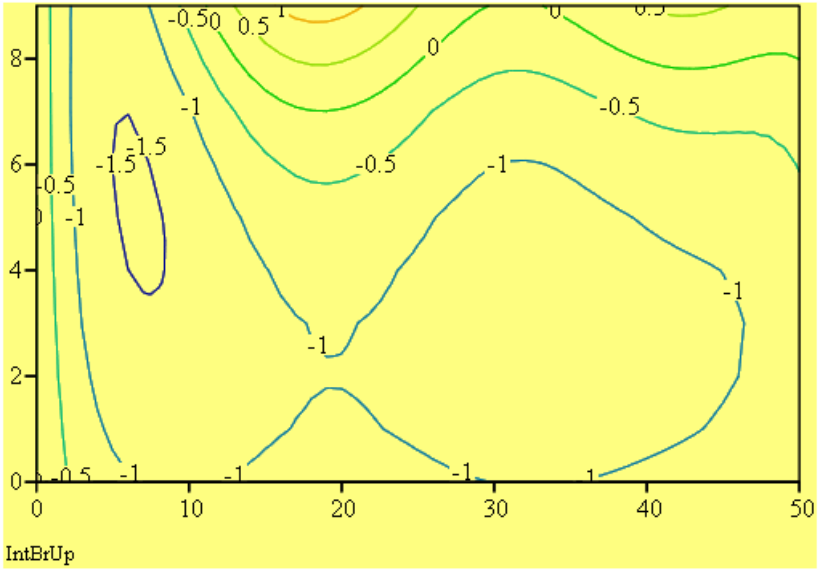
No saturation of magnetic field in the iron yoke parts

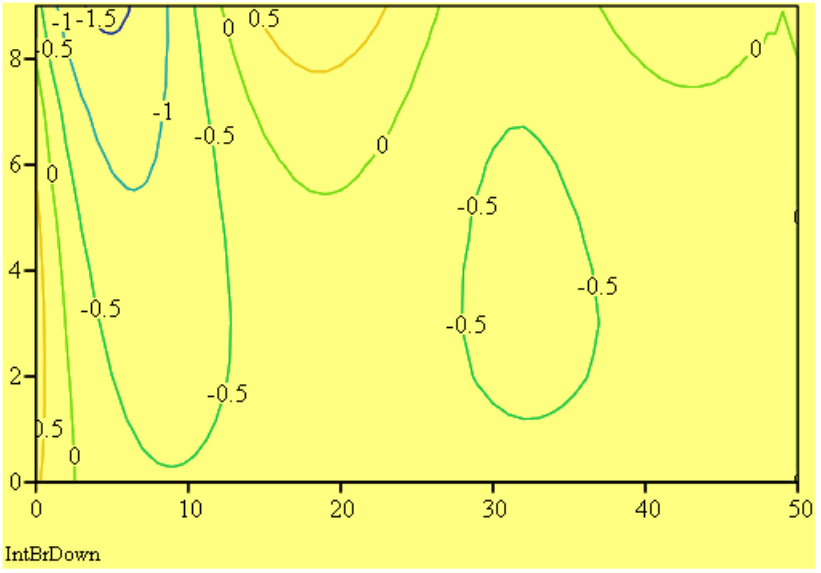
Possibility of coil movement ± 1 cm in any direction is assured

Radial component integral

$$I_{up}(R, Z_0) = \int_{-400}^{Z_0} B_r(R, z) / B_Z(R, z)\, dz$$

$$I_{down}(R, Z_0) = \int_{1100}^{Z_0} B_r(R, z) / B_Z(R, z)\, dz$$





-1.5 mm < I_{up} < 1.2 mm

-1.6 mm < I_{down} < 0.9 mm

Coil shortening options

J [A/mm^2]	$Z_{min} \div Z_{max}$ [mm]	Coil movement ± 1 cm		
		F_Z [kN]	ΔB/B [%]	$\int Br/Bz\,dz\,[mm]$ max{up,down}
55.4	-951 ÷ 1840	+47 ÷ 190	1.6 ÷ 1.8	1.5 ÷ 1.8
60.8	-904 ÷ 1783	+37 ÷ 163	1.7 ÷ 1.9	1.6 ÷ 1.8
64.9	-868 ÷ 1747	+46 ÷ 167	1.8 ÷ 2.0	1.7 ÷ 1.9

Simultaneous shortening of the yoke from upstream by 20 mm and change of the shape of upstream end cap

Coil shortening options

Without increase of current density:

Conductor cross-section: (3.2mm × 25 mm) → (3.2mm × 29.5 mm)

Coil thickness increase (2 layers): 9 mm

Current density: J = 55.2 A/mm^2

Axial dimensions of the coil: -868 mm ÷ 1747 mm

Axial magnetic force: +98 kN

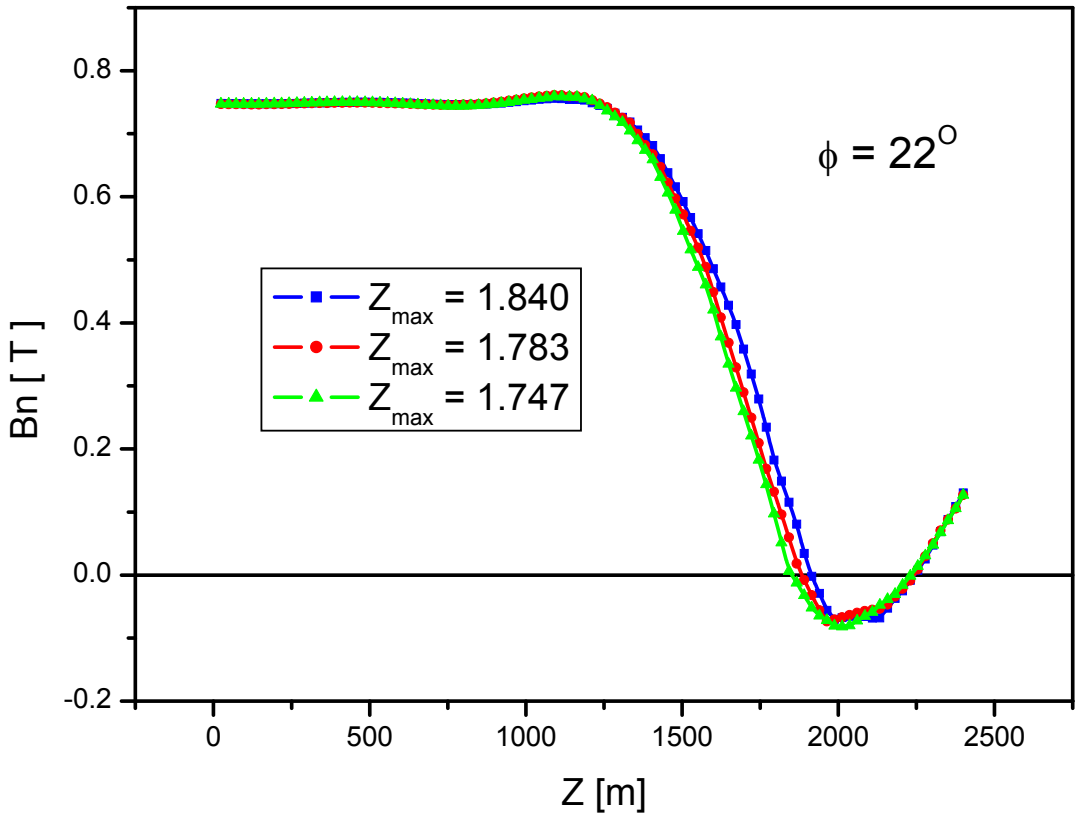
Field inhomogeneity: $\Delta B/B < 1.9\%$

Radial component integral: $-1.8 \text{ mm} < I_{up} < 0.7 \text{ mm}$;

$-1.3 \text{ mm} < I_{down} < 1.1 \text{ mm}$

Field normal component

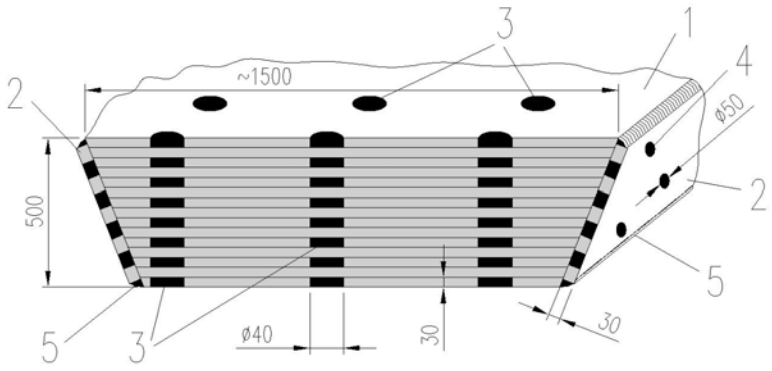
(along the line from IP at 22^0 to the beam axis)



Which are the physical requirements for the Bn integral?

Yoke beam construction

Solid yoke



1 – sheets

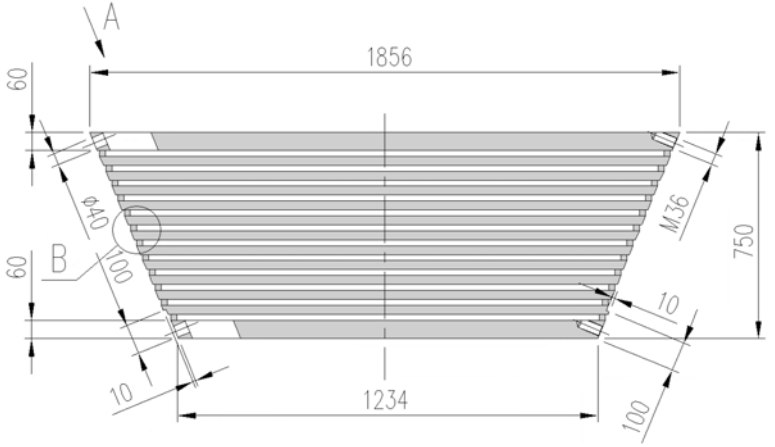
2 – side (external) sheets

3 – internal welding spots

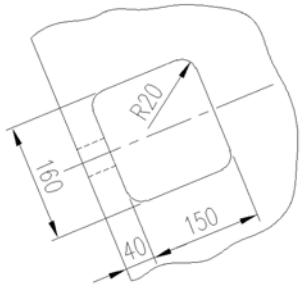
4 – welding spots on side sheet

5 – welding seams

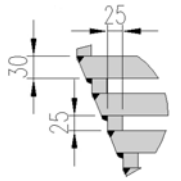
Laminated yoke



View A



View B



Cost increase of laminated yoke with respect to the solid yoke

Based on the cost estimate method for iron yoke
of the 800t Dipole Magnet for ALICE experiment at LHC (CERN)

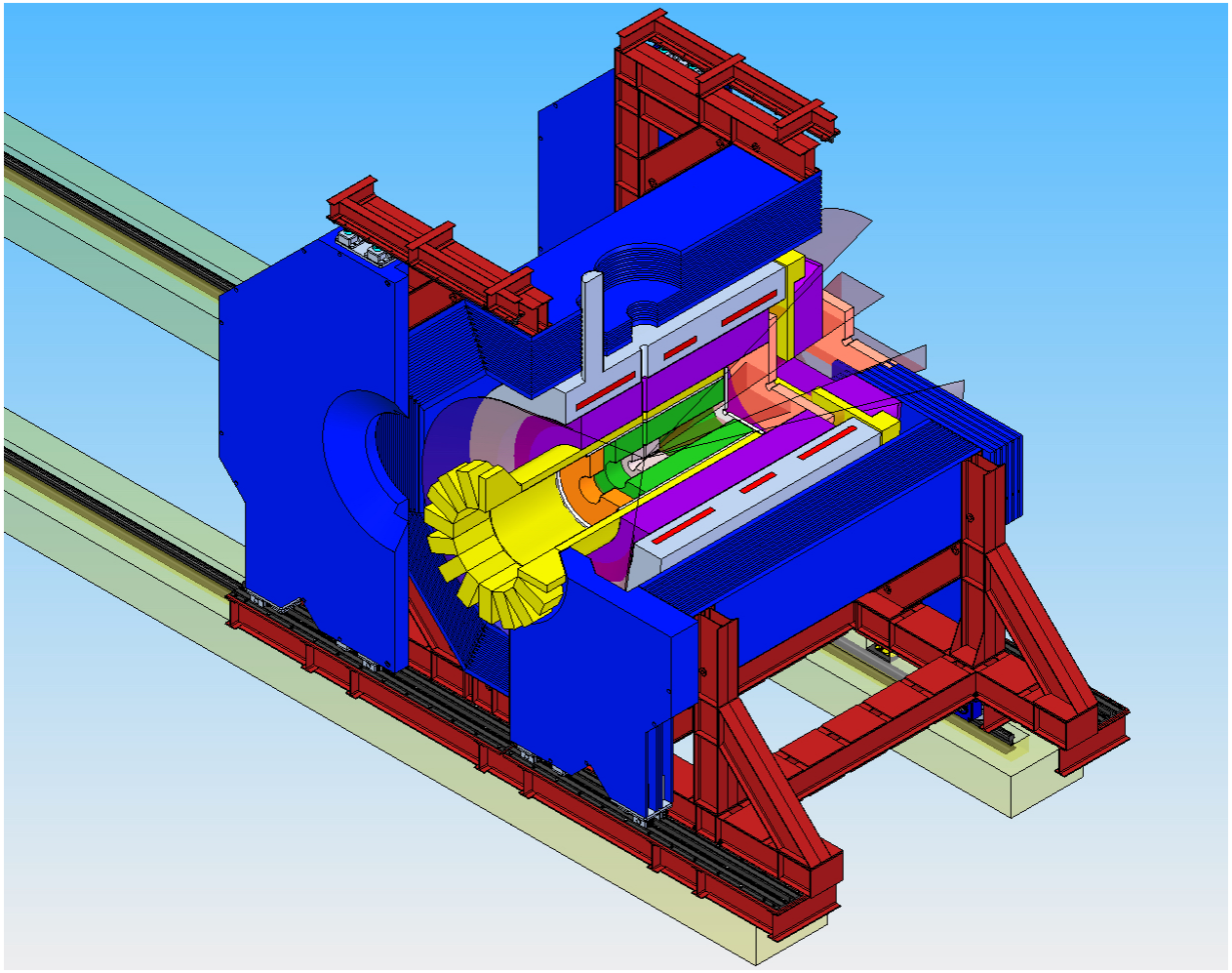
Yoke mass	Machining	Welding	Other	Total
50%			50%	100%
Barrel End caps Carriage	Holes drilling: - Surface cutting: +	Welding seams length	Blank production Lifting works Assembly	All factors
Total: 1.17	1.15	1.2	1	1.1

Additional cost increase may appear from:

- transportation of >20 ton pieces (depends on the manufacturing place and transport method)
- or from additional construction solutions reducing the weight

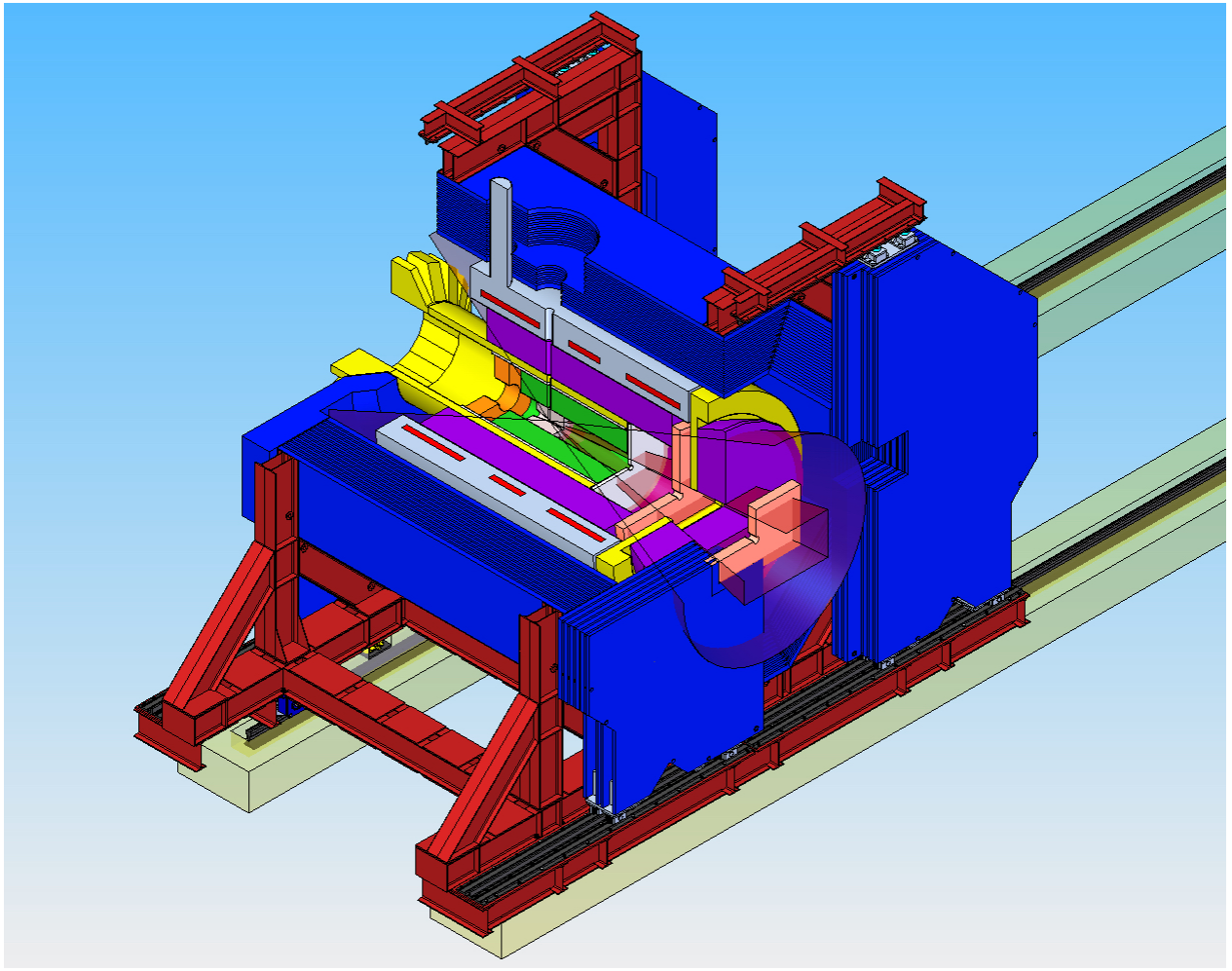
3D view of the solenoid

from upstream direction

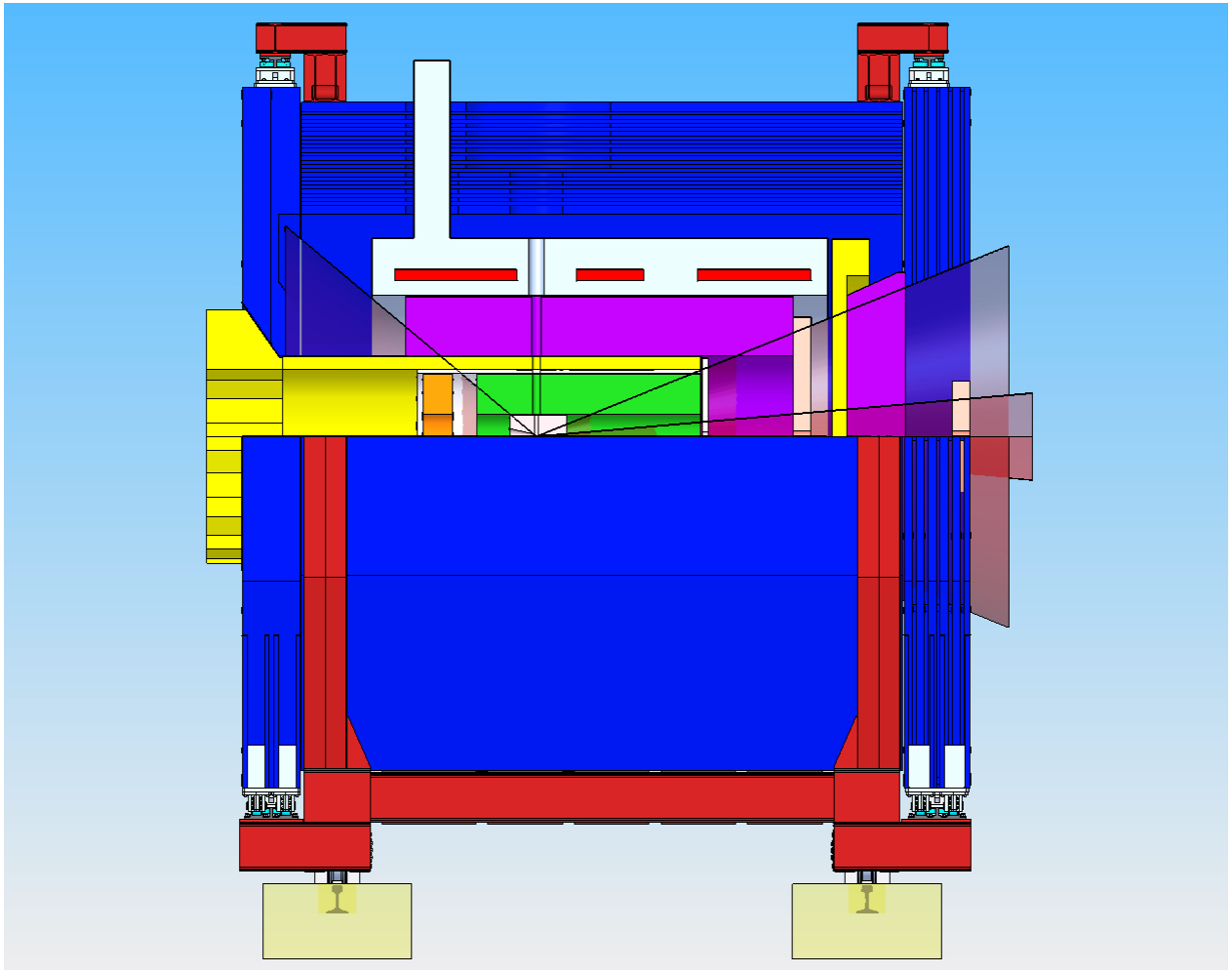


3D view of the solenoid

from downstream direction

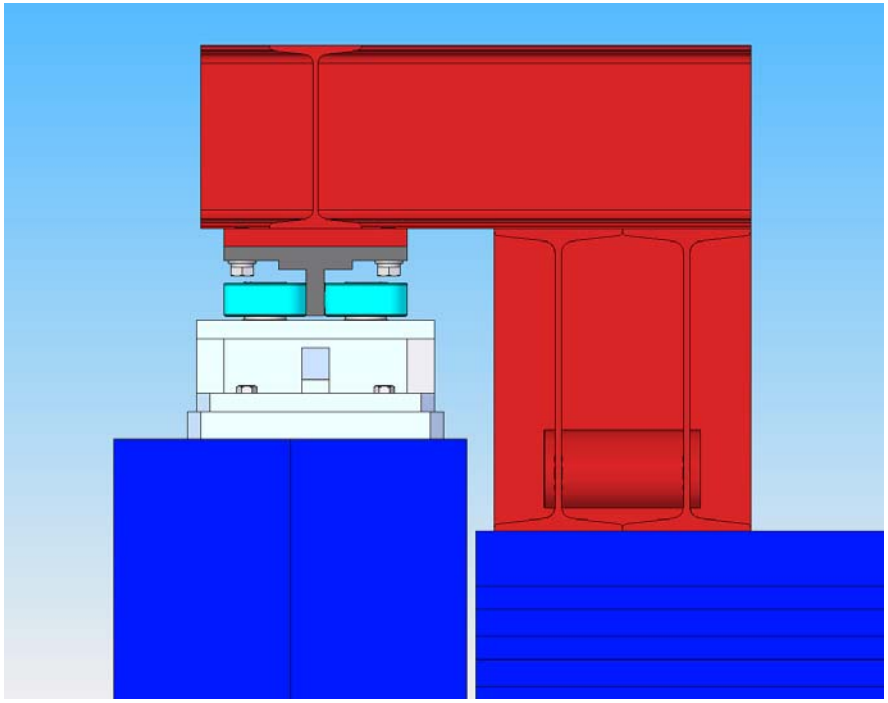


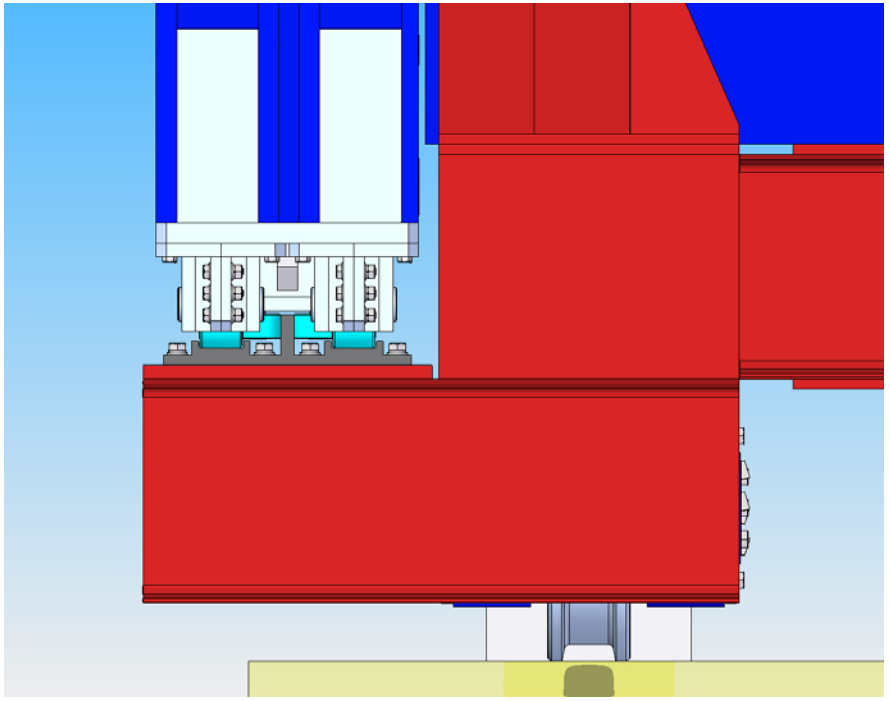
Side view of the solenoid



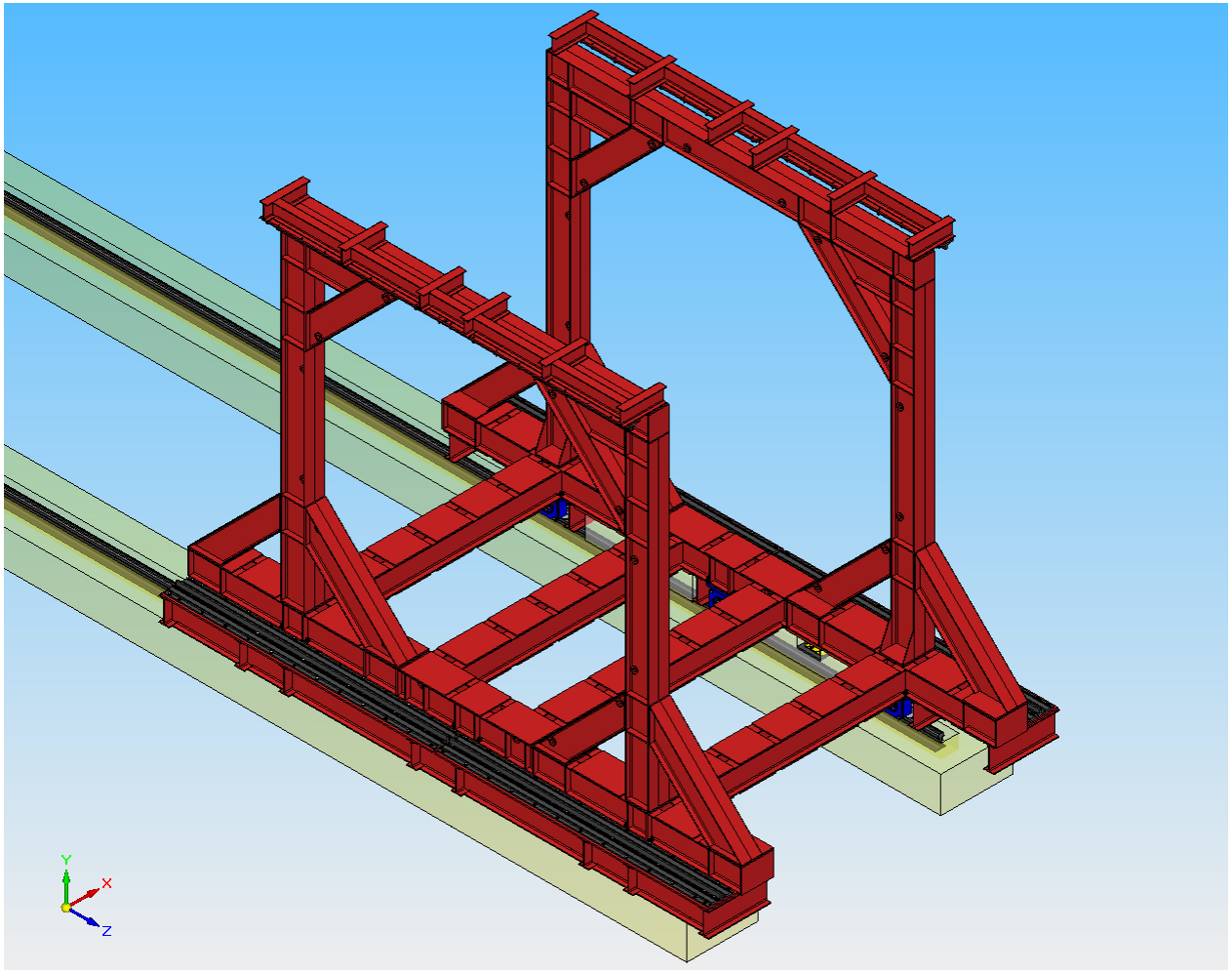
Upstream end cap

up and down bearing supports

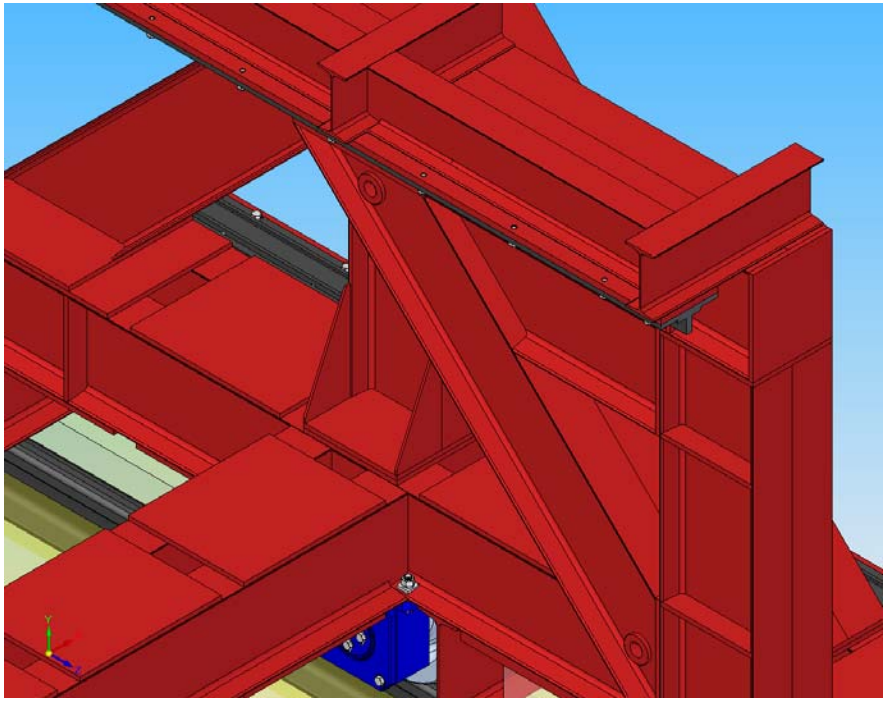


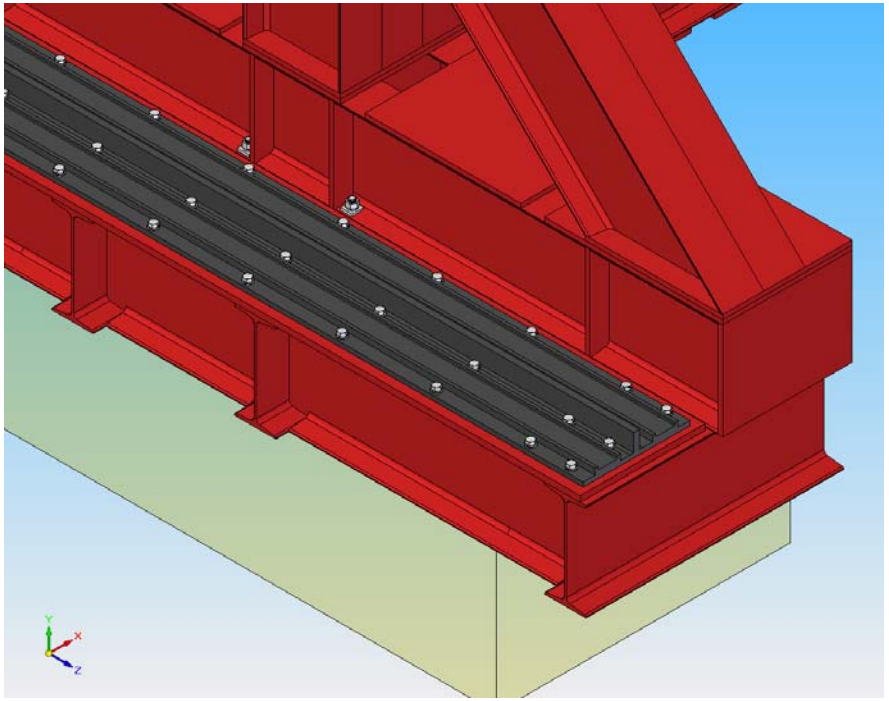
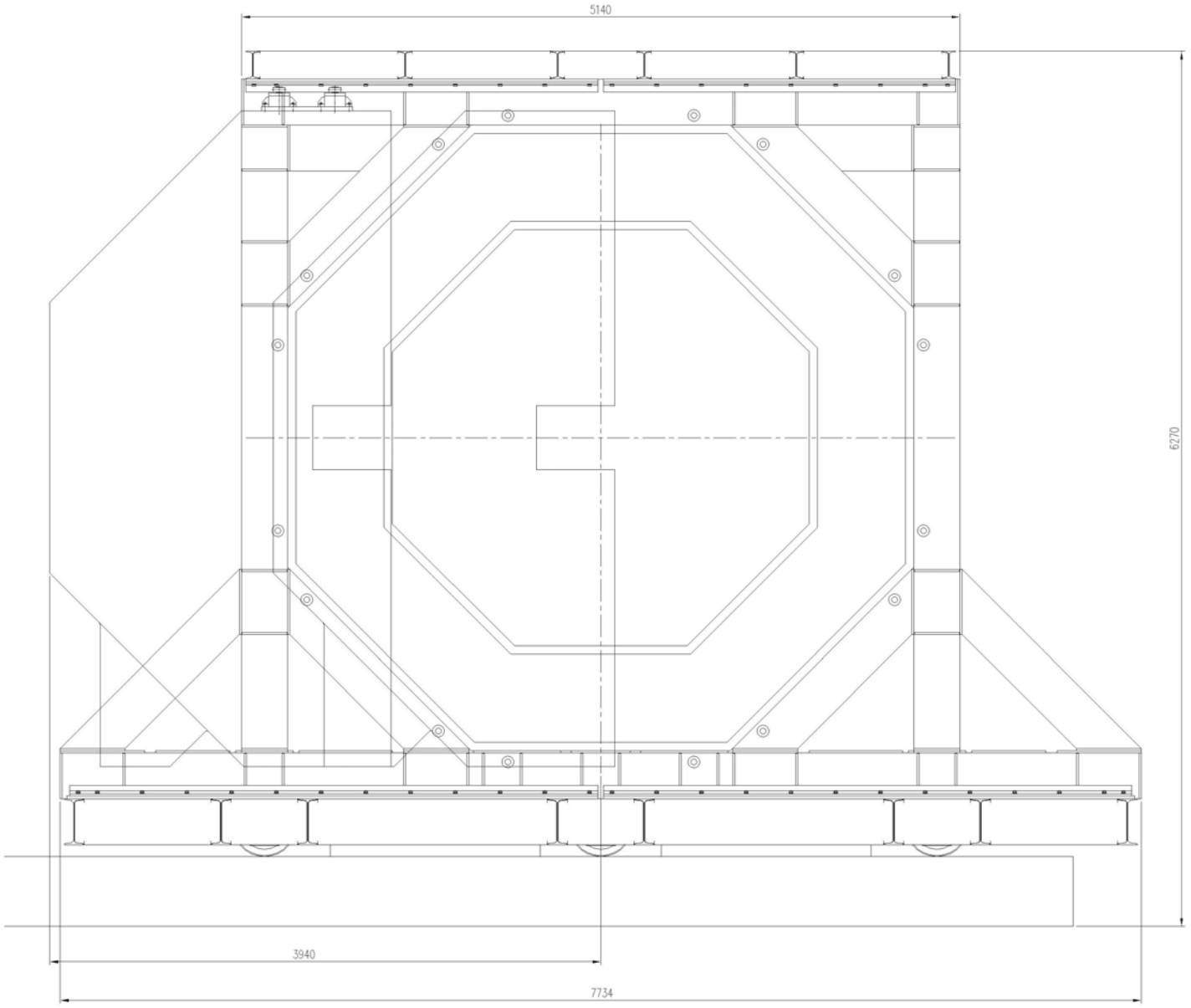


Transportation carriage and support frames



Up and down guide rails of upstream end cap





Solenoid front view