Joint Institute for Nuclear Research (Dubna)

Status of the PANDA TS magnet

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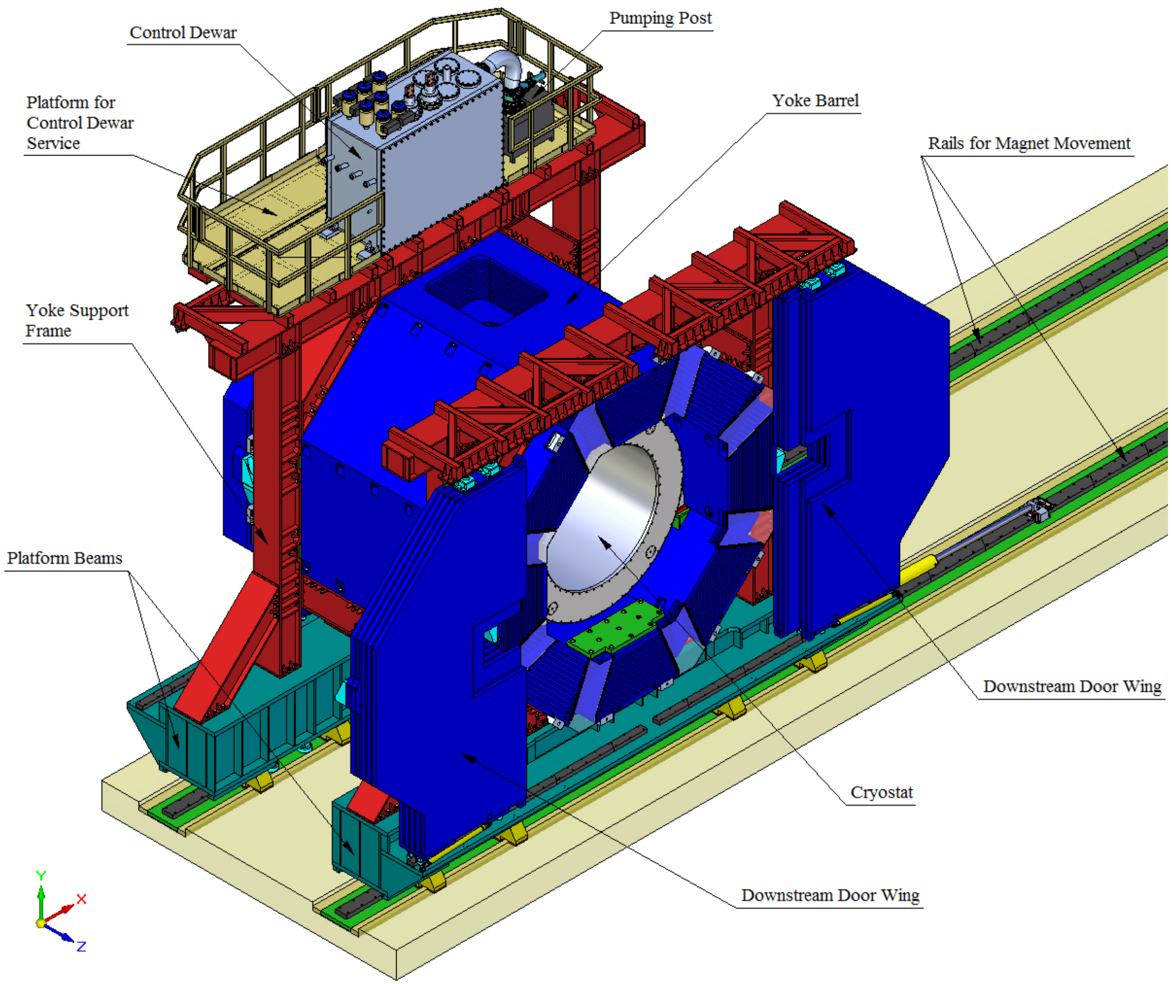
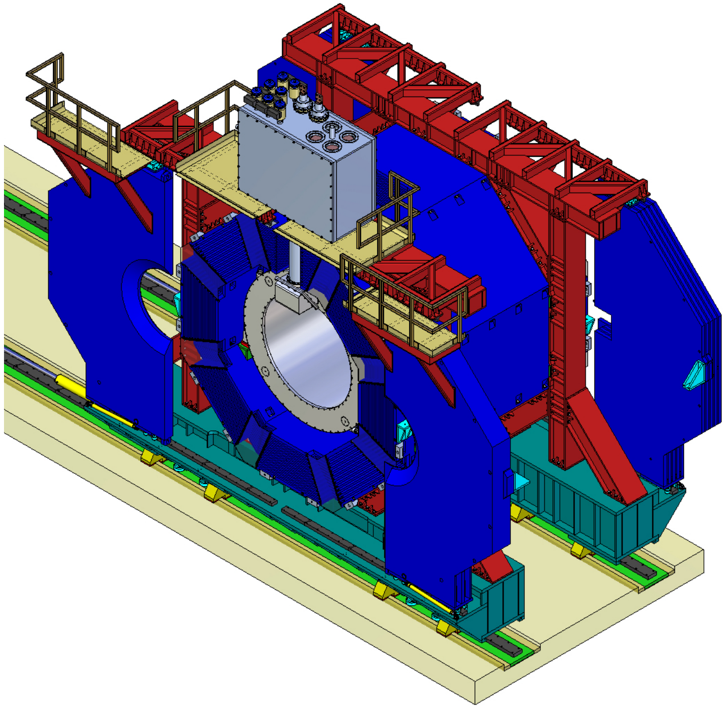
PANDA LV. Collaboration Meeting,
Stefan Meyer Institute, Vienna
December 3, 2015

- Iron Yoke
- Cryostat and control Dewar
- Cold mass
- Interfaces with detectors and auxiliary equipment

PANDA TS magnet





Status of the TS Magnet Yoke

- Yoke 3D model, assembly drawings, Technical Specification and Technical Description have been prepared by JINR and transmitted to BINP (Novosibirsk) in May 2015
- According this documentation BINP organized the work to obtain a preliminary cost estimation from BINP workshop and neighbor plants
- In parallel, cost estimate on the basis of this documentation has been requested from SMZ (Savelovo, Moscow region)
- Besides a very preliminary cost estimation was given by GSI tender specialist

Preliminary cost estimations of the yoke

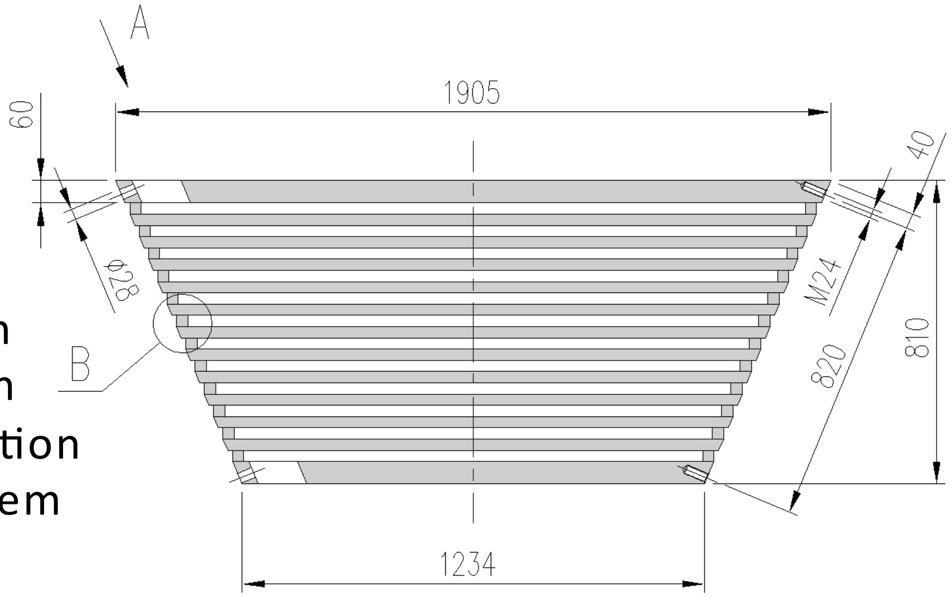
In accordance with the proposal of BINP it takes **32 months and 3.647 M€** for elaboration of working documentation, manufacturing, delivery and final assembly of the Yoke in GSI

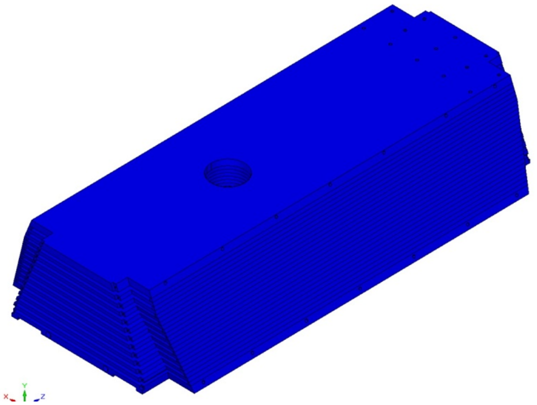
SMZ asked for **32 months and 376.74 MRb (5.4 M€)** for working documentation, manufacturing and assembly in Savelovo (Russia)

The cost estimation of the yoke barrel manufacturing made by GSI tendering specialist is **400 -480 k€**.

Cost estimation should take into account the real complexity of the manufacturing process

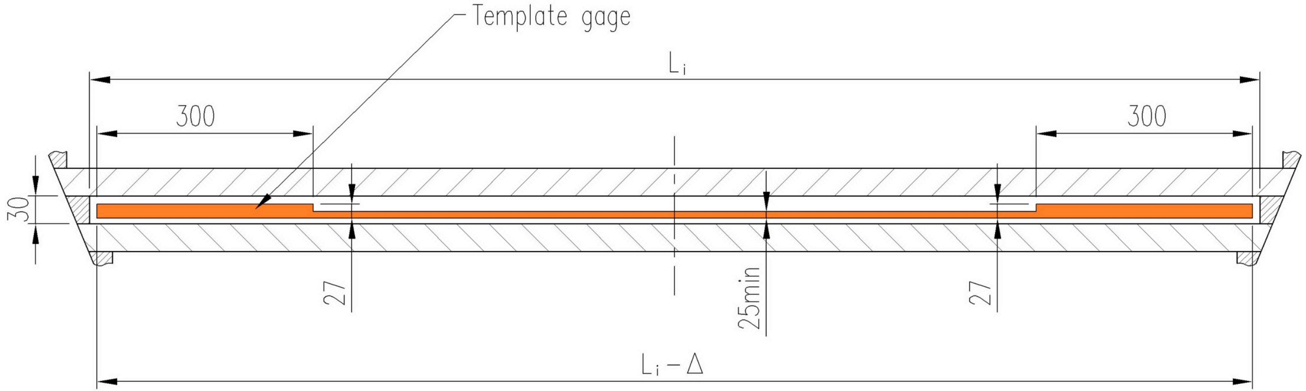
The nominal value of the gaps between the yoke beam sheets was chosen to be of 30 mm. This value was predetermined by Dubna Muon group on the basis of their practical experience.



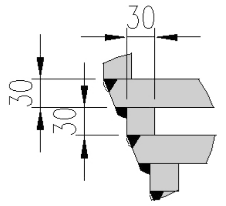


13 slots for muon panels provide an “ideal” configuration of the muon system

View A



View B



Resolving the technology issue of the yoke manufacturing

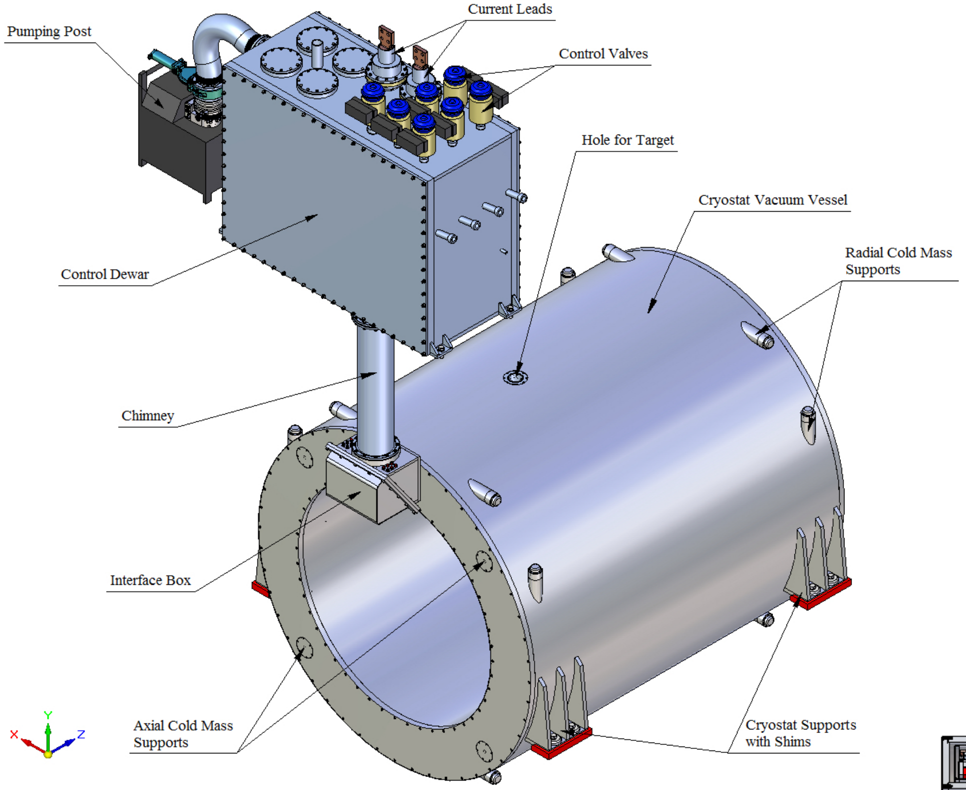
It became clear now that the producers (at list the Russian ones) can not provide requested technology deviations without preliminary modeling at list. We can expect two variants of conclusions on the results of modeling:

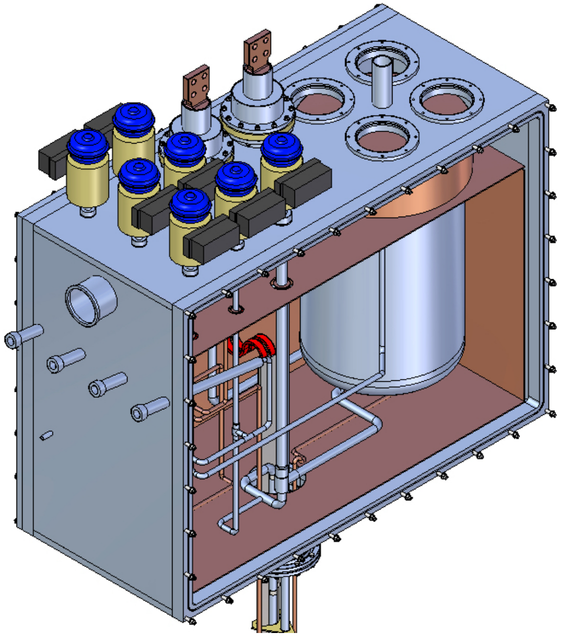
1. Nominal value of the gaps has to be increased up to the value clearly adapted for insertion. It would require some additional efforts to change the design of the magnet yoke, to make additional field and mechanical calculations.

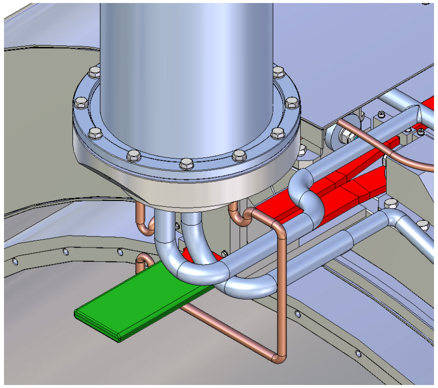
2. The gaps of 30 mm are kept. It may require a significant increase of the manufacturing cost of the yoke in compare with the previous case.

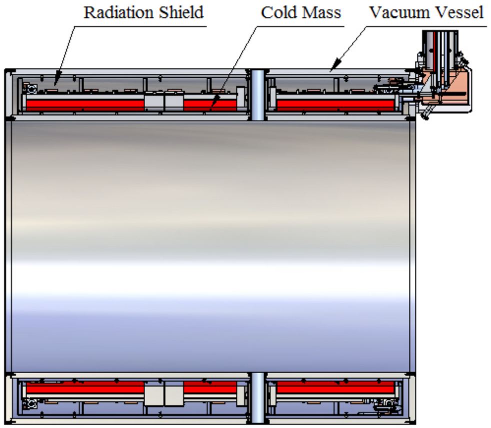
Of course it would be optimal to sign a contract for a certain number of layers (13, 12 or 11) without modeling.

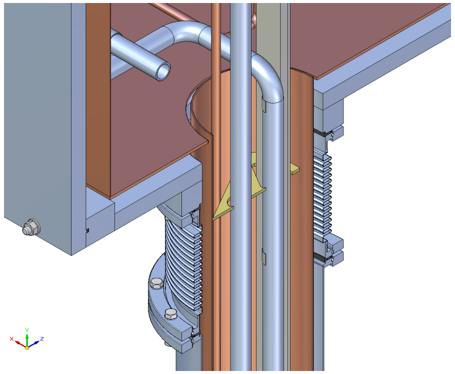
Cryostat and control Dewar





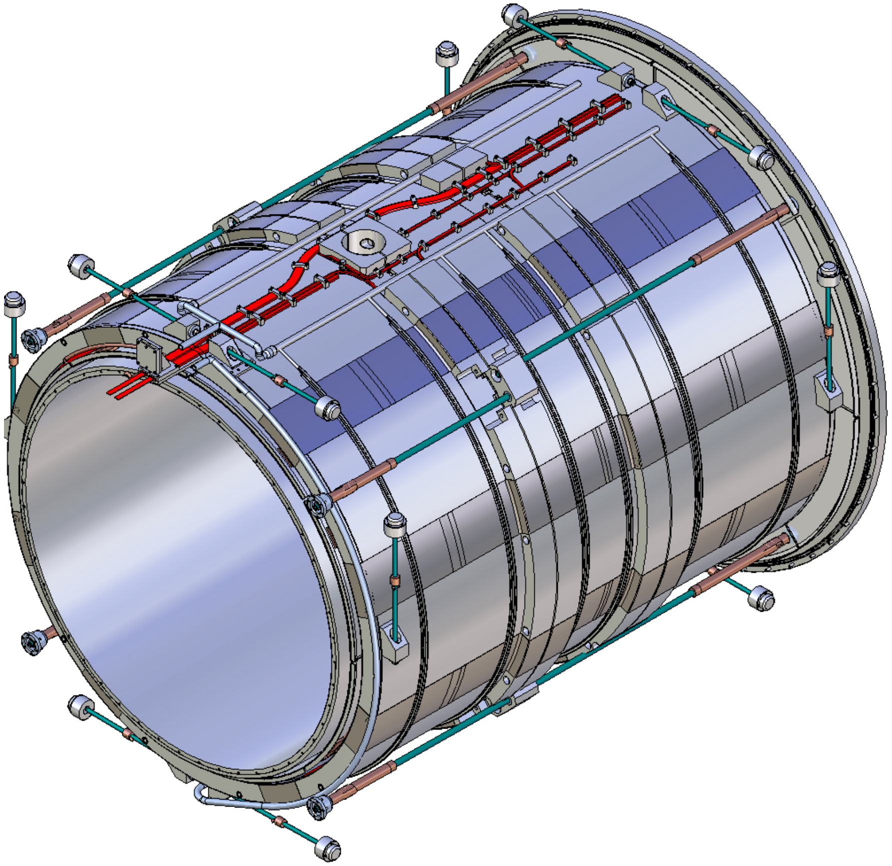






Suspension system of the cold mass

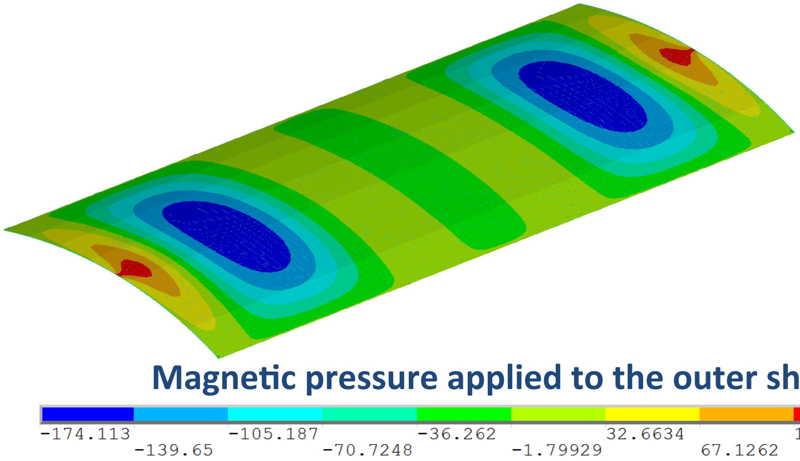
- All tie rods are made of Inconel 718. Diameter of 8 horizontal and 4 vertical tie rods of the radial suspension is 16 mm and diameter of 8 rods of axial suspension is 24 mm.
- The horizontal rods of the radial suspension are pre bended at RT to minimize the bending stresses in cold state
- According to computations static strength of the cryostat cold mass suspension system is ensured at Normal Operating Conditions and in case of a seismic accident under action of gravity and thermal loads and magnetic forces;
- High rigidity of the cold mass suspension system components, rigidity of the outer vacuum shell of the cryostat and of the attachments of the cryostat allows to minimize offset of the sc coil under action of the magnetic forces not more than **0.5 mm**.



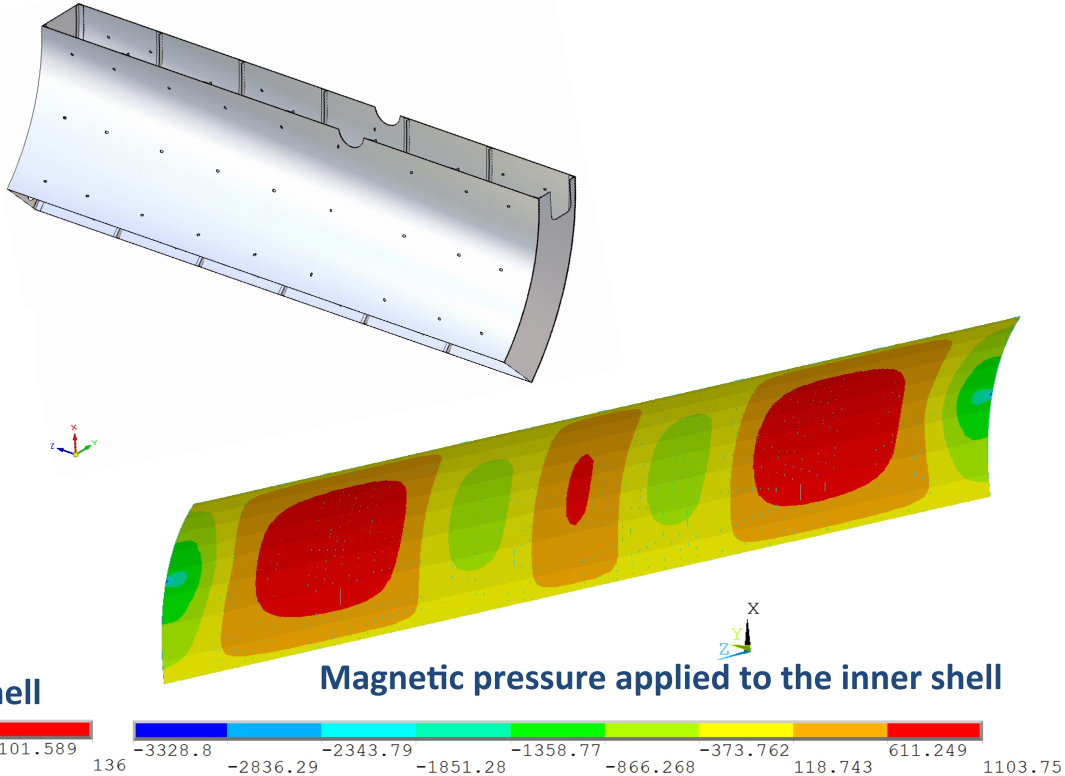
Analysis of magnetic forces applied to the thermal screen in the transient process of the sc discharge

Different options of separation of the thermal screen were considered. It was chosen the screen separated on insulated octants. The maximum magnetic pressure for the chosen design of the thermal shield is reduced up to 300 times as compared with a solid copper shell and up to 30 times as compared with the solid AL shell. The difference in the maximal magnetic pressure for quadrants and octants is 40%.

Maximal dI/dt in the transient process of the sc coil discharge
294 A/sek (τ=L/R ≈17 sek)



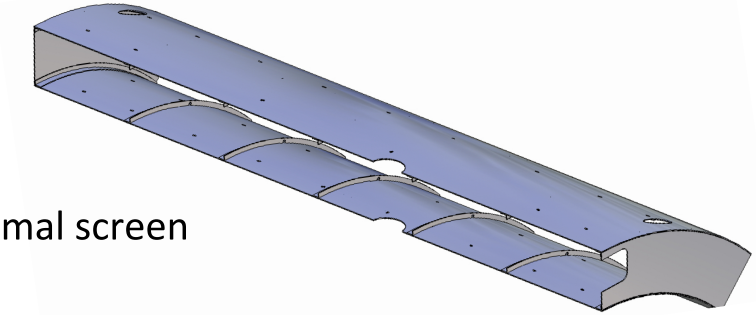
Magnetic pressure applied to the outer shell



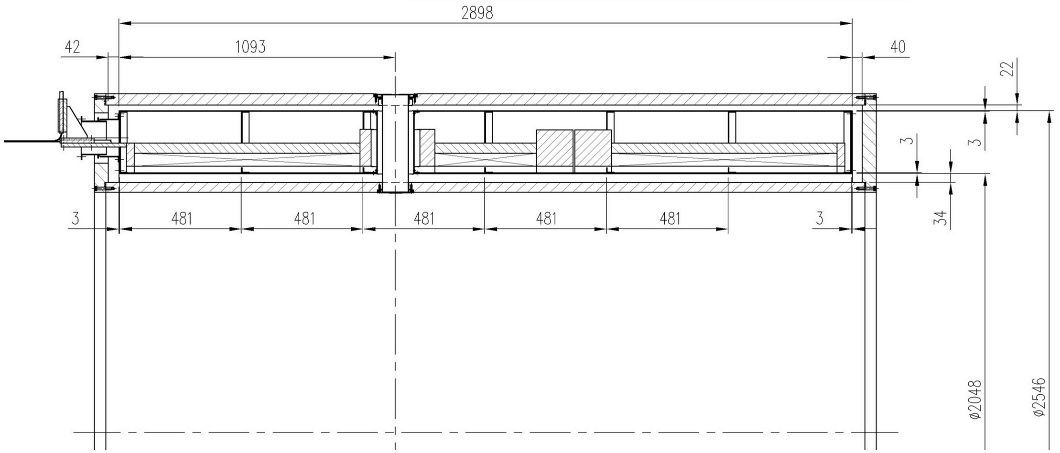
Magnetic pressure applied to the inner shell

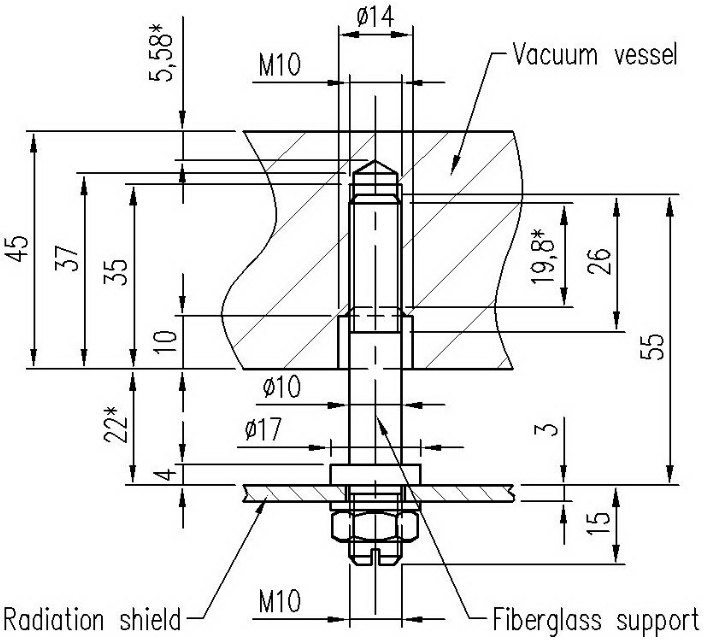
Optimized design of the thermal shield of the cryostat

- Design of the cryostat thermal shield cooled by gaseous helium was optimized to minimize the magnetic forces applied to it during protected energy relies of the sc coil.
- Dimensions and weights of the octant shells provide comfortable work with them in the process of the cryostat assembly.

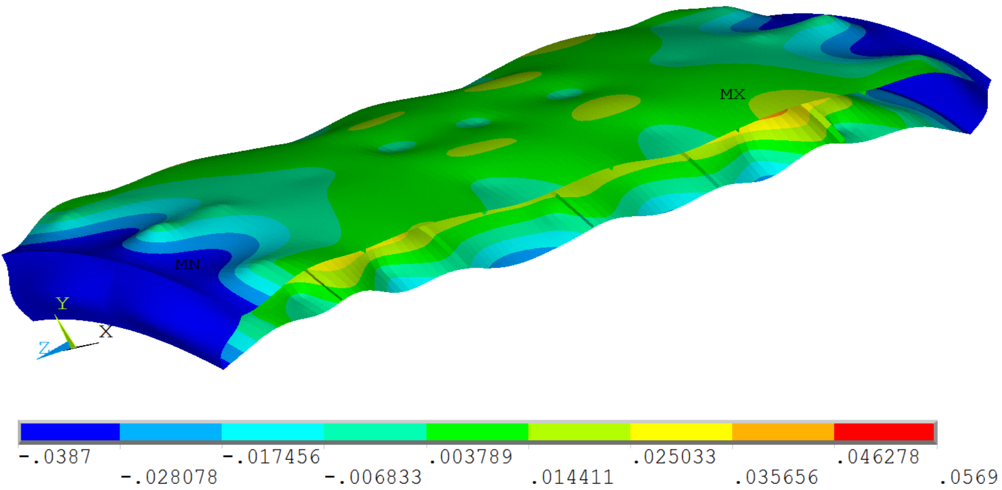


Material of the thermal screen
Al5083





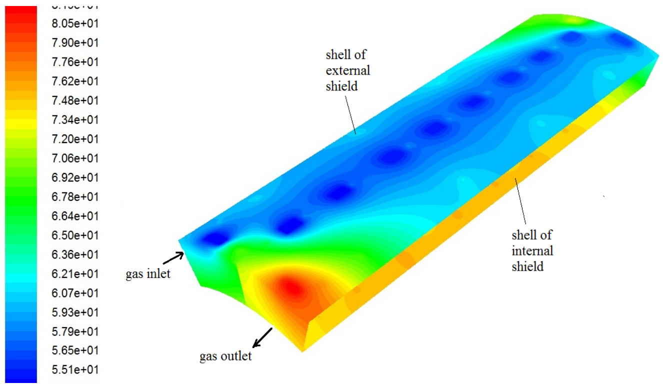
Analysis of Stress-strained state of the radiation shield



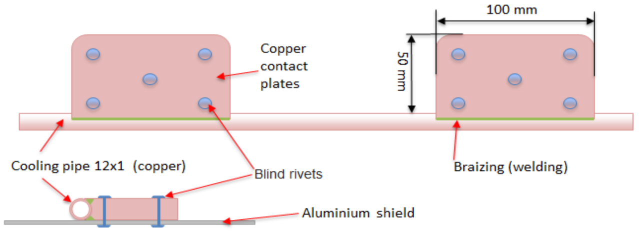
The distribution of radial displacements in an octant of the screen because of magnetic load, mm

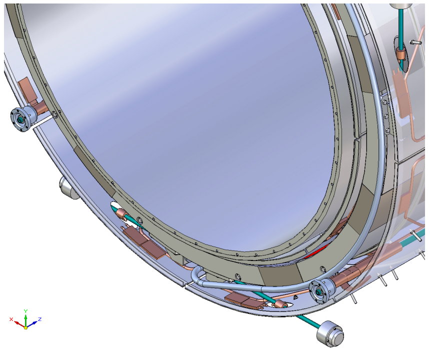
- In operation, the screen is exposed to gravity and thermal loads and to the electromagnetic forces
- The resulting stresses in the octants of the screen from thermal, magnetic and weight loads are not large and do not exceed **39 MPa**, which is less than the allowable stress 96 MPa.
- Biggest contribution to the the stress-strained state of the radiation shield makes thermal load.
- The contribution of magnetic load in the stress does not exceed **12%**
- Deflections of all parts of the octants do not exceed **0.06 mm** from the impact of the magnetic load and **0.63 mm** from the cool down to 60 K;
- **Thus, the conditions of static strength for all elements of the screen are provided**

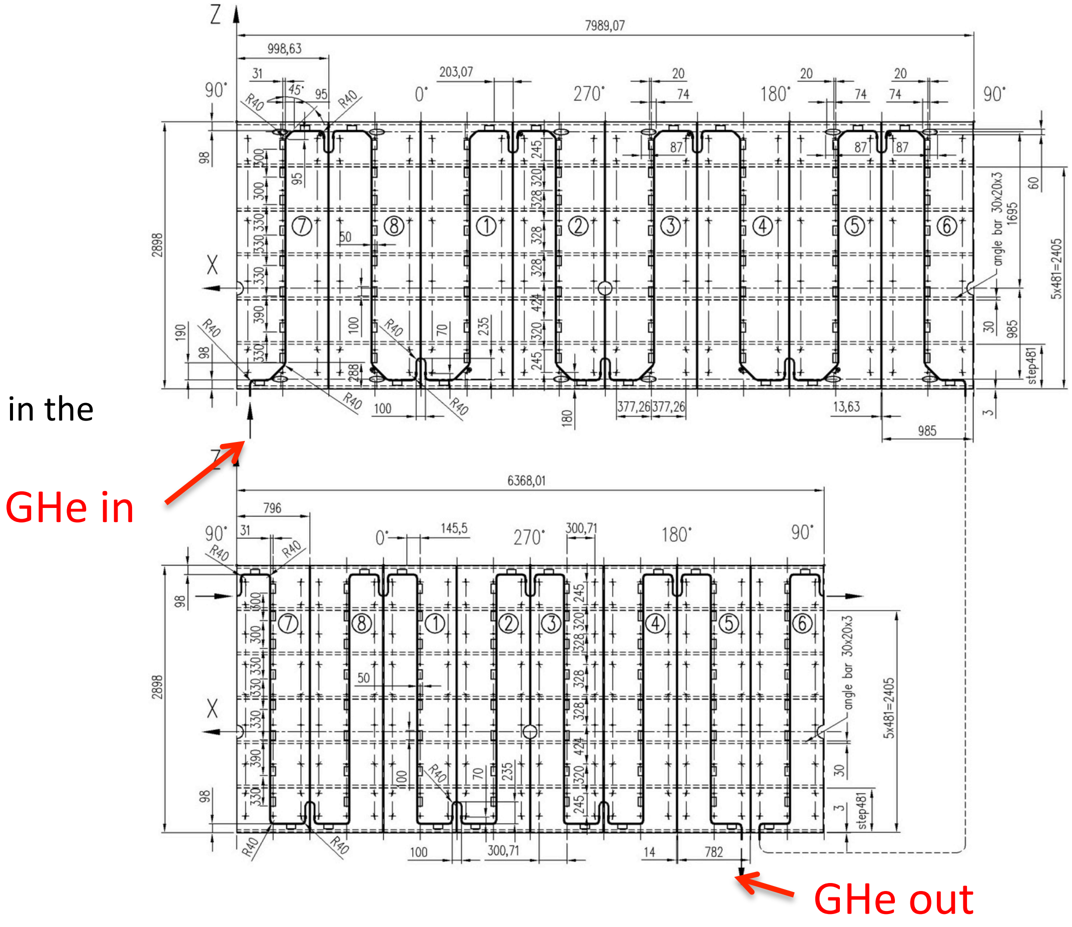
Thermal analysis



Temperature distribution of the most heated octant in the steady-state operation of the solenoid

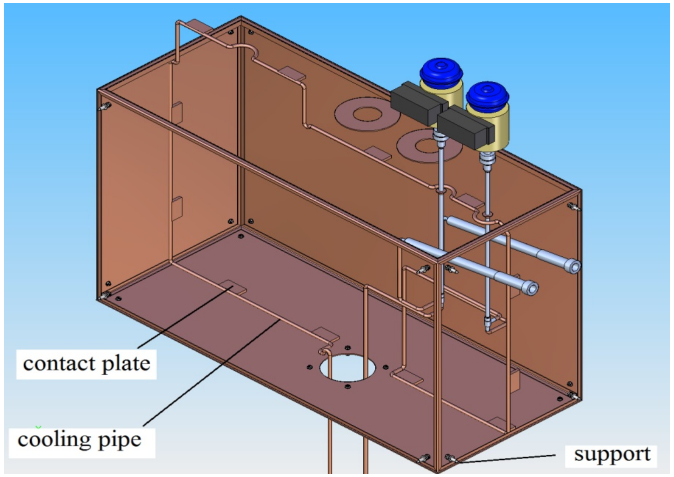


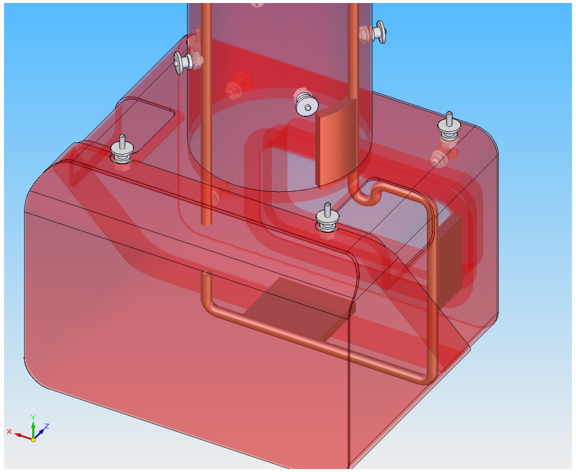


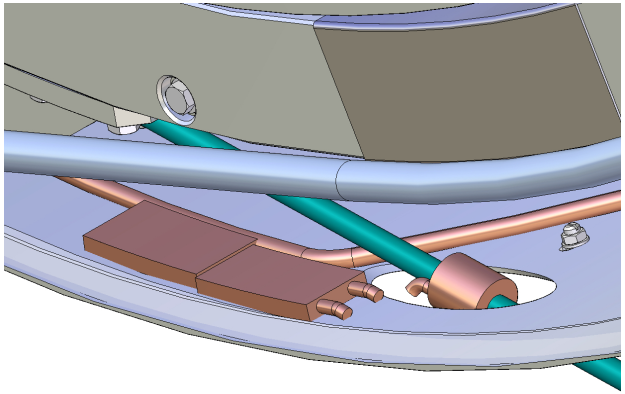


Positions of the heat interceptions of the suspension ties were chosen to minimize the temperature drop

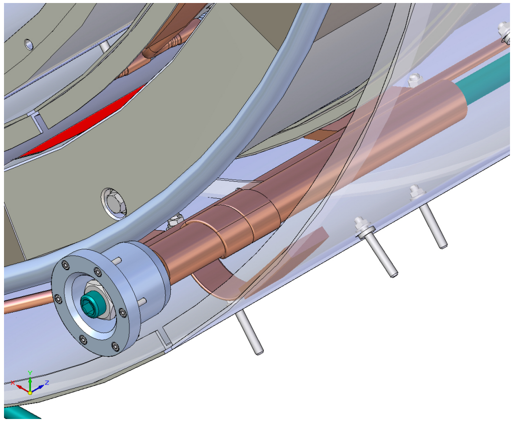
Thermal screens of the control Dewar and of the interface box. Heat interceptions of the suspension ties







Heat interception of a radial tie



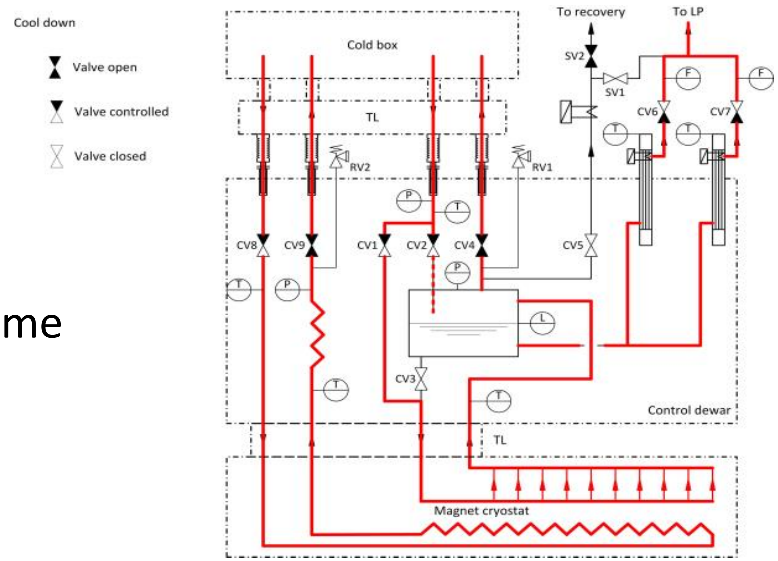
Heat interception of an axial tie

Heat loads to the cold mass and thermal shield

T=4.5 K	Thermal load, W
Cryostat	
Radiation	1.5
Heat inflow to the cold mass supports	2.6
Conductor joints	0.5
Gas load	0.5
Eddy current losses in the Al cylinder	11.5
Eddy current losses in the conductor	0.05
Cryogenic chimney and Control Dewar	
LHe vessel, tubing, valves, supports	3.3
Transfer line	9.7
Total (normal/transit regime):	**18.1/29.7**
With safety factor 2	**36.2/59.4**
Current leads	
without current	6.2 (10 l/h)
with current	10.5 (17 l/h)
T=60 K	
Cryostat	
Radiation	62.4
Heat intercepts of the coil supports	33.4
Shield supports	91.2
Gas load	2
Wires	1
Cryogenic chimney and Control Dewar	
Thermal screen, valves, supports	36.5
Transfer line	14.1
Total:	**240.6**
With safety factor 2	**481.2**

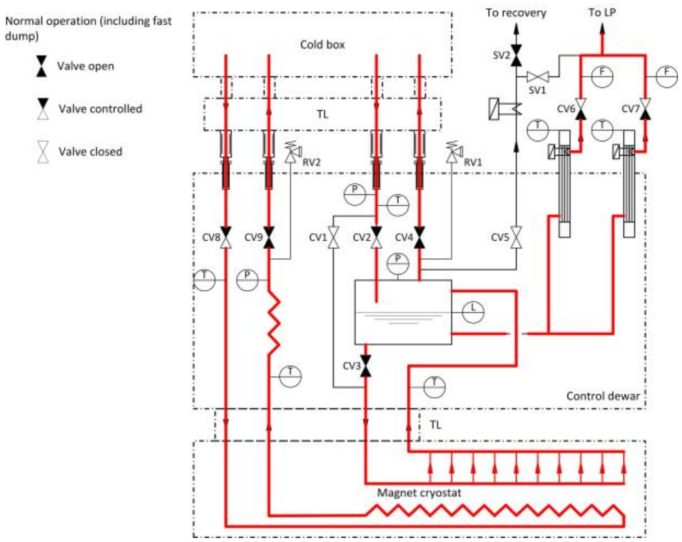
Operating regimes of the magnet ctyogenic

1. Cool-down regime 300 - 4.5 К
2. Steady-state and transit regime (normal operation)
3. Warm-up regime
4. Cooling of the thermal shields in the parking position
5. Emergency I (quench of the sc coil)
6. Cool-down after a quench
7. Emergency II (liquefier failure)
8. Emergency III (power failure)
9. Emergency IV (current lead failure - voltage rise above allowable level)
10. Emergency V (loss of vacuum)



Cool-down regime (300 - 4.5 К)

Steady-state regime (normal operation)



Parameters of the helium flows for discussions with the refrigerator producer

Object	Stream	Parameters	Regime		
			steady-state (normal operation)	**cool-down /warm-up**	**slow dump (refrigerator failure)**
Cold mass	incoming flow	gas/liquid	LHe (saturated liquid)	GHe	-
		flow	2.52 g/s (75.6 l/h)	2.5 g/s (1 K/h)	-
		temperature	4.5 K	300 – 4.5 K	-
		pressure	1.3 bara	≤ 10 bara	-
		vapor quality	< 5 %	-	-
	return flow	gas/liquid	GHe (saturated vapor)	GHe	-
		flow	1.95 g/s	2.5 g/s (1 K/h)	-
		temperature	4.45 K	300 – 4.5 K	-
		pressure	1.25 bara	≈ 1.5 bara	-
Current leads	–	gas/liquid	GHe	-	GHe
		flow	0.57 g/s (17 l/h)	-	0.57 g/s (17 l/h)
		temperature	≈ 300 K	-	≈ 300 K
		pressure	1.25 bara	-	1.25 bara
Thermal shield	incoming flow	gas/liquid	GHe	GHe	-
		flow	2.3 g/s	2.3 - 5.2 g/s*	-
		temperature	40 K	300 – 40 K	-
		pressure	2 bara	1 – 4.2 bara	-
	return flow	gas/liquid	GHe	GHe	-
		flow	2.3g/s	2.3 - 5.2 g/s*	-
		temperature	80 K	300 – 80 K	-
		pressure	1.5 bara	≈ 1.5 bara	-
Recovery line	–	gas/liquid	-	-	GHe
		flow	-	-	2.15 g/s (64.5

Status of the cryostat and control Dewar

To date,

stp file and assembly drawings of the cryostat with control Dewar and cold mass have been prepared,

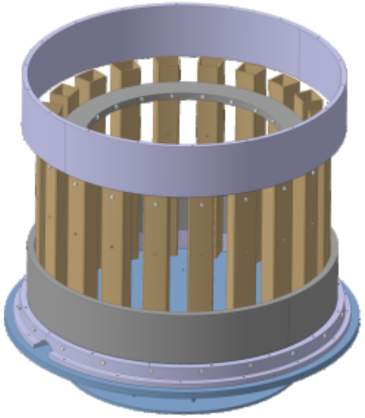
and the following computations have been completed to substantiate the cryostat design:

- Computations of the electrodynamics forces applied to the radiation shields of the cryostat during energy relies from the superconducting coil to the protective resistor;
- Computations of the deflected mode of the cryostat, control Dewar and cold mass suspension system;
- Computations of the stress-strain state of the radiation shield of the PANDA magnet cryostat;
- Computations of the cooling system of the superconducting PANDA magnet;
- Computations of cryogenic parameters of the PANDA solenoid cryostat and control Dewar

- In accordance with a preliminary estimation prepared by BINP the Cost of manufacturing of the Cryostat with Control Dewar is **2778 KEuro**.
- JINR has to complete the technical design of the cryostat and to transmit it to BINP until the middle of 2016.

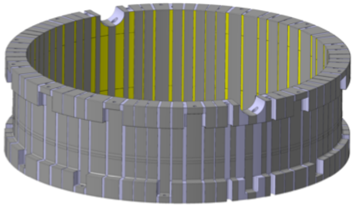
Cold mass. Coil winding and assembly

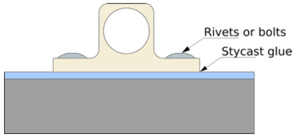
(CERN presentation of September 2015)

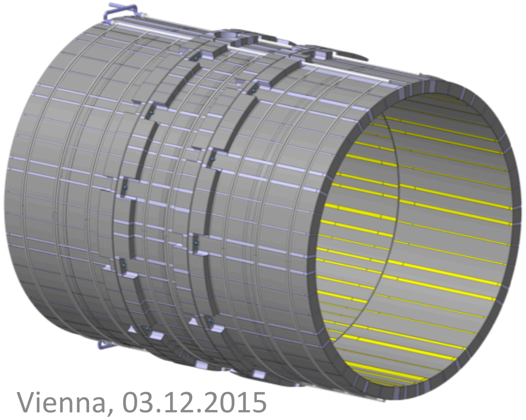


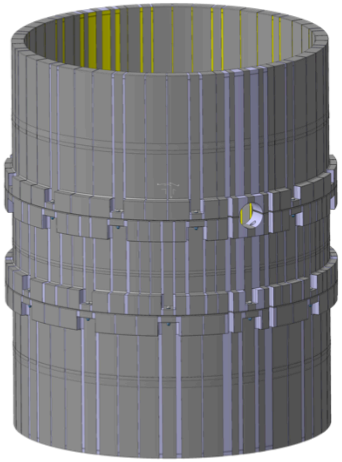
CERN team intends to apply a very advanced technology of the sc coil manufacturing instead of traditional winding the coil onto the inner surface of the support cylinder. The support cylinder and 6 layer coil are split up into three sections. It is planed to use rectangle aluminium stabilized sc cable 7.9x10.9 mm^2 instead of traditional for detector magnets flat cables wound on edge. The sequence of winding and assembly of the cold mass is as follows:

1. Coil winding on a collapsible mandrel
2. Vacuum impregnation and curing epoxy
3. Machining of coil outer surface
4. Machining mating support cylinder
5. Shrink fit cylinder on coil windings
6. Place closing flange
7. Remove module from mandrel
8. Glue aluminium strips
9. Connect the three different modules
10. Install cooling pipes
11. Make the electrical joints
12. Add instrumentation









Status of Cold mass for September 2015

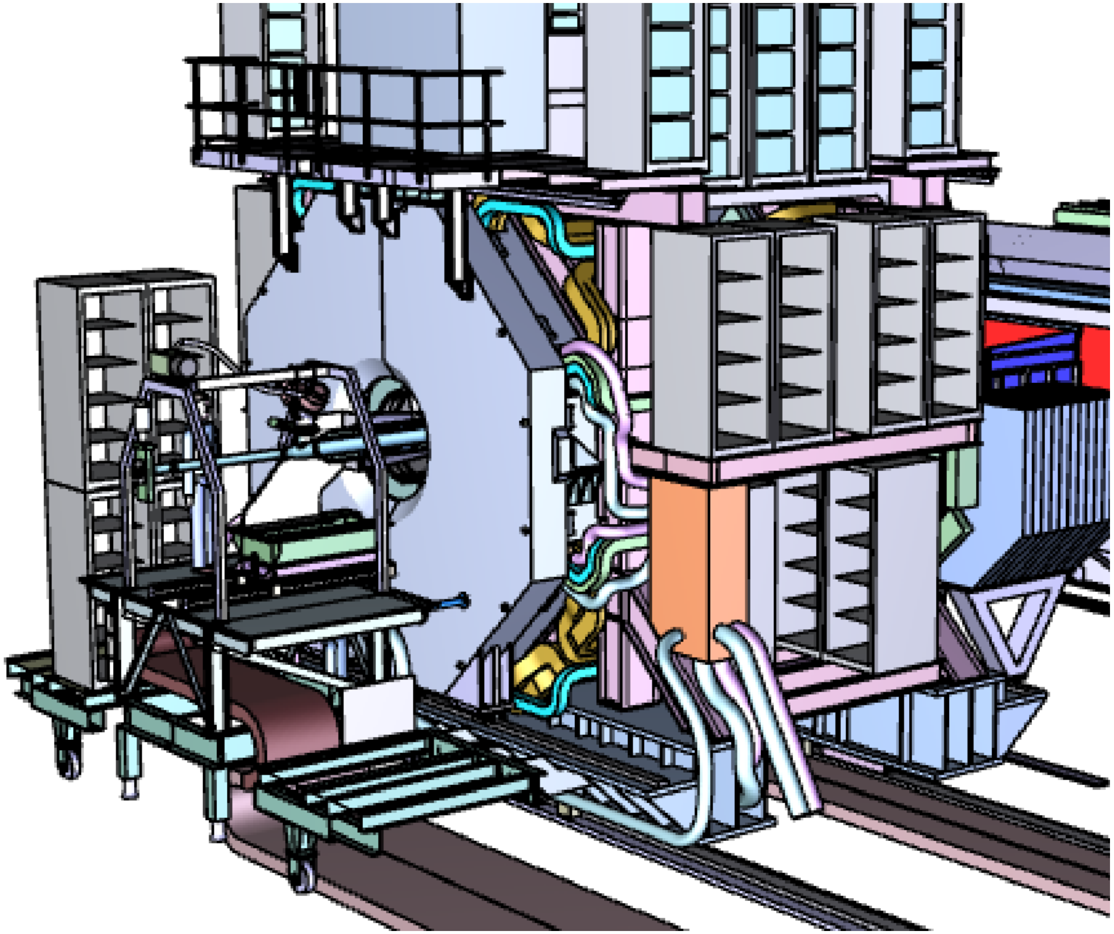
(CERN presentation of September 2015)

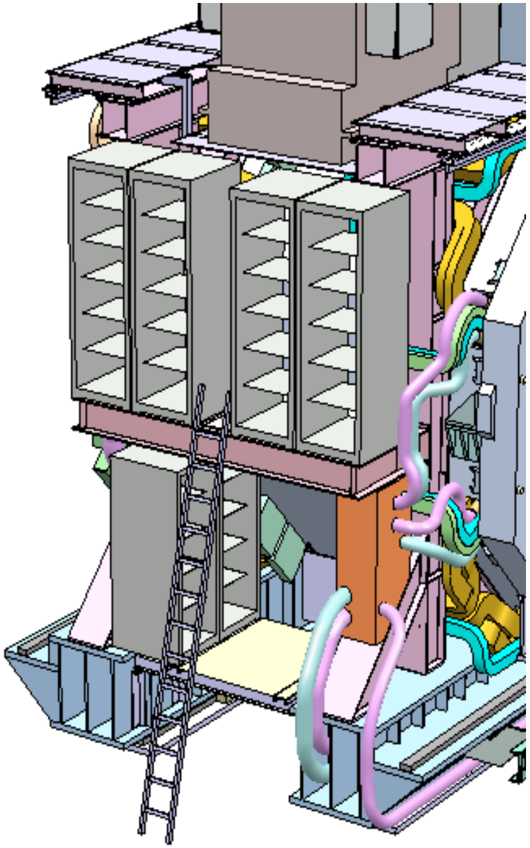
- Conductor specifications and tender documents ready.
- Cold mass magneto-structural analysis and thermal analyses completed.
- Cold mass design and integration scenario in advanced state, ready for discussion with potential suppliers to get feed back on production methods and tooling.
- Next steps is consulting few companies to investigate their manufacturing options and tooling and to finalize the default cold mass, coil winding and assembly scenario.
- Cold mass technical specification drafted, waiting for company feedback to fine tune the scope and splitting of work packages.
- At CERN the coil integration and test area is being prepared.
- Essentially design and engineering for cold mass is almost completed.

What remains to be done next year for finalization of the magnet Technical Design?

- Final correction of the 3D model and assembly drawings of the cryostat and control Dewar to take into account the latest changes of the the cold mass design
- Elaboration of the assembly procedures of the cryostat and control Dewar.
- Final correction and coordination of the magnet parameters by all parties
- Preparation of the Technical descriptions and Technical Specifications for manufacturing of the cryostat and cold mass

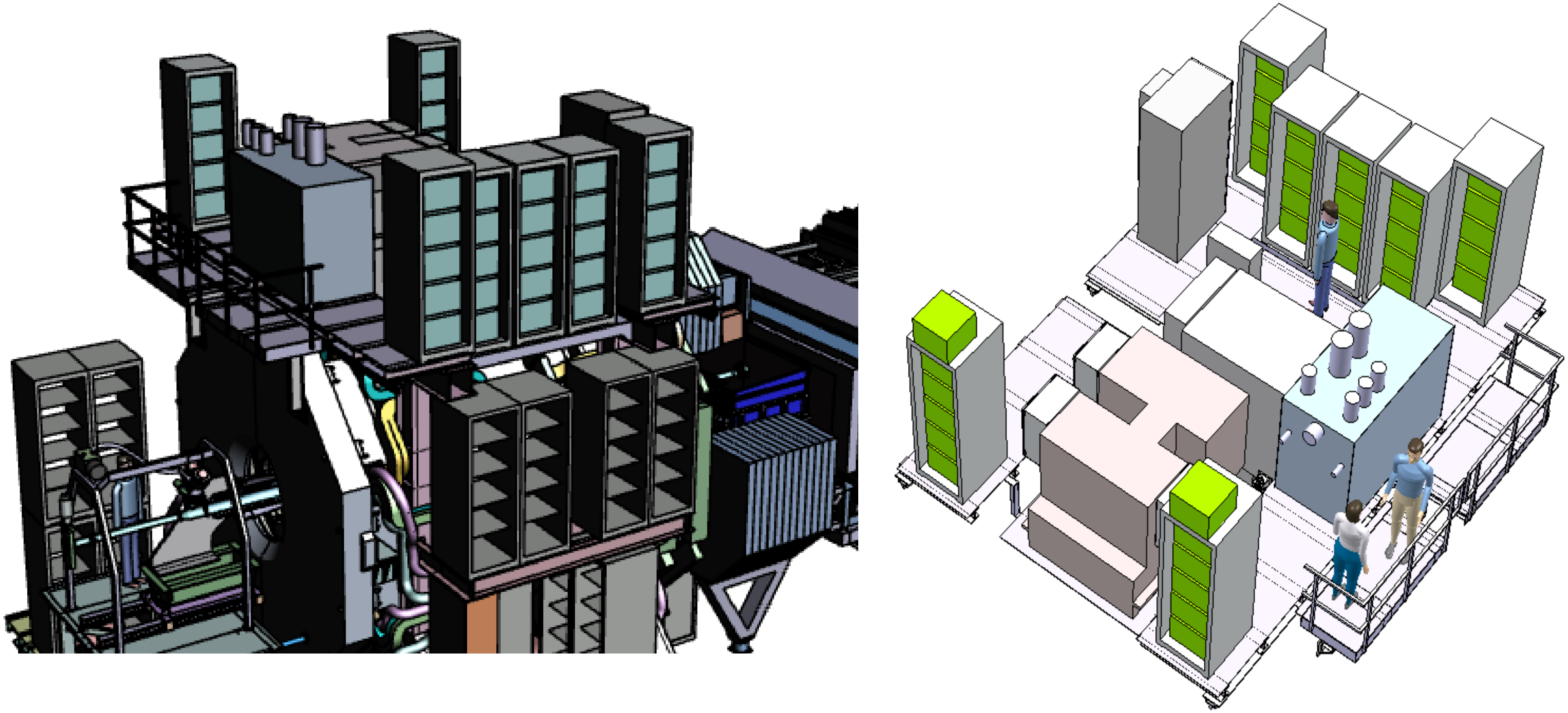
Lack of space to serve the magnet units





It takes interface coordination of the access to the hydraulic tools (for magnet and magnet doors lifting and moving) and to the bolts fixing the doors

Luck of space at the top platforms



It takes interface coordination of areas for service of the Control Dewar and Target equipment

THANK YOU
FOR YOUR ATTENTION!