Update PANDA solenoid design

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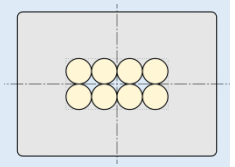
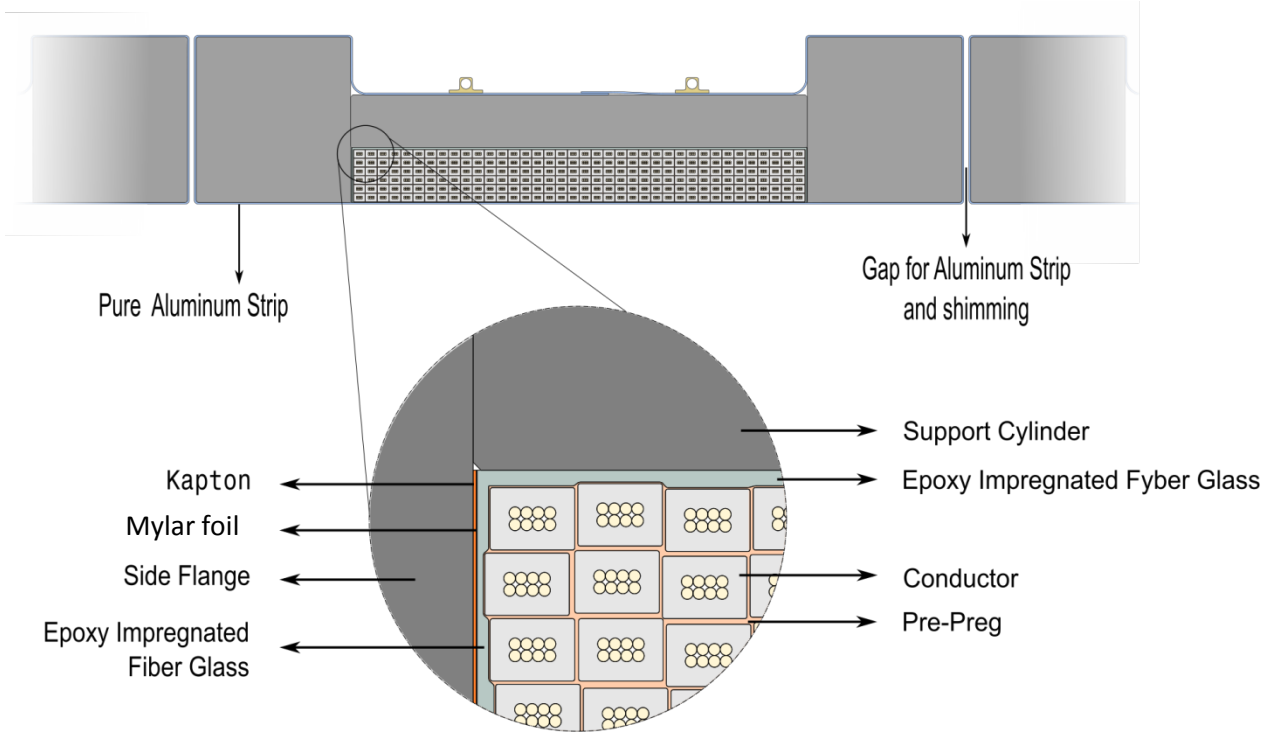
1. Conductor

Parameter	Value
Layout	
No. of strands	8
Strand diameter [mm]	1.4
Cu / nonCu ratio	1.0
Cable dimensions [mm]	2.6 x 5.3
Conductor bare dimensions [mm] @ 4.5 K	7.9 x 10.9
Temperature margin ΔT [K]	2.4

- **Final conductor** design is an 8-strands Al-stabilized Rutherford cable with low height-to-width-ratio.
- **Conductor specification** is available at
- *https://edms.cern.ch/edmsui/#!master/navigator/document?D:1384383179:1384383179:subDocs*
- Draft **tender documents** are **ready**.
- Two companies identified with confirmed interest for production: Hitachi and Furukawa.
- **Discussion** with Furukawa about **conductor** inspection **tests**.
- **We** are **waiting** for budget release needed for launching the **tender**.
- **Procurement delay** due to waiting-for-budget is now **9** months.

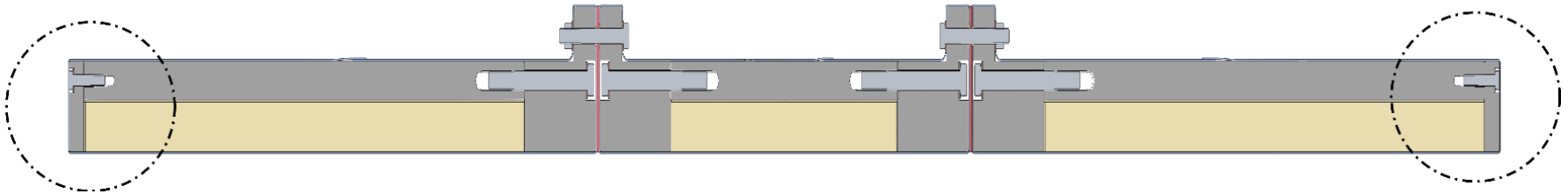
2. Cold mass layout

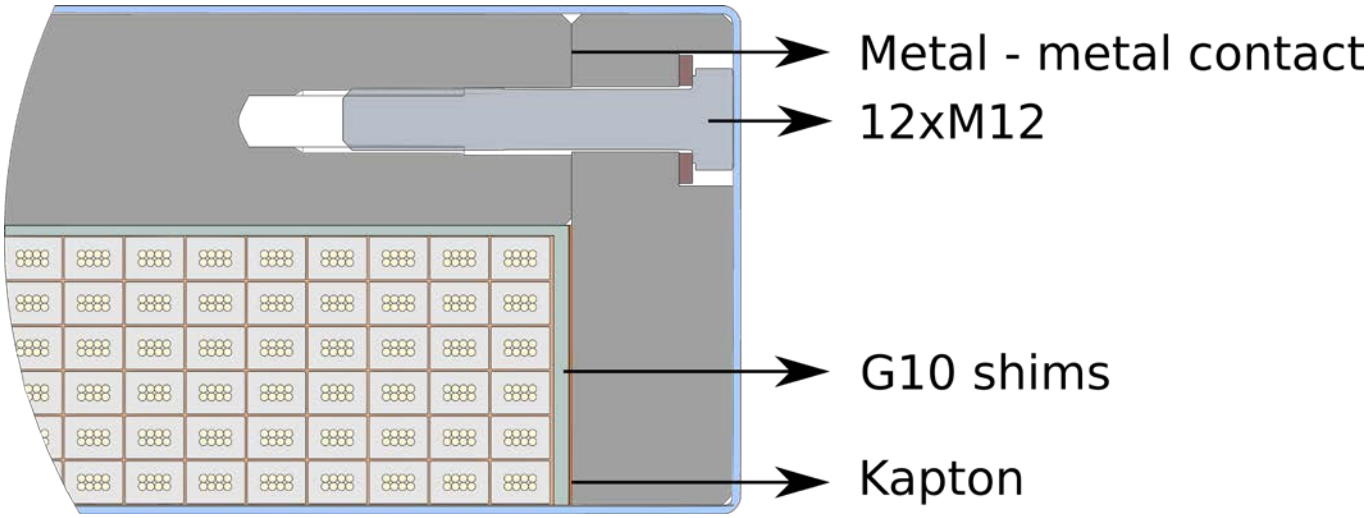
- Built in 3 sections, bolted together.
- **Connections will rely on friction**.
- No gaps between flanges and cylinder.
- FRP **shims** used **to compensate** for winding **deviations.**



Parameter	size @ 4.5 K	size at @ 300 K
r [mm]	1050.1 < r < 1099.9	1054.4 < r < 1104.4
$z_{upstream}$ [mm]	-1024.9 < z < -143.50	-1029.1 < z < -144.1
z_{center} [mm]	157.25 < z < 552.75	157.90 < z < 555.02
$z_{downstream}$ [mm]	853.5 < z < 1734.9	857.02 < z < 1742.02

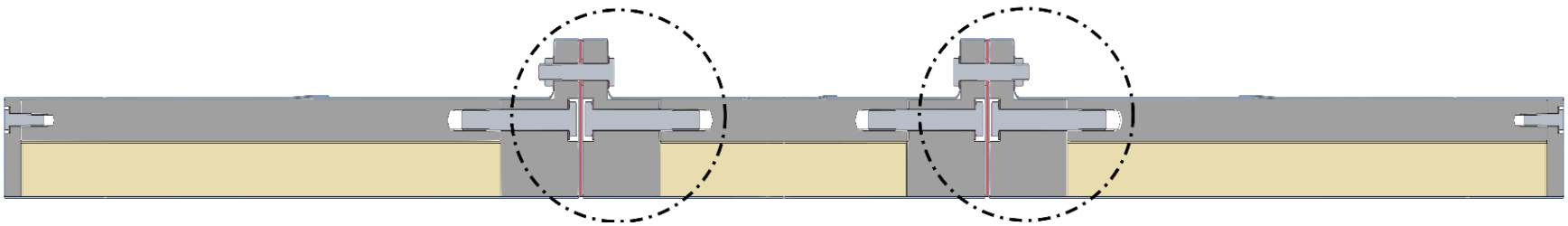
3.1 Interfaces between coil modules

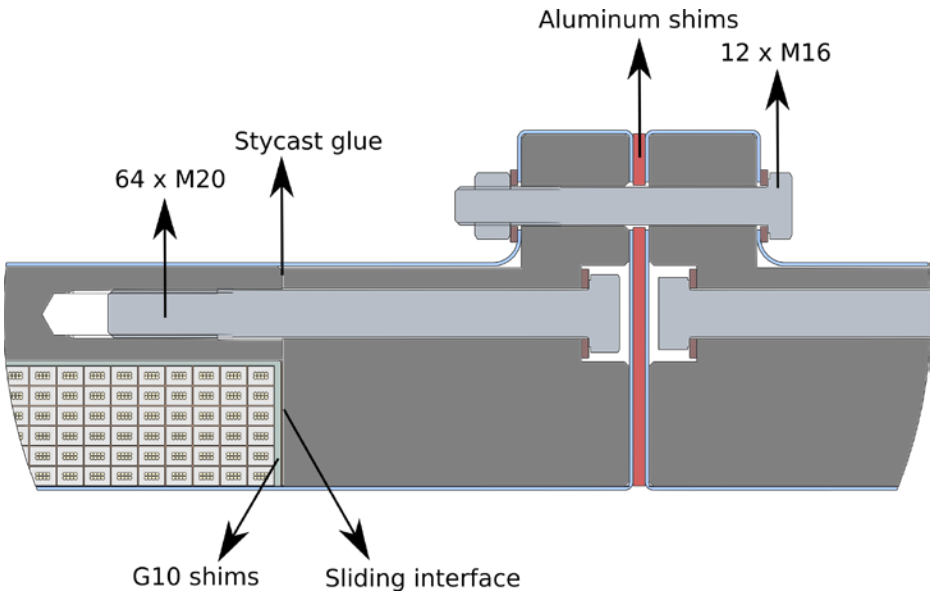




- Bolt load: end flange load is by **weight of the flange** only (all forces directed z-inwards)
- Connection designed to hold the mass of the cold mass in tension.

3.2 Interfaces between coil modules



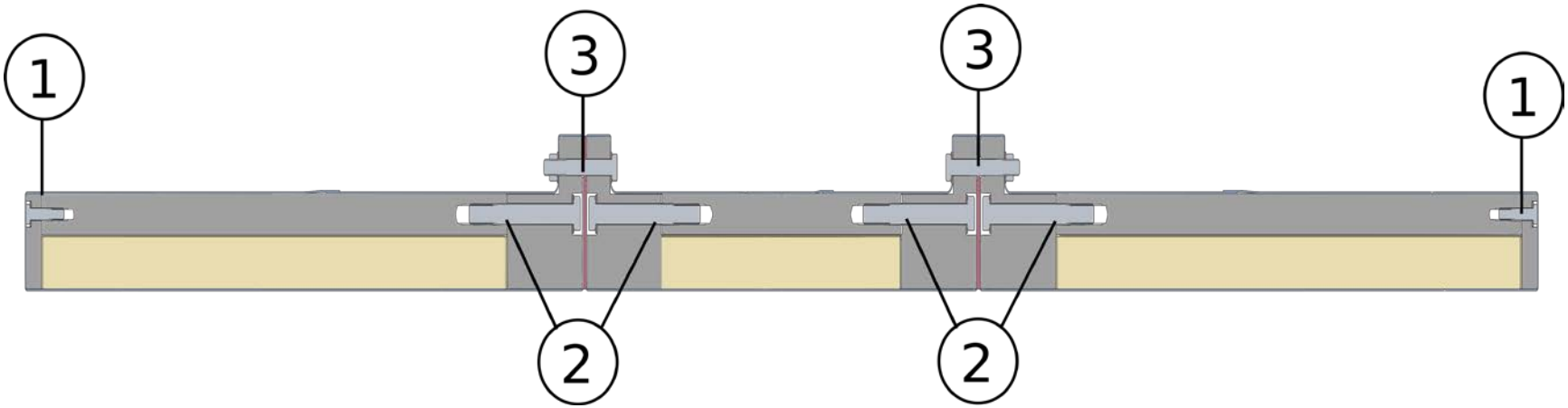


64 bolts M20 between cylinder and flange needed to warrant friction, to stand the radial forces.

12 bolts M16 between flanges to hold the weight of the central module.

Compressive forces reduce the pretension of the bolts.

3.3 Interfaces between coil modules

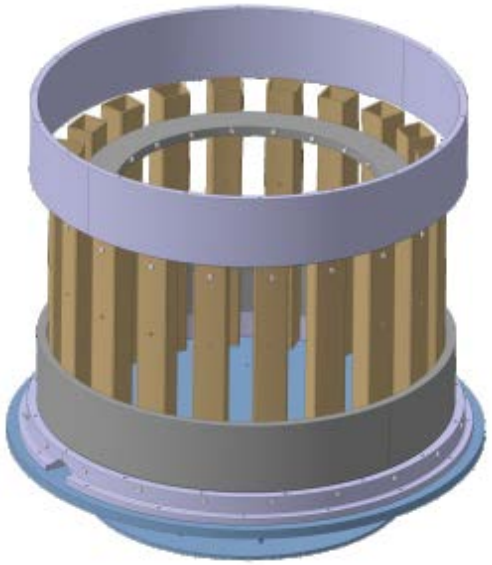


	Bolt material	Number bolts	Type of bolt
1: small flange to cylinder*	Al 7075-T73	12	M12 x 65
2: big flange to cylinder	Al 7075-T73	66	M20 x 200
3: big flange to big flange	Al 7075-T73	12	M16 x 120

** Force will be experienced during assembly. All contacts are slip critical.*

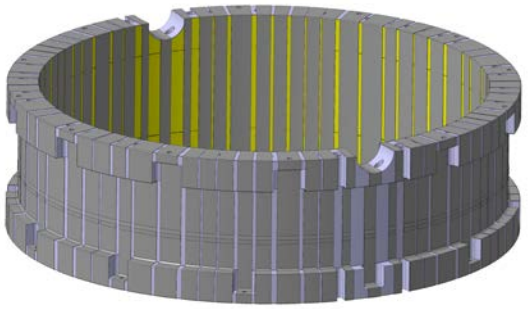
4.1 Cold mass assembly

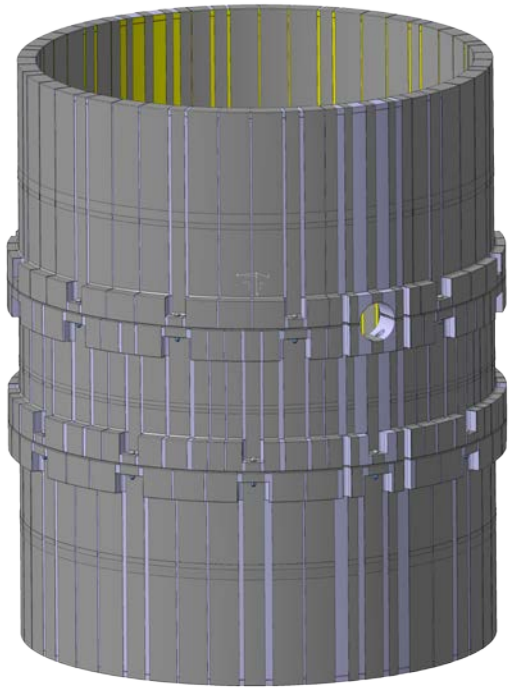
1. Production of a collapsible mandrel
2. Coil winding
3. Curing of the coil
4. Machining of coil outer surface
5. Machining mating cylinder
6. Shrink fit cylinder on coil windings



4.2 Cold mass assembly

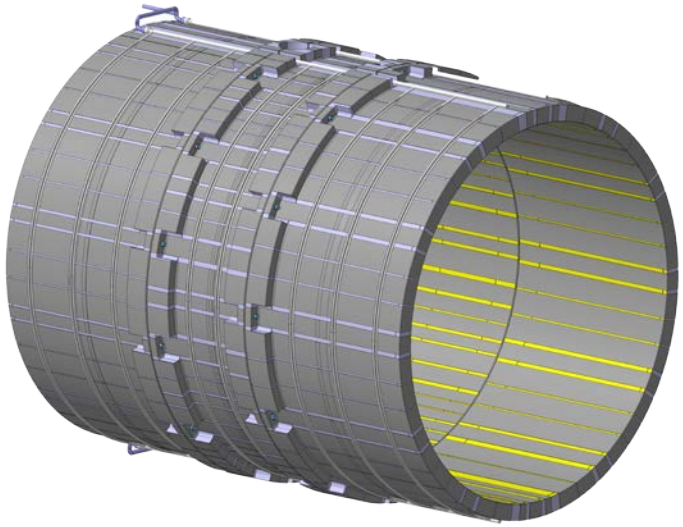
1. Production of a collapsible mandrel
2. Coil winding
3. Curing of the coil
4. Machining of coil outer surface
5. Machining mating cylinder
6. Shrink fit cylinder on coil windings
7. Put in place closing flange
8. Remove module from mandrel
9. Glue aluminium strips
10. Connect the three modules with adapted axial shims

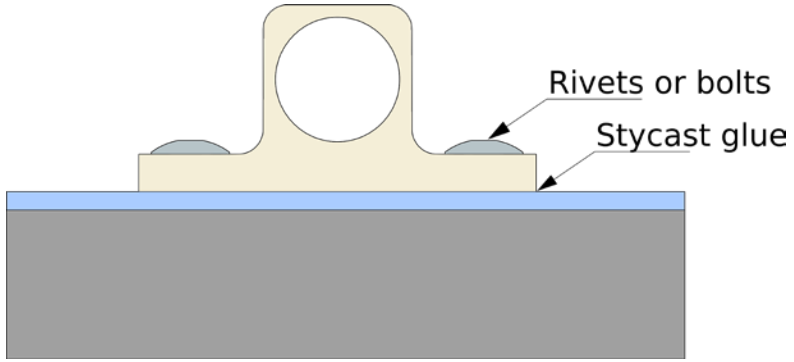




4.3 Cold mass assembly

1. Production of a collapsible mandrel
2. Coil winding
3. Curing of the coil
4. Machining of coil outer surface
5. Machining mating cylinder
6. Shrink fit cylinder on coil windings
7. Place closing flange
8. Remove module from mandrel
9. Glue aluminium strips
10. Connect the three different modules using adaptive shims
11. Install cooling pipes
12. Make the electrical joints
13. Add instrumentation
14. Finishing touch



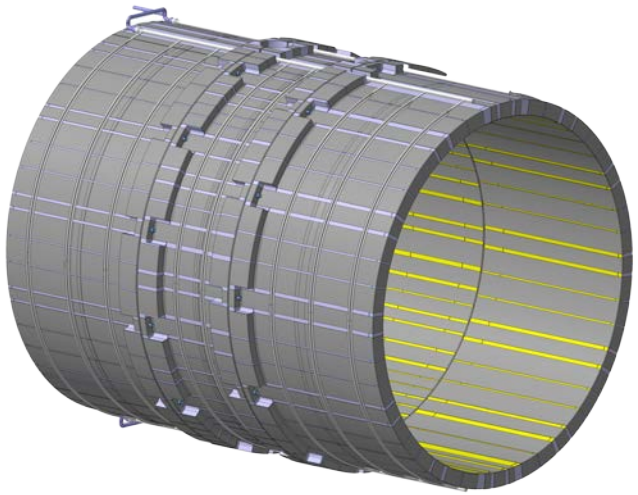


5. Cold mass, mass distribution

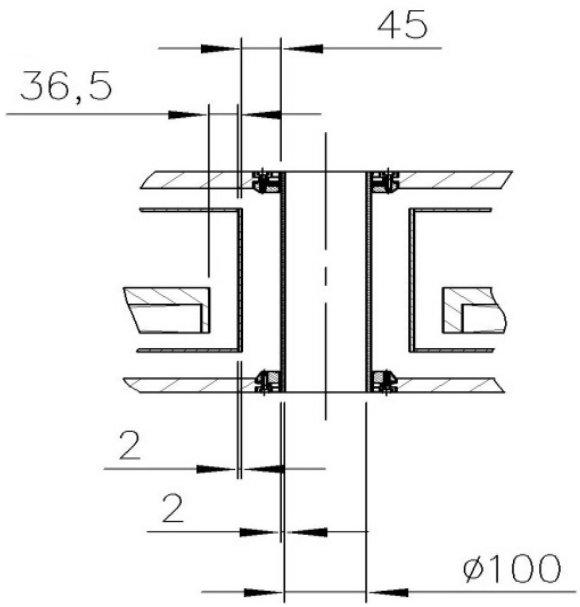
Parameter	Value	
	Volume [m^3]	Mass [t]
Coils pack	0.775	2.6
Flanges	0.573	1.5
Support cylinders	0.612	1.7
Aluminum strips	$6x10^{-2}$	0.16
Bolts	$2x10^{-2}$	0.06
Cooling pipes	$1x10^{-2}$	0.03
Shims	$1x10^{-2}$	0.03
Total	2.1	6.1

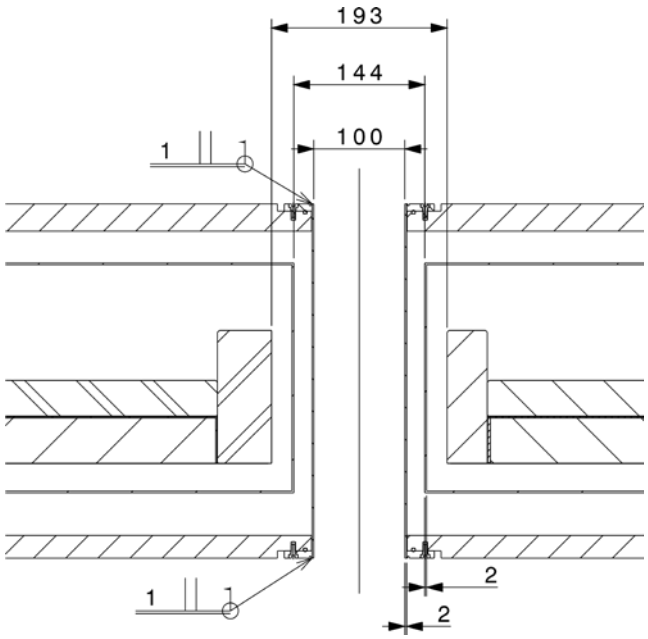
Advantages 40 mm cylinder over 30 mm:

- Stiffer thus **easier to handle and machine** inner surfaces for fitting.
- Additional rigidity for bolting.
- 10% **increase** in coil **safety factor** (1.4).
- **Less overlap** (0.15mm) for shrink fit allows more gap of 1.5 mm for assembly (0.15mm)**.

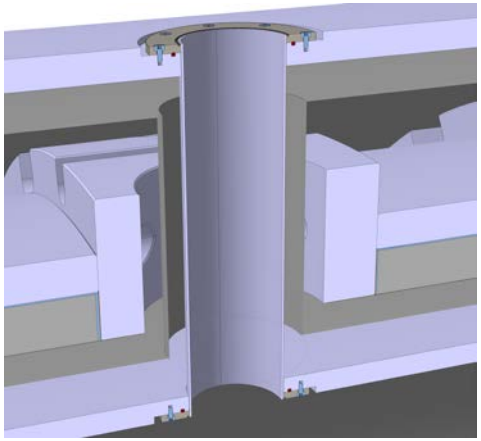


6. Cryostat: interface to passage for target



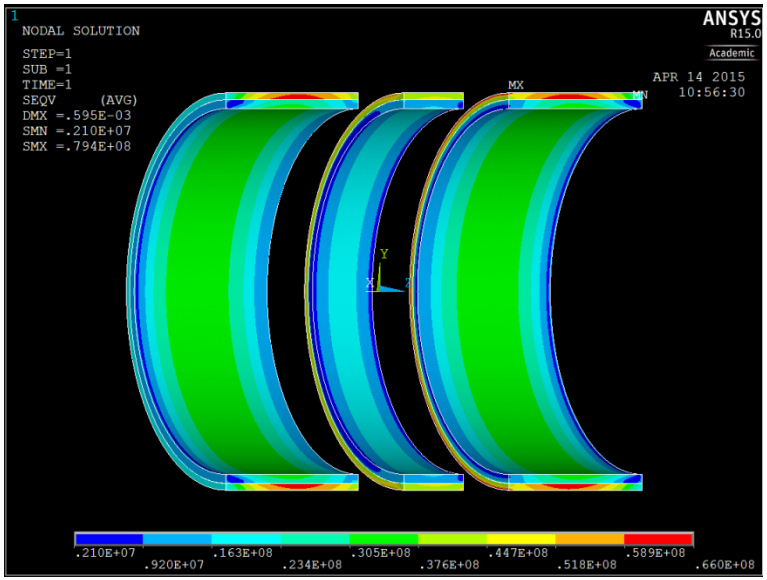


- Current hole **Ø of 267 mm makes flanges** locally thin and **weak** for handling.
- Diameter of the target holes on the cold mass will be 193 mm.
- Alternative design to accommodate smaller hole on cold mass is proposed.
- **New** target holes diameter is reduced.



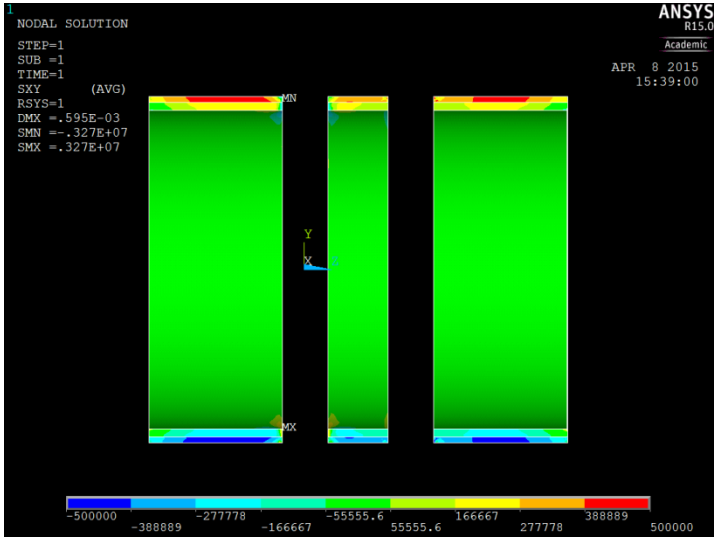
7. Magneto-structural analysis

Magneto-structural analysis including up-to-date coil/casing dimensions, yoke and all assembly steps (shrink fit, cool down and coil powering) **is completed**.



Step	Max stress on coil [MPa]	Max stress on casing [MPa]
Shrink fit	18	25
Cool down	17	27
Coil powering	36	66

Maximum **shear stress** at **coil-casing interface** 0.5 MPa, thus well **below** the **epoxy limit** of 3 MPa.



8. Thermal analysis

Completed the assessment of **thermal loads** on the **cold mass** (cryogenic chimney and dewar excluded). **Total load** (including safety factor 2) **30 W.**

Next: 3D FEM analysis to **optimize cooling pipes** and **Al-strips** positions & dimensions.

Component	Q [W]	Model details
Eddy current in Casing*	11.5	3D FEM Up-to-date geometry
Eddy current in Conductor *	0.05	Mixed (FEM + analytic)
Radiation**	1.5	Analytic
Residual gas***	0.5	Analytic
Conduction (Axial & Radial supports)	1.1	Analytic
6 joints (0.25 nΩ, 1 m long)	0.5	2D FEM

** Current ramp time = 2000 s.*

*** For a thermal shield temperature of 60 K and no superinsulation.*

**** For an operating pressure of 2e-6 mbar.*

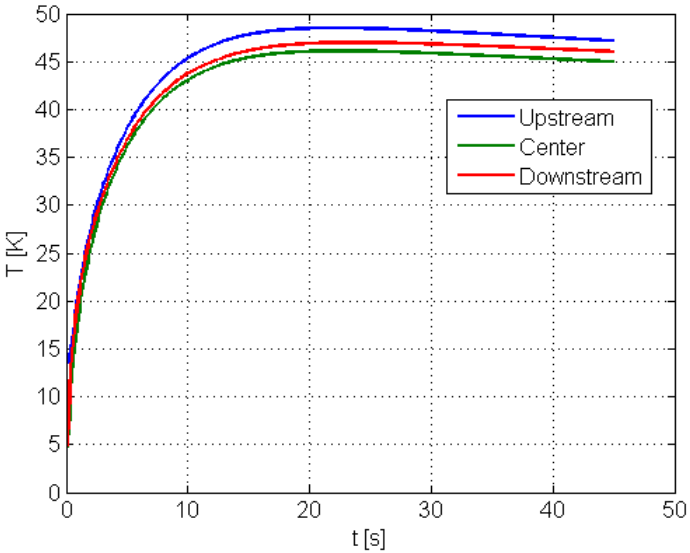
9. Quench analysis

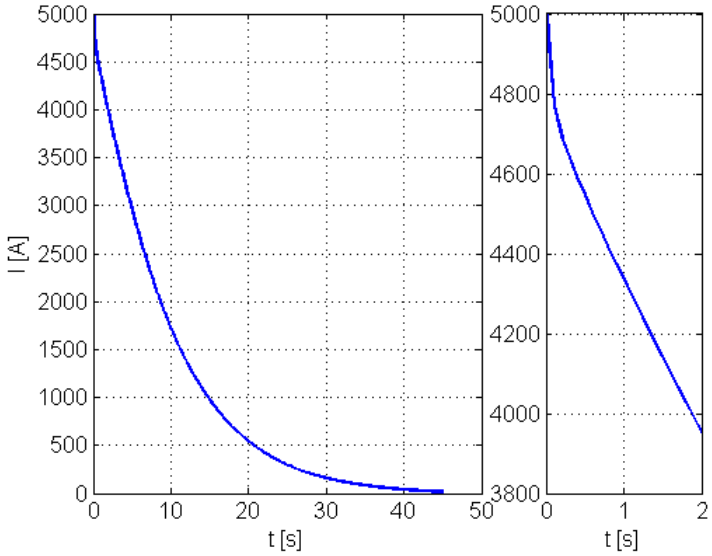
Update of **quench analysis** from September 2014 to account for **6-layers coil design.**

Model details:

- All turns included
- Casing included to model quench back
- Spacers between coil made of epoxy (worst case assumption)

Data for quench origin at turn 1, inner layer of upstream coil.





Peak coil **temperature 45-50 K.**

10. Conclusion and next steps

- Conductor specifications available in EDMS and tender documents ready.
- Magneto-structural analysis of the cold mass completed.
- Thermal analysis of the cold mass to be completed in the coming months.
- 6-layers coil design does not pose problems from quench point of view. Use of quench heaters does not seem necessary given peak temperature and voltage.
- Cold mass design and integration scenario in advanced state, finalization of details in progress.
- Next step is to consult few companies to investigate their manufacturing options and tooling and to finalize the default cold mass coil winding and assembly scenario.
- Issue Cold Mass Technical Specification and tendering documents.
- In parallel at CERN the coil integration and test area is being prepared.
- We need budget for conductor and coil winding, almost linear project delay now!