MDI MECHANICAL MODEL AND MOCKUP PLANS

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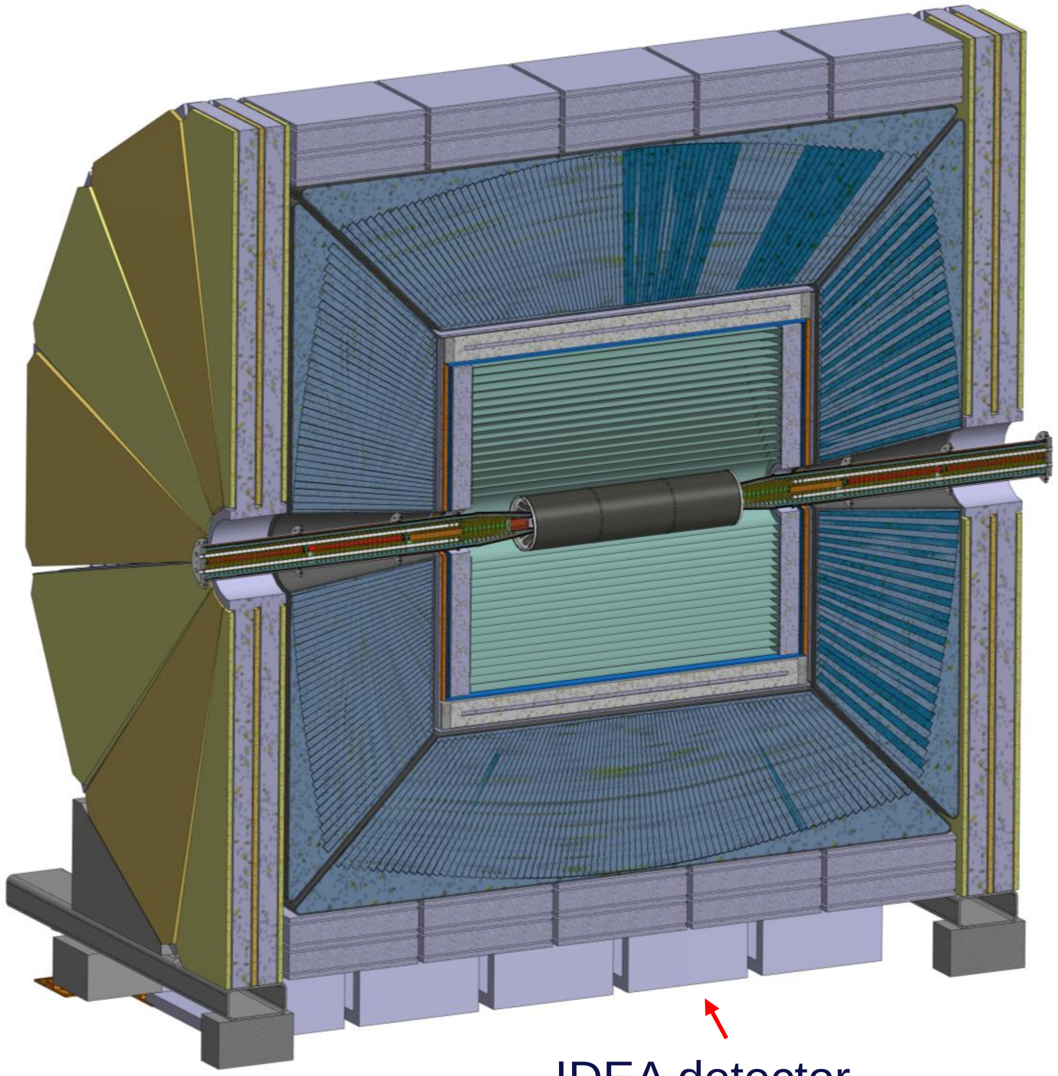
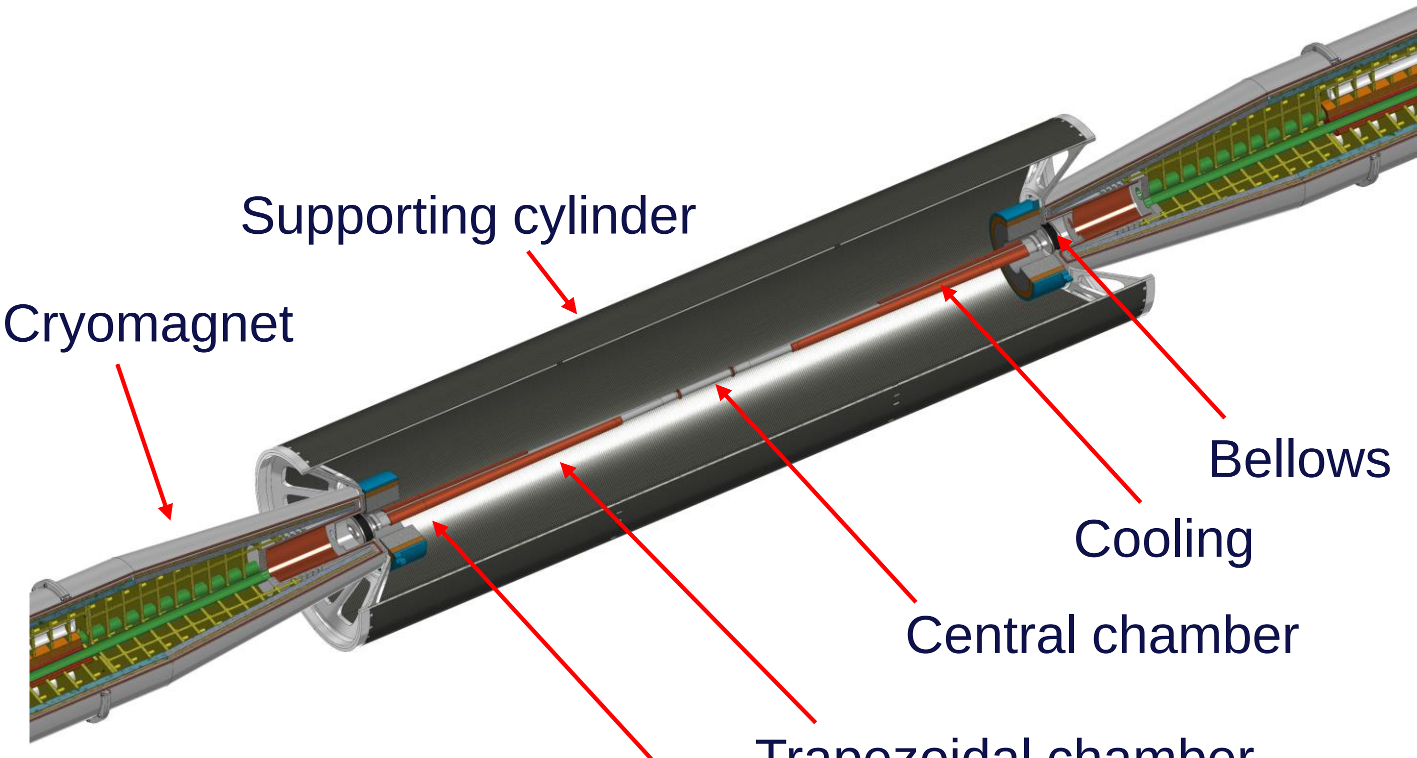
MDI mechanical model

At the moment every design is based on IDEA detector concept, in fact we are working in close contact with INFN-Pisa integrating their Vertex Detector design.

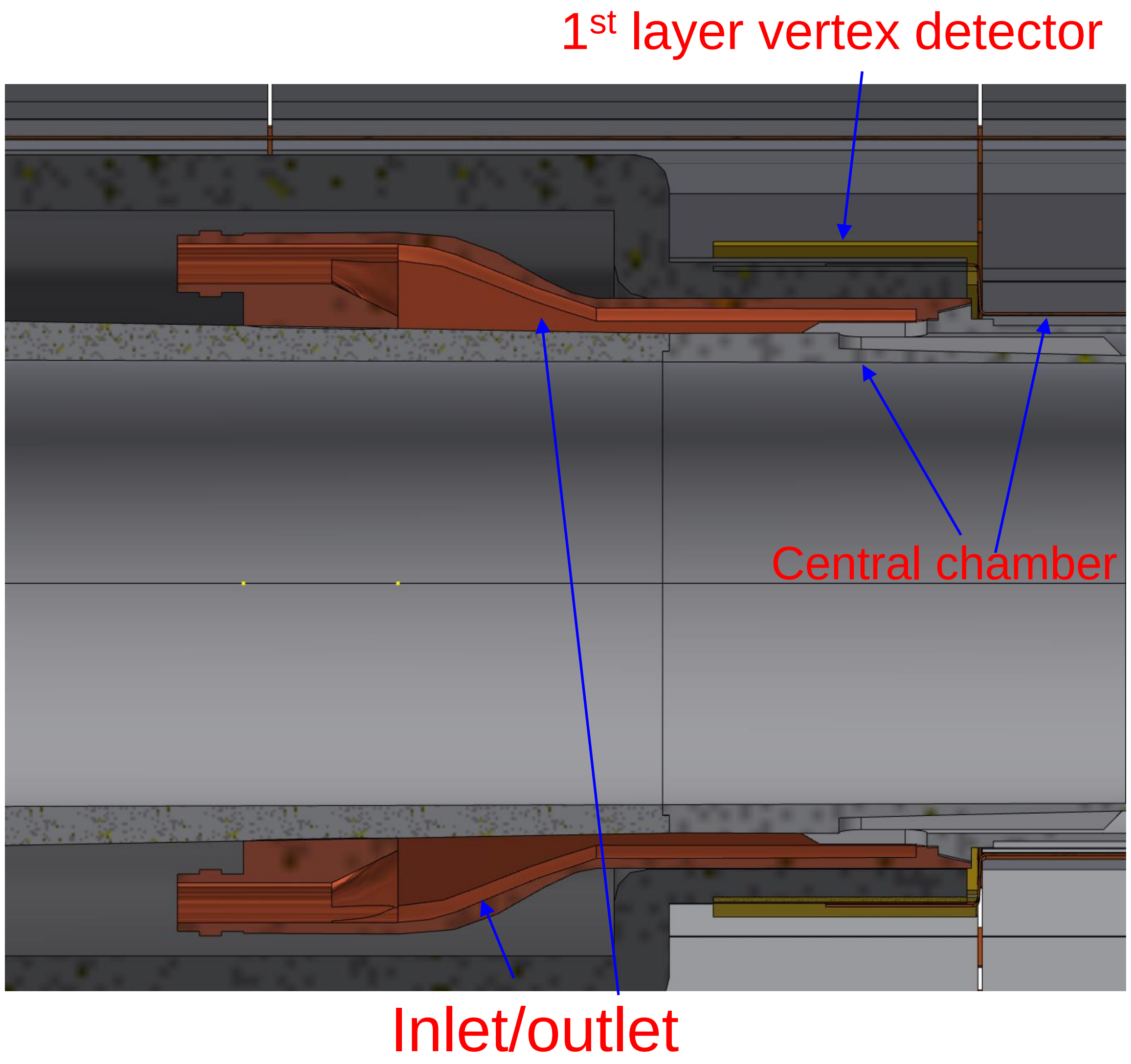


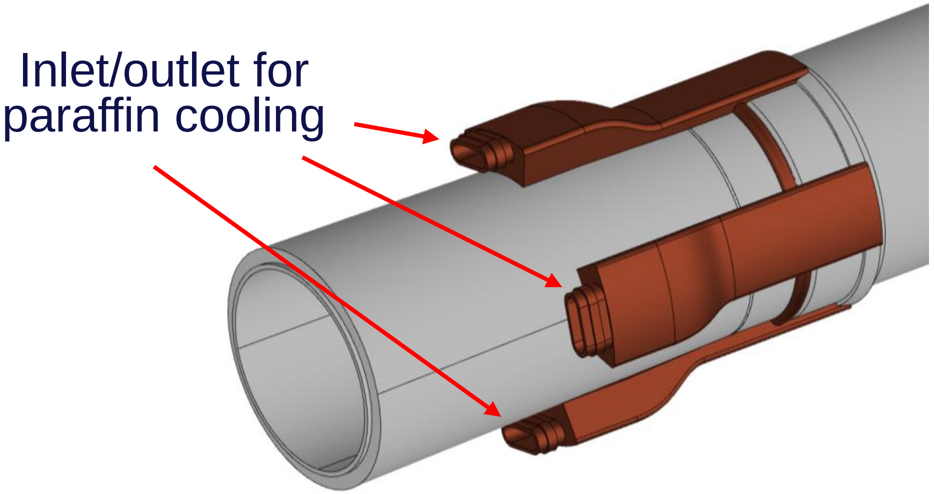


Central chamber (1)

The central has the following characteristics:

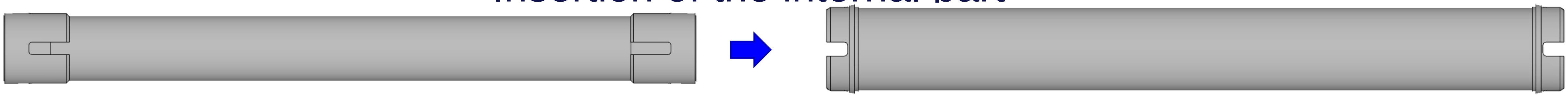
- AlBeMet 162 as main material
- Three layers from 0-90 mm from IP
  - ➢ 0.35 mm of AlBeMet162
  - ➢ 1 mm gap for Paraffin
  - ➢ 0.35 mm of AlBeMet162
- Paraffin as coolant
- Geometry studied to integrate the central chamber with the vertex detector



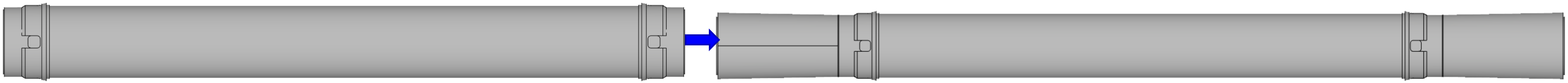


Central chamber (2)

Insertion of the internal part



Welding of transition part



Thick copper deposition to create the cooling inlet and outlet

Gap for the paraffin flow

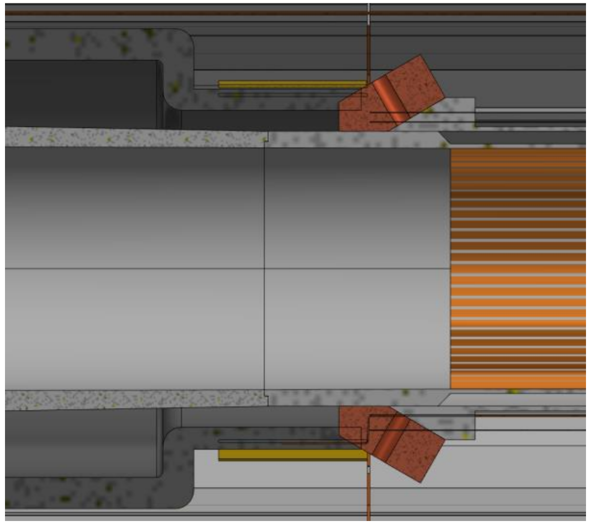
Central chamber (3)

Issues for the integration between vertex detector and chamber

Problems:

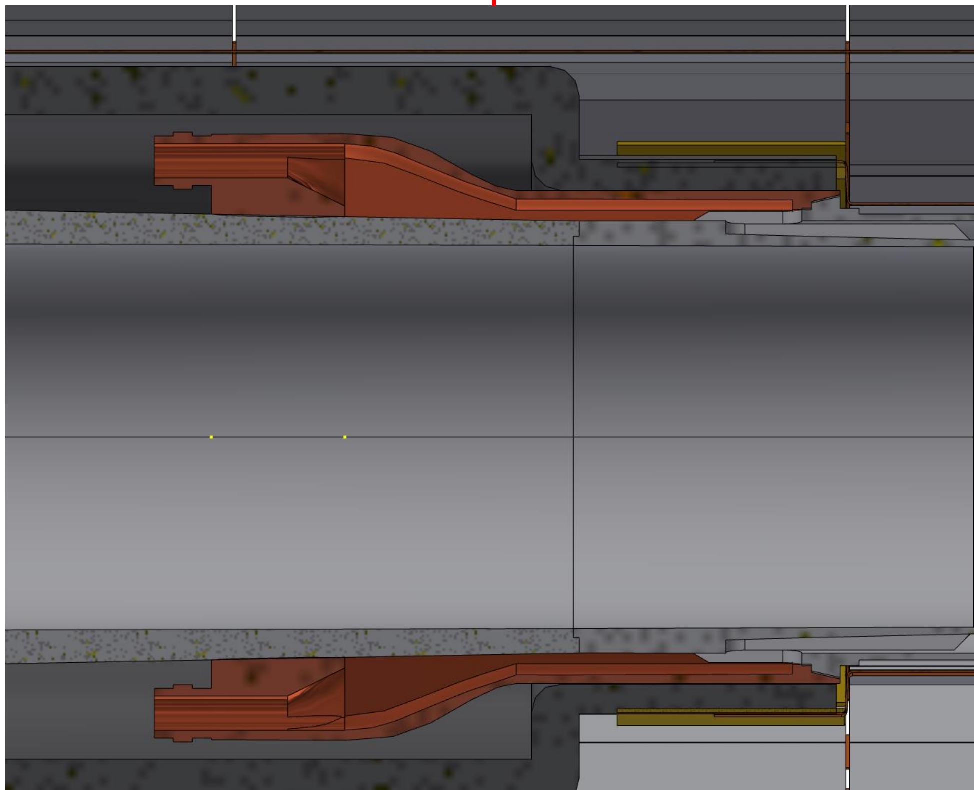
- Compenetration between inlet/outlet and the chamber
- No space to arrange the first layer

PREVIOUS DESIGN



CURRENT DESIGN

Presented on FCC-EIC Joint & MDI workshop 26/10/2022



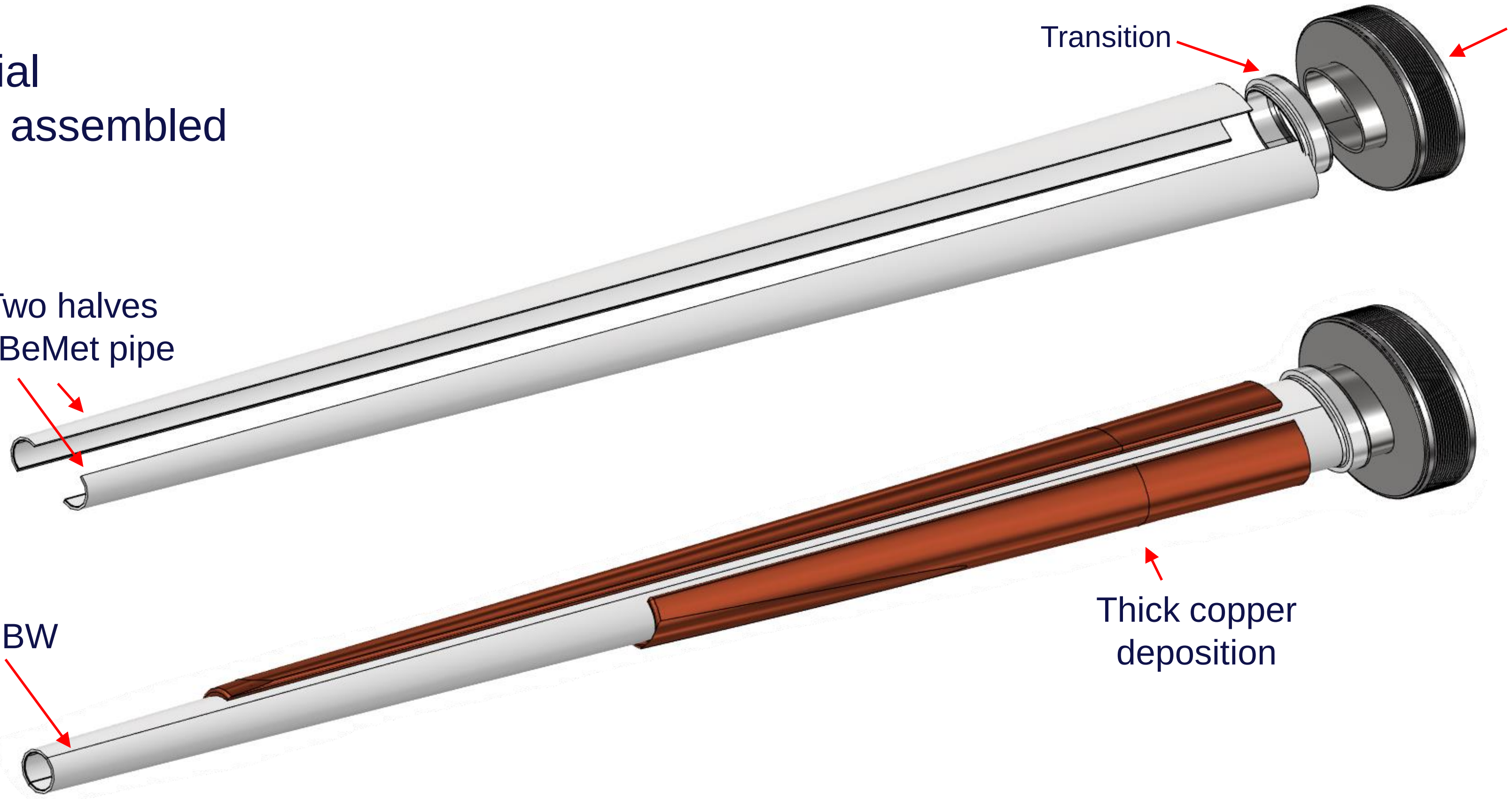
Solution:

- move forward inlet and outlet creating a longer channel; inlet and outlet into the first cavity of the vertex detector support.
- 4 different channel instead of massive one, to reduce the copper

Trapezoidal chamber (1)

Main characteristics:

- AlBeMet162 as main material
- Chamber in two halves and assembled using EBW
- Copper cooling system

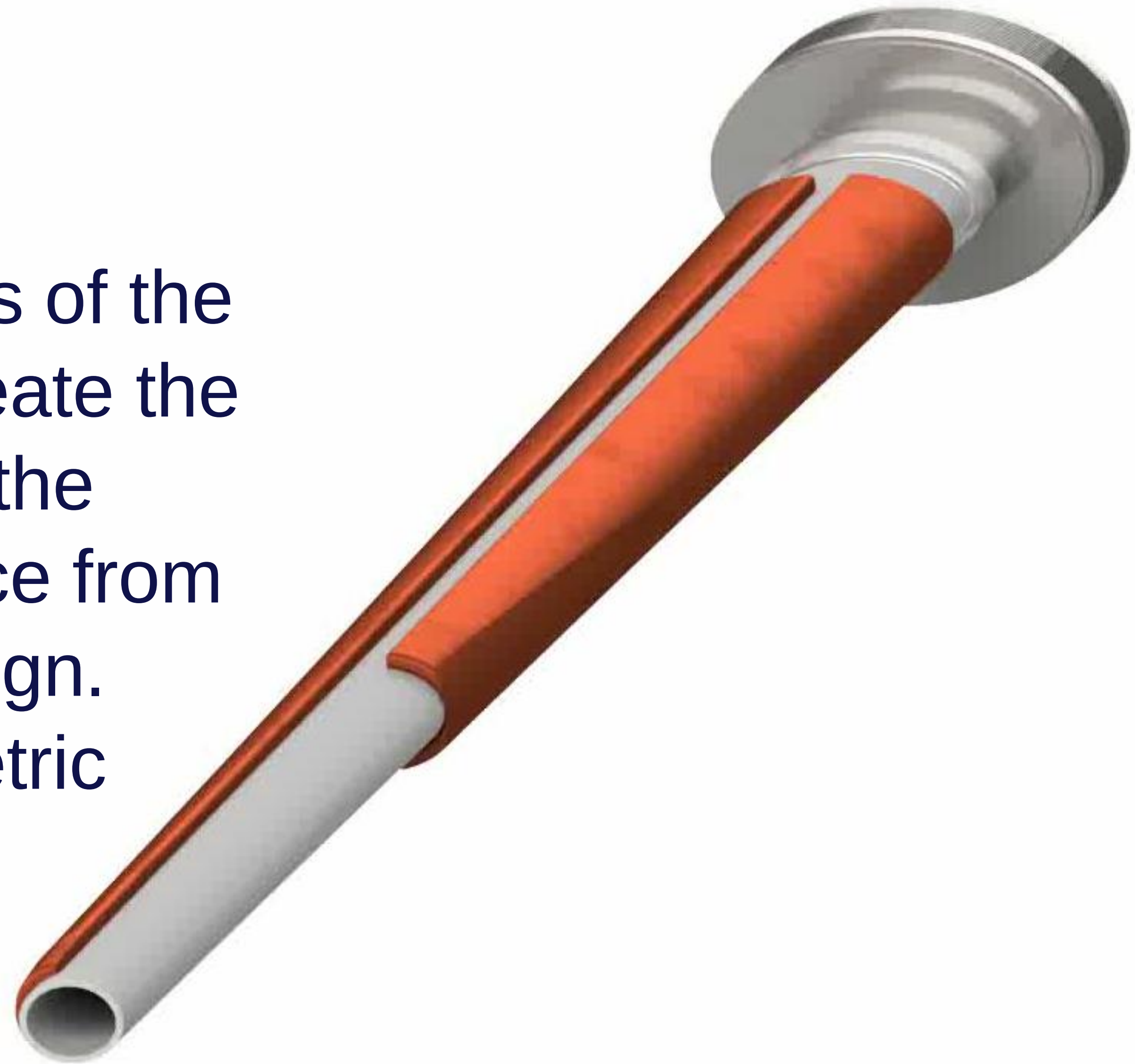


- The cooling is based on an **asymmetric solution**, using the 50 mrad cone as the cutting profile, to assure the respect of the spatial constraint due to the **LumiCal requirment**.
- To reduce the cooling material, the design provides **five couples of channels** for each side; in this way is possible to use the needed quantity of coolant and reduce the material, creating a light structure.

Trapezoidal chamber (2)

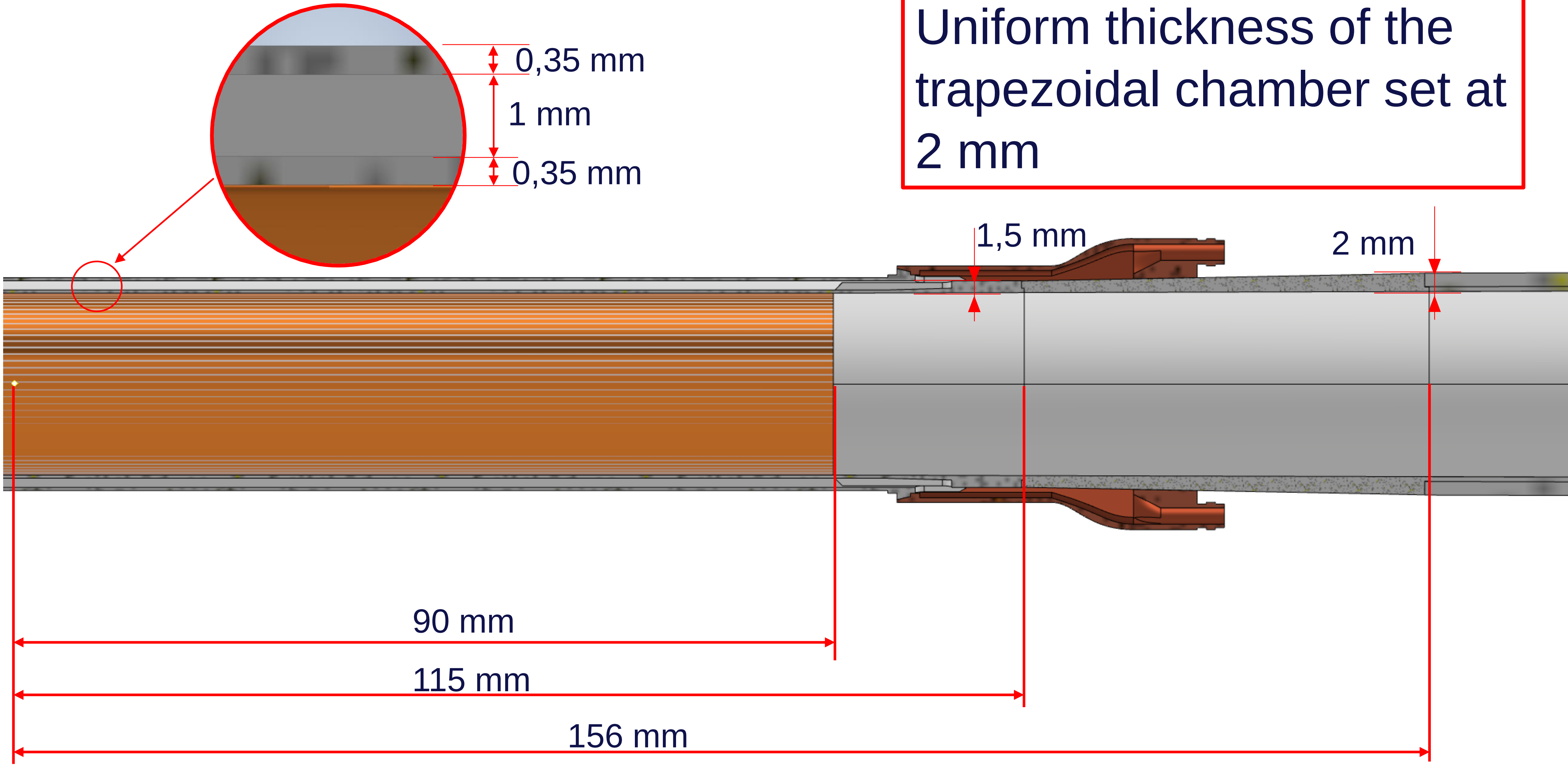
Cooling

- To assure the structural thickness of the cooling channels walls and to create the structure less massive possible, the channels start at different distance from the IP, creating the following design.
- This solution creates an asymmetric behavior but still effective.



Thickness of the chamber

Uniform thickness of the trapezoidal chamber set at 2 mm



Termo-structural calculation - Chamber (1)

It is necessary to **consider** every **thermo-structural aspect** using a detailed model ➡ FEA (Ansys) ➡ **Temperature distribution** along the pipe

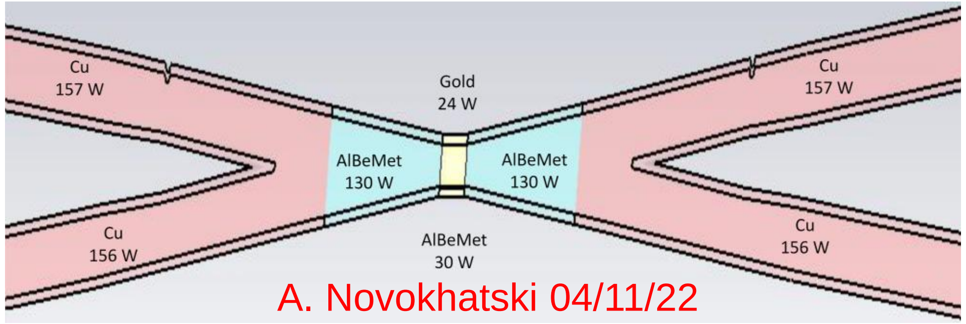
- **Paraffin flow (central chamber)**
  - Flow rate: 0,015 kg/s
  - Section:68,17 mm^2
  - Velocity: 0,3 m/s
  - Inlet temperature: 18°C
  - Convective coefficient: 900 W/m^2K

- **Water flow (trapezoidal chamber)**
  - Flow rate: 0,0019 kg/s
  - Section: 9,62 mm^2 (20 different channel)
  - Velocity: 0,2 m/s
  - Inlet temperature: 18°C
  - Convective coefficient: 1200 W/m^2K

Heat load :

- 54 W central
- 130 W AlBeMet162 for each part

Thanks to **Alexander Novokhatski**



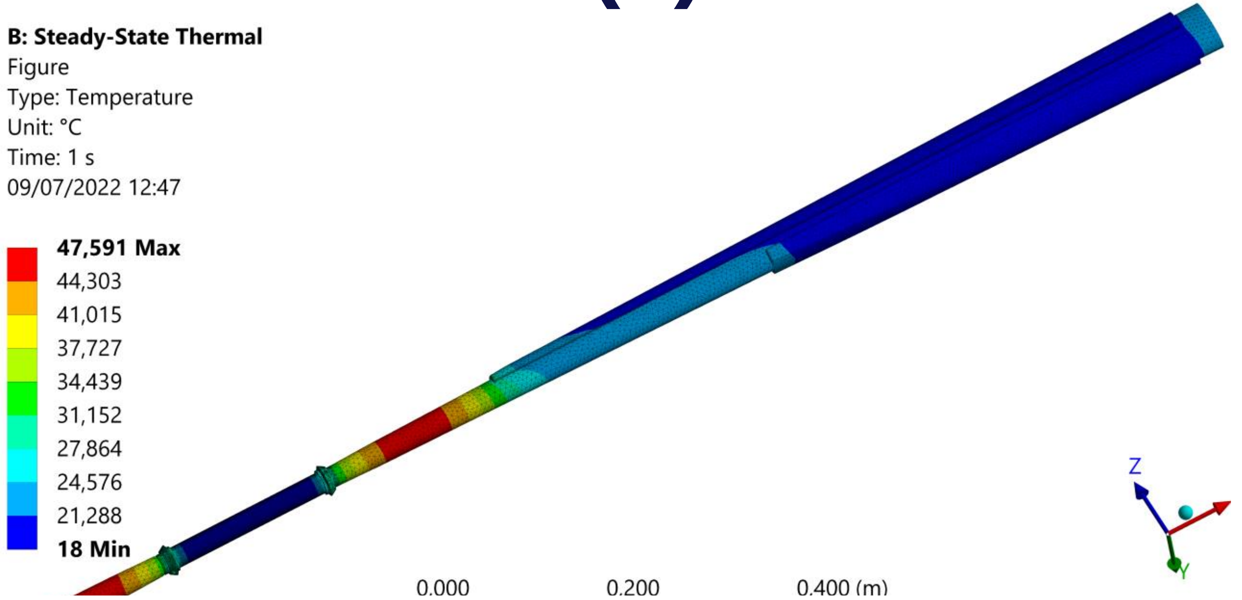
Termo-structural calculation – Chamber (2)

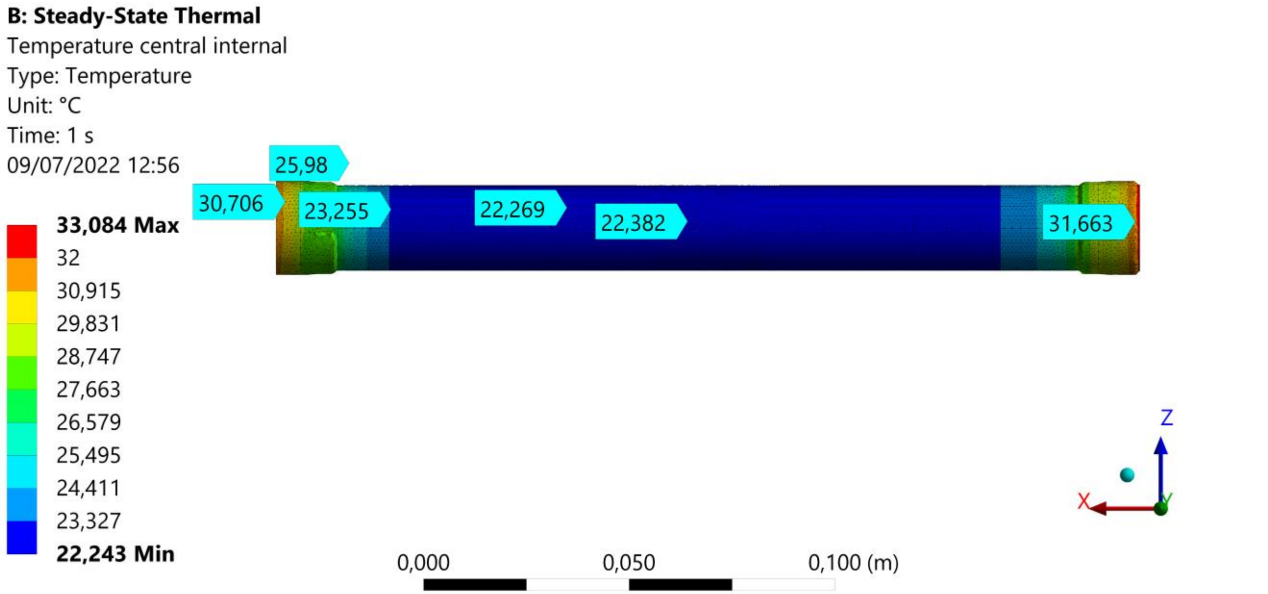
Hypothesis:

- Perfect thermal contact between the materials

Results:

	Trapezoidal chamber	Central chamber
Coolant	Water	Paraffin
Maximum chamber temperature [°C]	47,6	33,1
T_out coolant [°C]	20,5	20,1

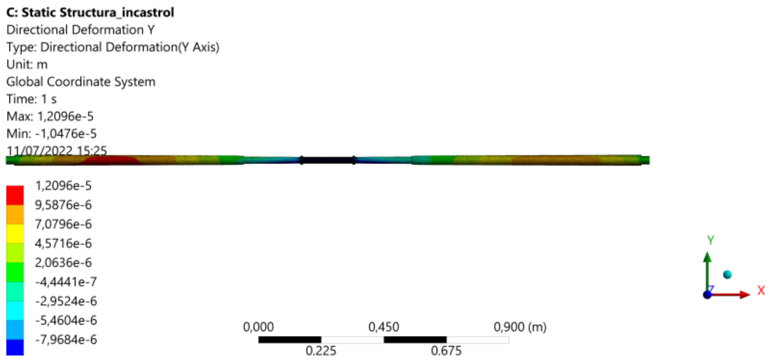


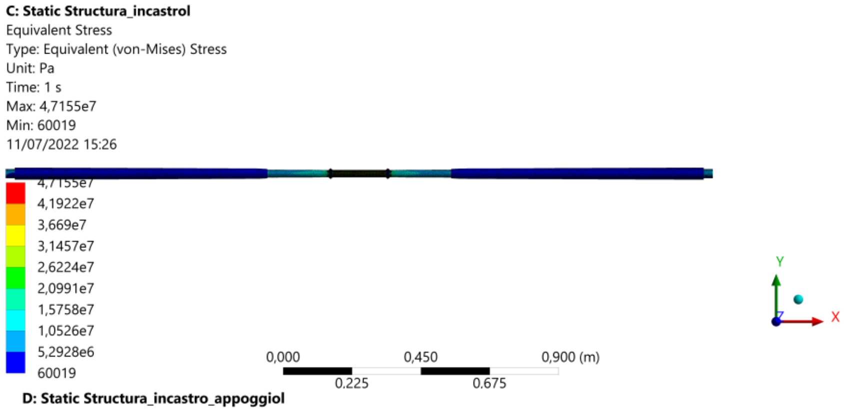


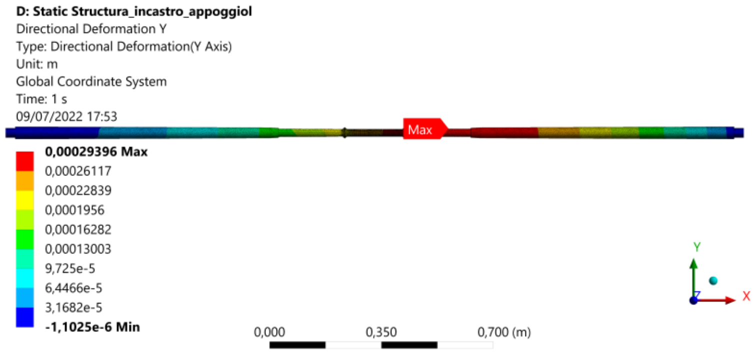
Termo-structural calculation – Chamber (3)

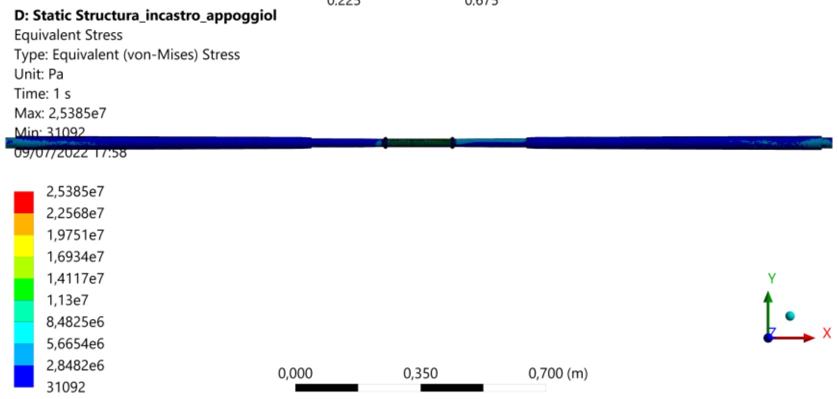
Fixed ended

Cantilevered, simply supported









Case	Maximum stress Von Mises	Maximum displacement
Fixed ended	46 MPa	0,01 mm
Cantilevered, simply supported	25 MPa	0,3 mm

The stresses and displacement are acceptable, but the **buckling study** of the central chamber is **ongoing**.

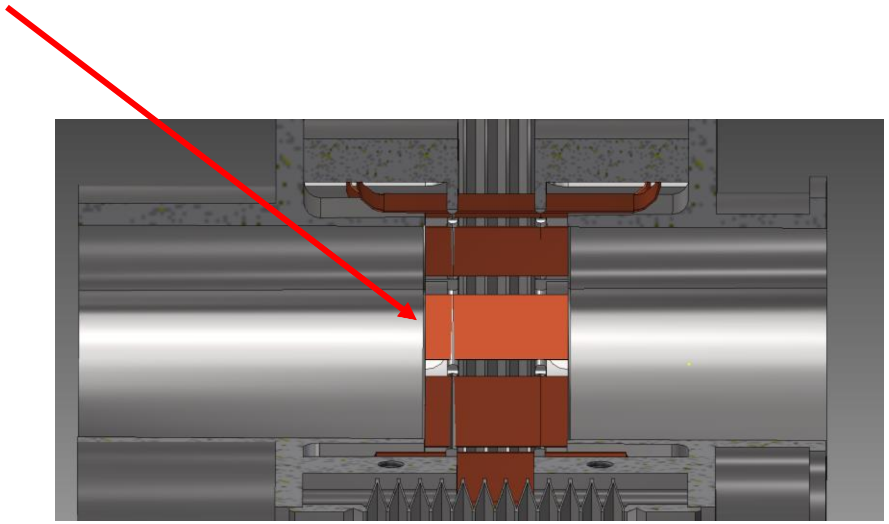
Termo-structural calculation - Chamber (4)

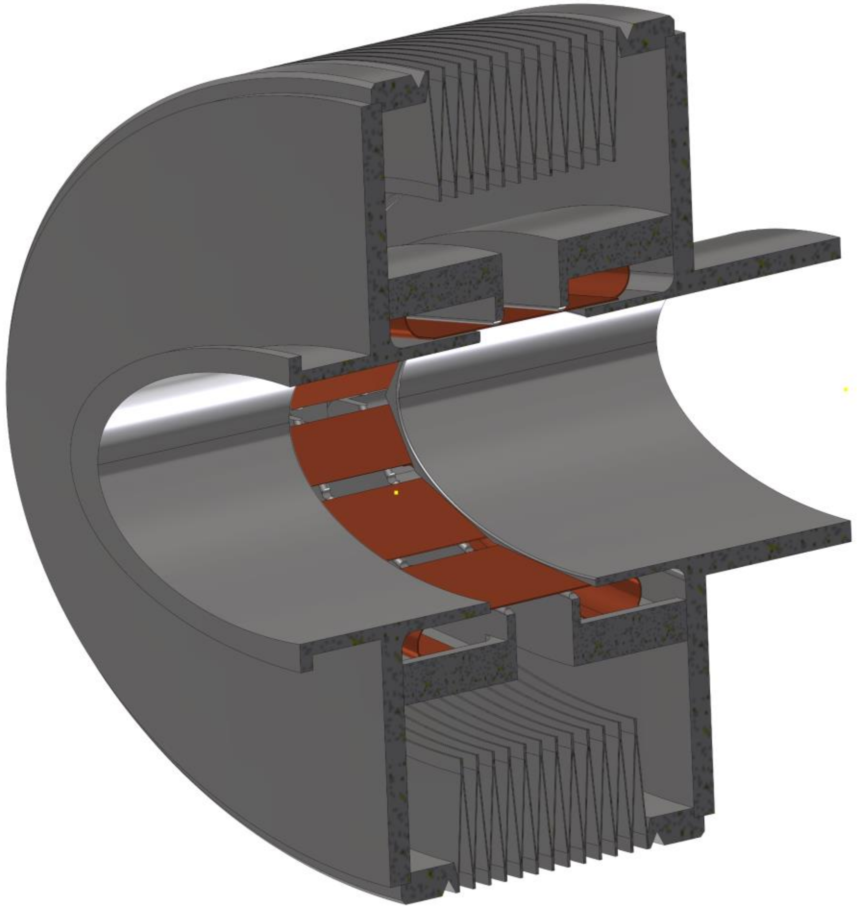
- To understand the behavior of the chamber under a load due to the weight of the **VTX first layers**, is useful to create a table.
- This table is created performing a Parametric design with Ansys, augmenting the weight of the layers and evaluating the central chamber stress and strain, analyzing the cantilevered-simply support case.

Configuration	VTX load [kg]	Maximum stress [Mpa]	Maximum displacement [mm]	Safety factor
1	0,5	46,8	9,56E-02	5,9
2	1,0	47,4	1,15E-01	5,7
3	2,0	48,4	1,47E-01	5,3
4	3,0	49,4	1,80E-01	5,0
5	4,0	50,0	2,03E-01	4,8
6	5,0	50,7	2,27E-01	4,5
7	6,0	51,6	2,62E-01	4,3

Bellows (1)

- 12 RF copper spring (can be increased to 16)
- Compact size in length
- 8mm stroke (-5mm +3mm)
- Finger to ensure contact between RF-spring to bellows (like ESRF bellows)





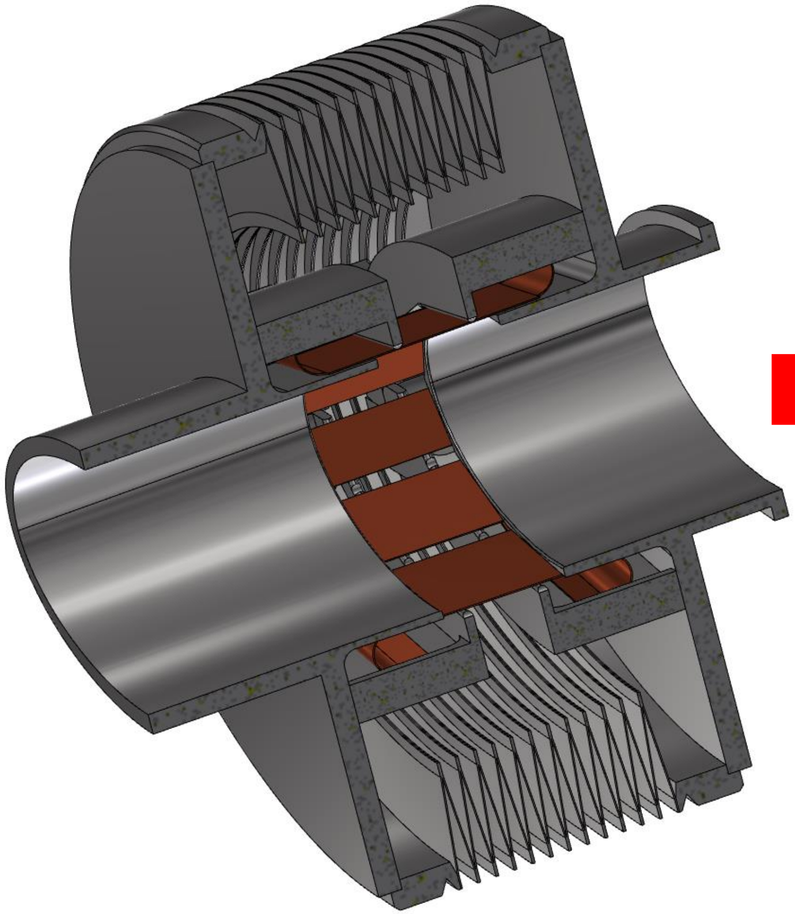
Bellows (2)

Thermal calculation due to the wake field: issues and progress (1)

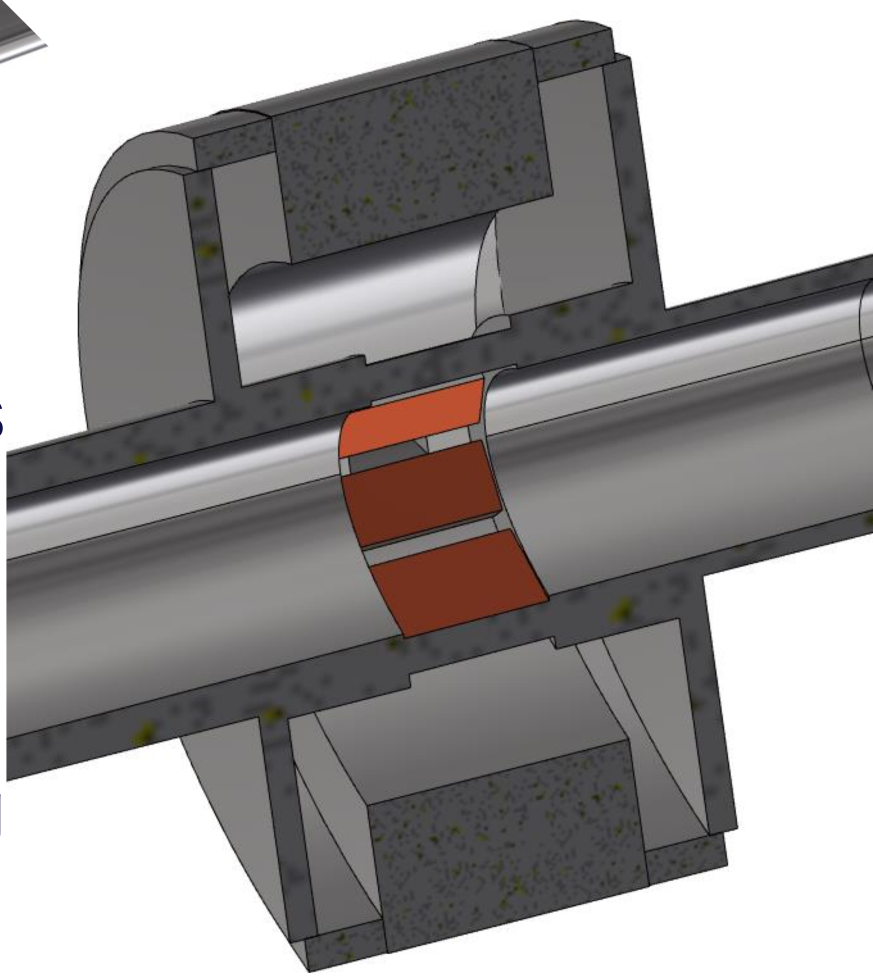
- This work has been started with Alexander Novokhatski and is currently in progress.
- To calculate the thermal contribution is necessary to progress step by step and create simplified models, compatible with CST requirement and needs.
- The chamber model is less complicated than the bellows, in fact for the last one it has been necessary a process of simplification of the edges, geometry and features.
- An effective **cooling system** has to be foreseen into the **bellows**

Bellows (3)

Thermal calculation due to the wake field: issues and progress (2)



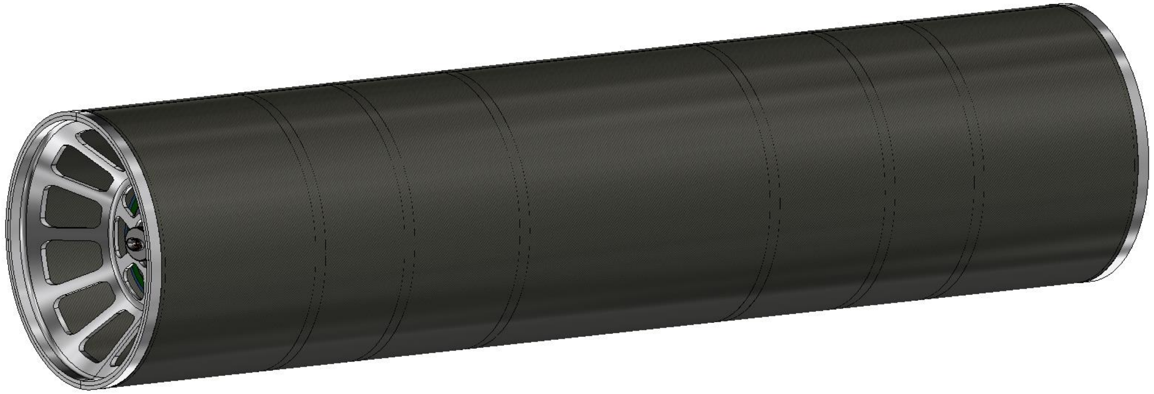
- Simplification of springs and fingers
- Simplification of edge: every edge bigger than 1 mm
- No compenetrating body

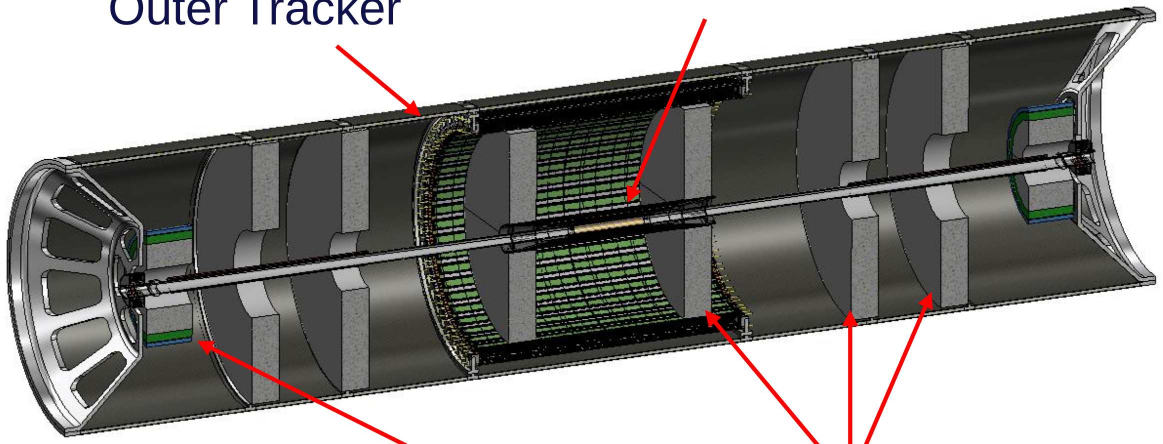


Carbon fiber supporting tube (1)

Use a lightweight rigid structure to:

- Provide a cantilevered support for the pipe
- Avoid loads on thin-walled central chamber during assembly or due to its own weight
- Support LumiCals
- Support the outer and disc tracker inside the structure

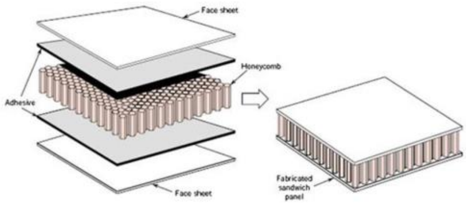




Carbon fiber supporting tube (2)

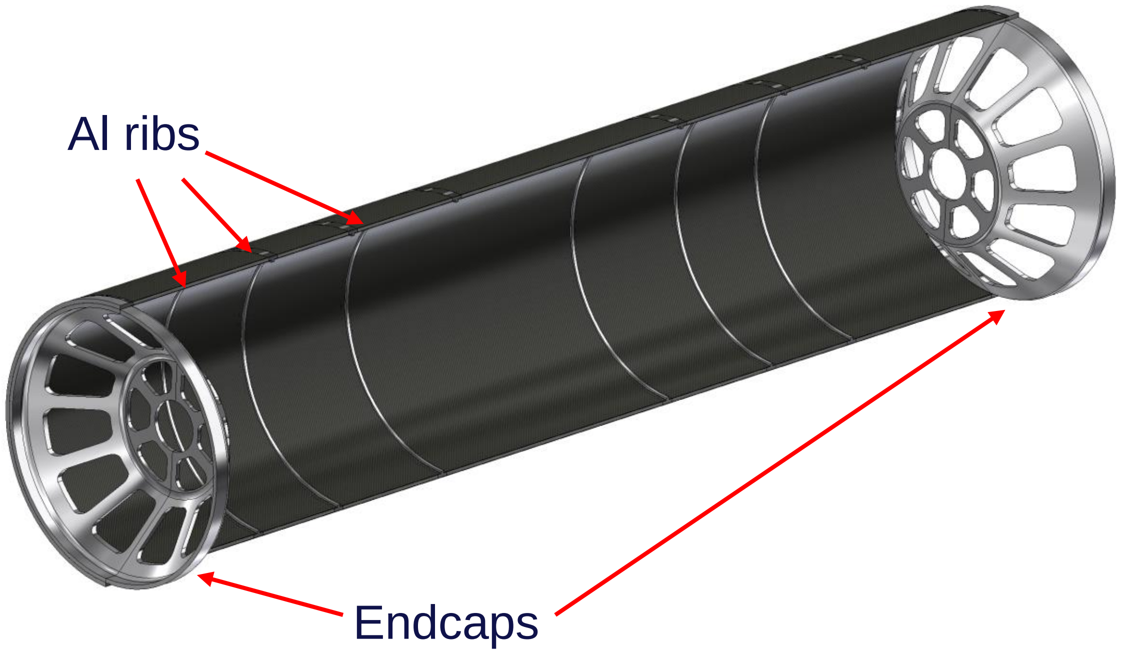
Sandwich structure:

- Cylinder structure (10mm)
  - ➢ 1mm CF
  - ➢ 8mm HC (or rigid foam structure (Rohacell))
  - ➢ 1mm CF
- Flanges:
  - ➢ 10mm Aluminium
- Cylinder splitted in two halves
- Aluminum ribs to fix detector
- Endcaps for supporting Lumical and beampipe



Honeycomb (fiberglass, aluminum, nomex/Kevlar)

Rohacell (polymethacrylimide)



CF=carbon fibre
HC=honeycomb

Structural calculation supporting tube

Materials

1) Cylinder structure (10mm)
- 1mm CF
- 8mm HC
- 1mm CF

Flanges:
- 10mm Aluminium

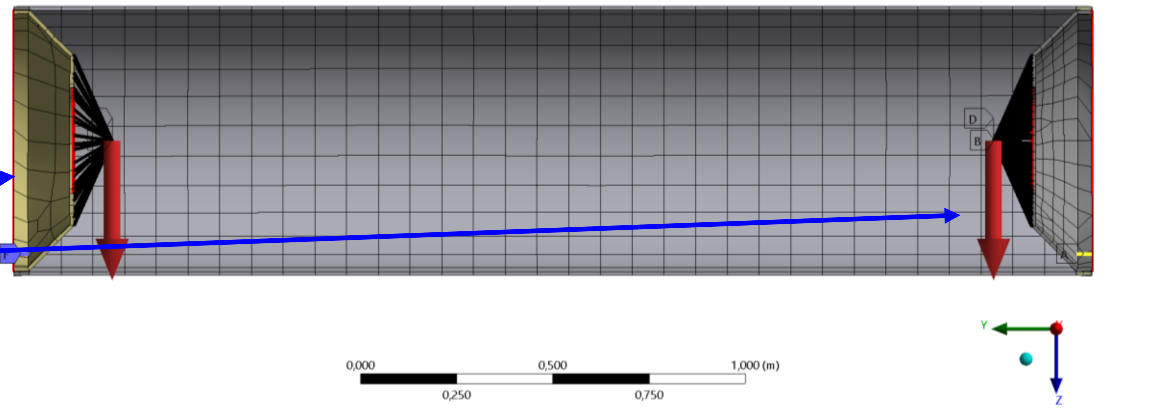
1) Cylinder structure (7mm)
- 1mm CF
- 5mm HC
- 1mm CF

Flanges:
- 10mm Aluminium

Layer	Material	Thickness (m)	Angle (°)
(+Z)			
5	Epoxy Carbon Woven (230 GPa) Wet	0,0005	45
4	Epoxy Carbon Woven (230 GPa) Wet	0,0005	-45
3	Honeycomb	0,008	0
2	Epoxy Carbon Woven (230 GPa) Wet	0,0005	-45
1	Epoxy Carbon Woven (230 GPa) Wet	0,0005	45
(-Z)			

Loads

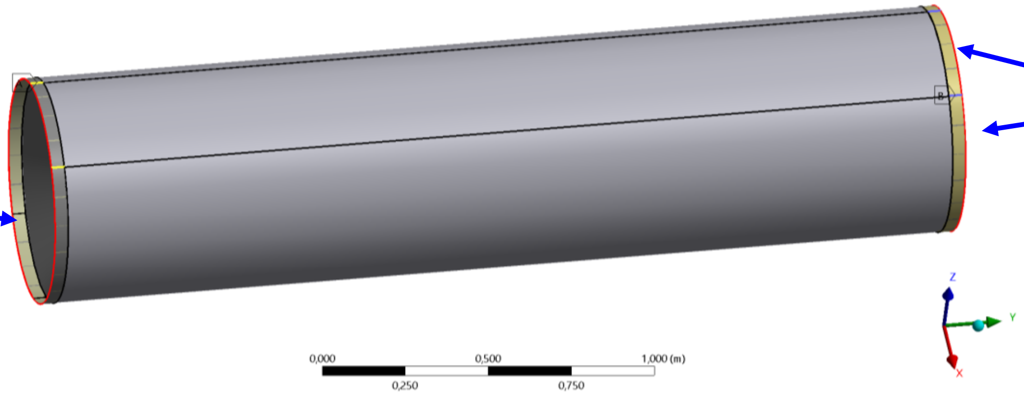
- 70 Kg on each flanges



Constraints

- Simply supported in order to simulate rail supports

Fixed

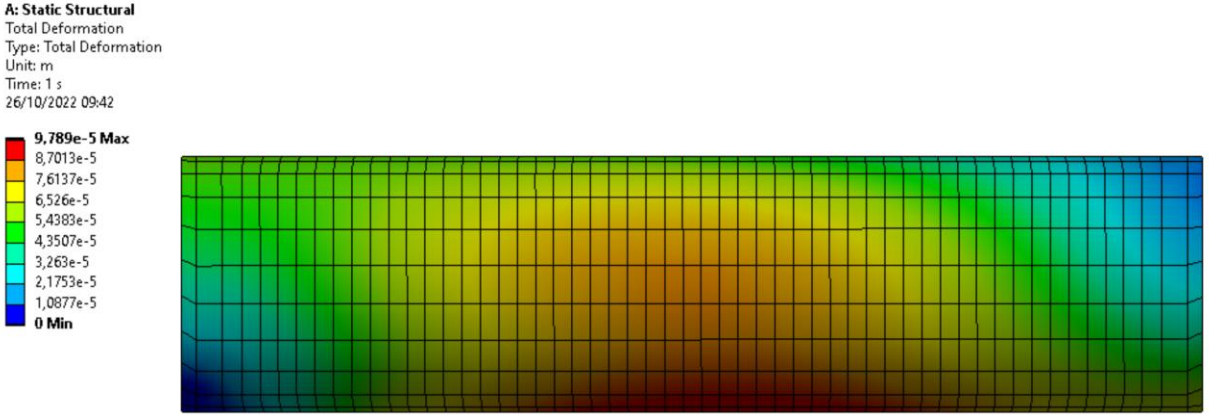


Free to move in longitudinal direction

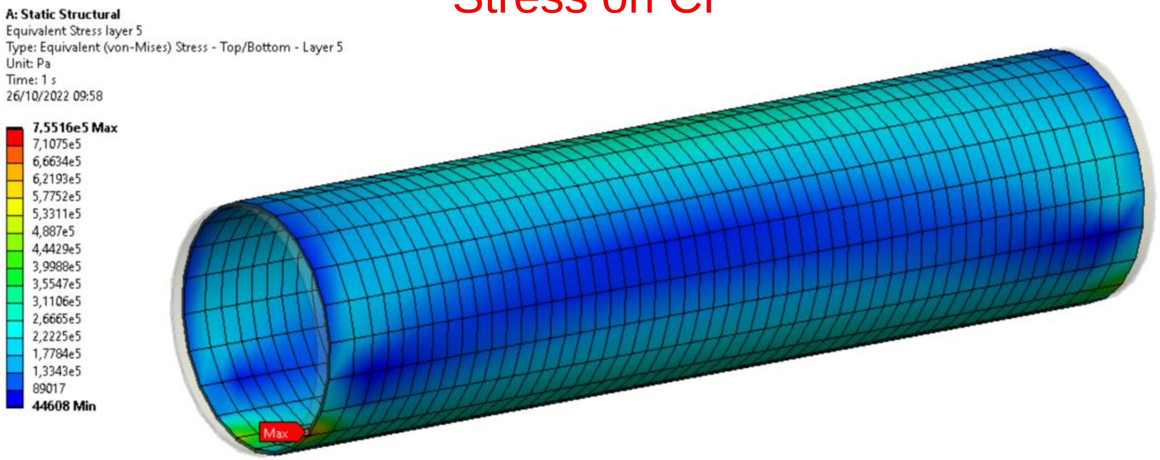
CF=carbon fiber
HC=honeycomb

Structural calculation supporting tube- Results

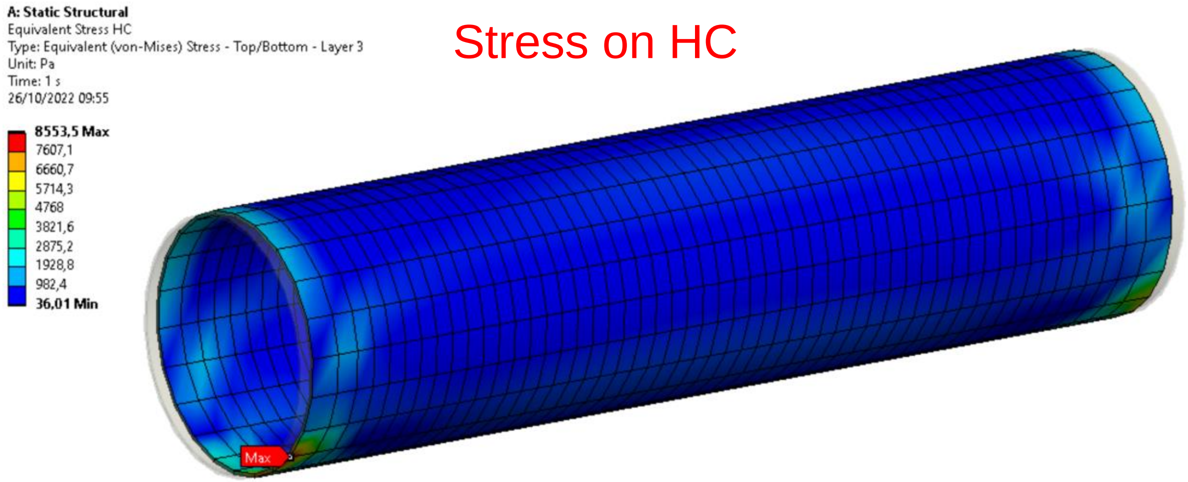
Deformation



Stress on CF



Stress on HC

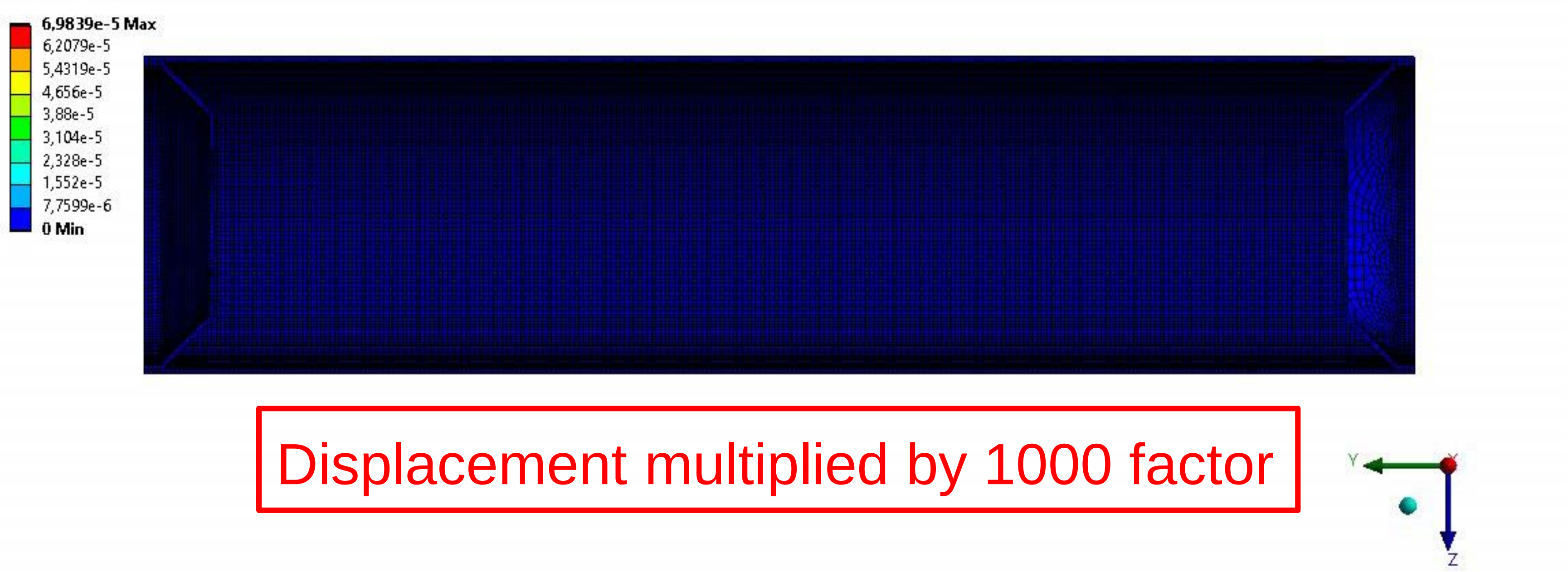


	Maximum deformation [mm]	Maximum stress on CF [MPa] Layer 1	Maximum stress on HC [MPa] Layer 3	First failure stress for CF [Mpa]
8mm HC	0,098	0,7	0,085	275
5mm HC	0,11	0,7	0,094	275

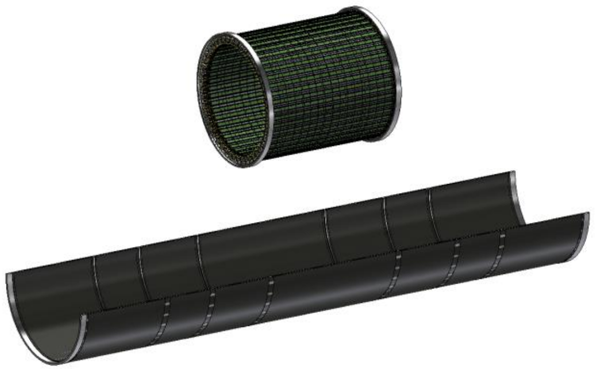
Structural calculation supporting tube- Rotation

It is very important to evaluate the flanges rotation due to the weight especially for the components' alignment.

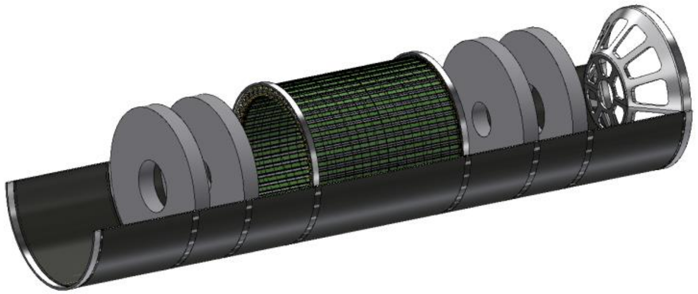
	Maximum rotation x [deg*10^-3 (mrad)]	
	Flange Left	Flange Right
8mm HC	-4,68 (0,082)	4,9 (0,086)
5mm HC	-4,63 (0,081)	4,8 (0,084)



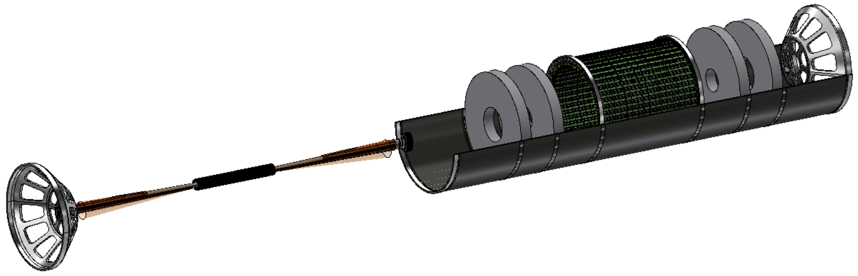
Conceptual assembly strategy (1)



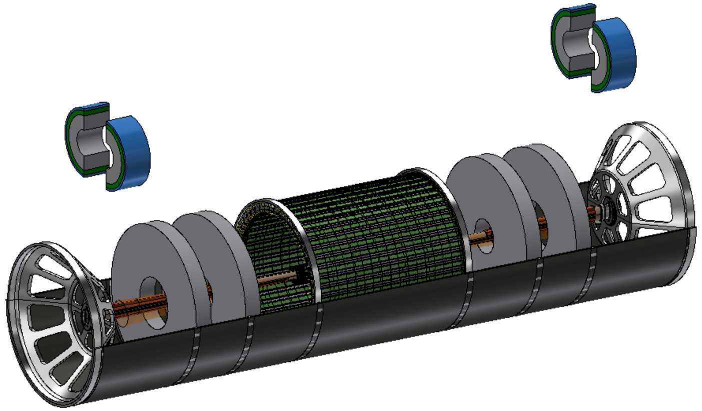
1) Outer tracker is assembled and laid down and fixed on half cylinder



2) Detector disc and one endcap fixed to the half cylinder

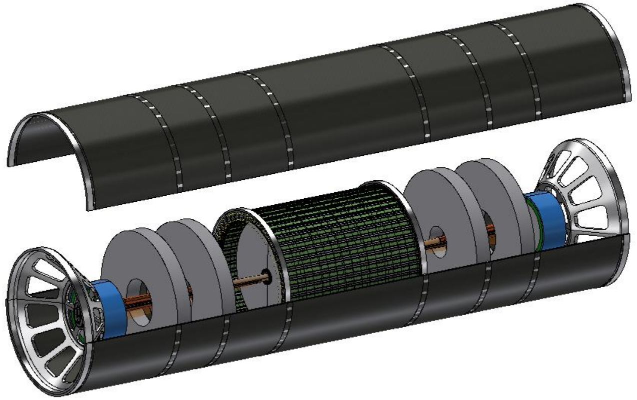


3) Beam pipe with vertex detector is inserted with a dedicated tool inside discs and outer tracker, then fixed to both endcaps

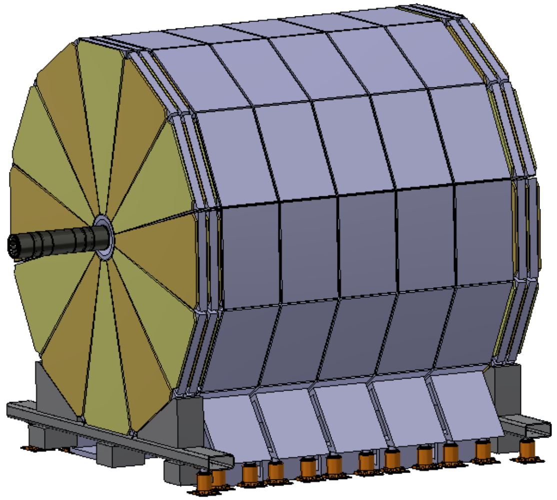


4) Lumicals are coupled to endcaps

In this case the LumiCal has to be manufactured in two halves; we are studying an alternative solution in case is not possible to divide the LumiCal

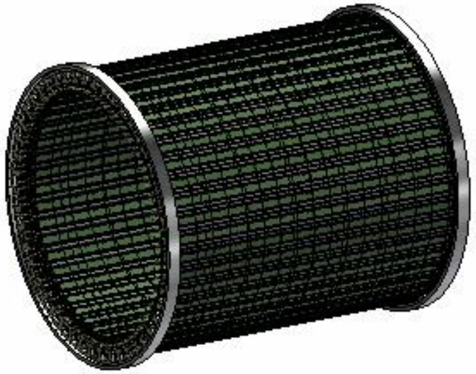


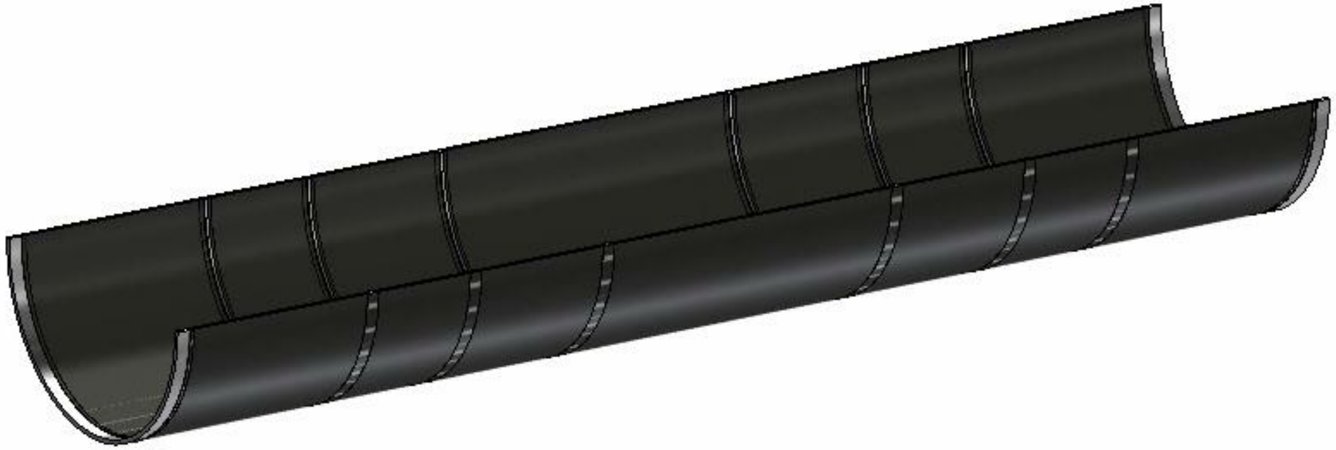
5) The whole cylinder can be composed



6) Cylinder can be inserted inside the detector using a rail system

Conceptual assembly strategy (2)





Mockup plans - Prototyping

In order to proceed with the feasibility study, it is necessary to start with a prototyping activity regarding:

1. Central IP chamber, to test:
- 1.1 double thin chamber precision and strength, as well as assembly procedure;
- 1.2 paraffin cooling effectiveness;
- 1.3 Thick copper deposition over AlBeMet 162 thermal interface and tightness.

2. Bellows, to study:
- 2.1 fabrication, assembly procedure and EBW (electron beam welding) over an elliptical shape.
- 2.2 thermal/electrical contact effectiveness
- 2.3 AlBeMet/SS transition

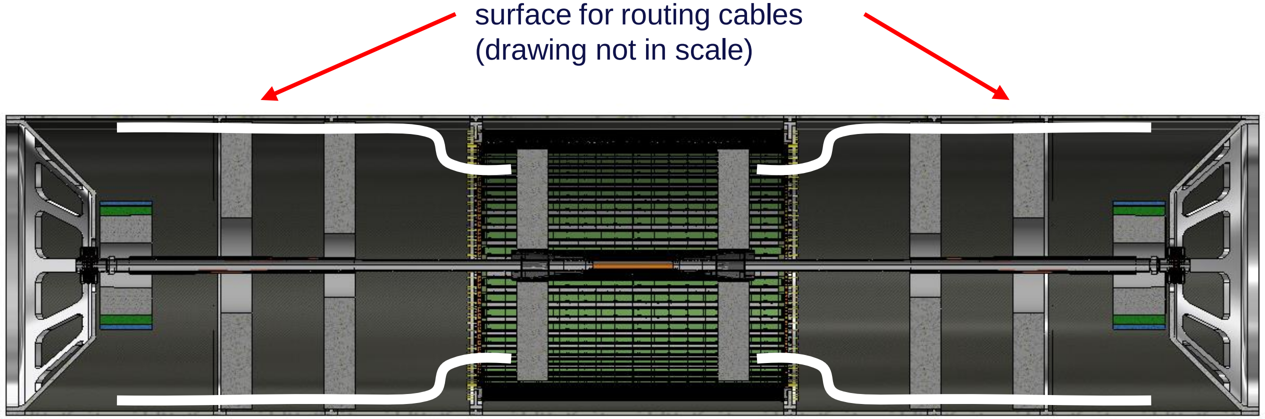
3. Trapezoidal chamber, to study
- 3.1 chamber fabrication (transitions from elliptical section, accuracy of the shape) and strength;
- 3.2 thick copper deposition over an elliptical shape with embedded channels;
- 3.3 tightness of the channels and thermal contact between deposited copper and AlBeMet.

4. Carbon fiber cylinder, to study
- 4.1 Fiber carbon composite fabrication technology,
- 4.2 shape accuracy and rigidity of the structure,
- 4.3 insertion of the reinforcements for anchoring LumiCal and Vertex;

Open questions (1)

- **Services** (cables and cooling) should be carefully taken into account
- **Detector design** is still preliminary, and some parts are represented only by an **envelope**, we will integrate further **details** when-available
- **LumiCal** should be split in **two halves** in order to be assembled, therefore it is necessary to **check the feasibility** and **study an alternative solution:**
  - ➢ Modify the geometry of the bellows to decrease the external diameter to fit in to the internal diameter of the LumiCal
  - ➢ Modify the geometry of the bellows to increase the internal space, adopting a conical shape (discussed during the FCC EIC joint meeting 10/2022

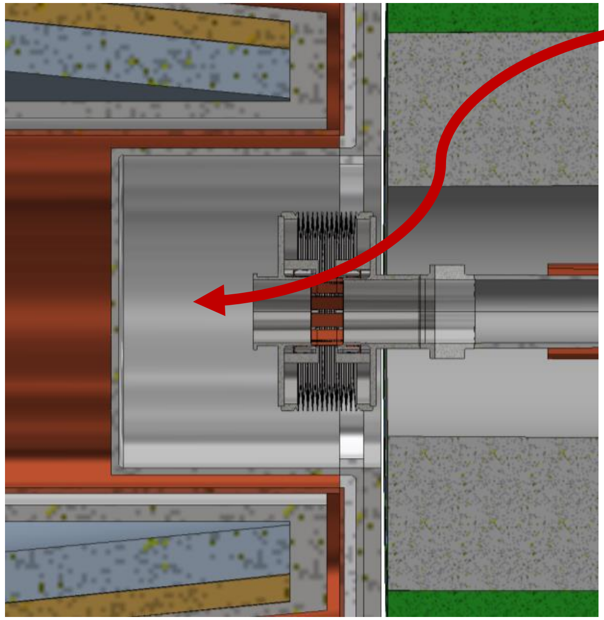
- It is necessary to study **how** and **where cylinder** can be **supported** inside the main detector



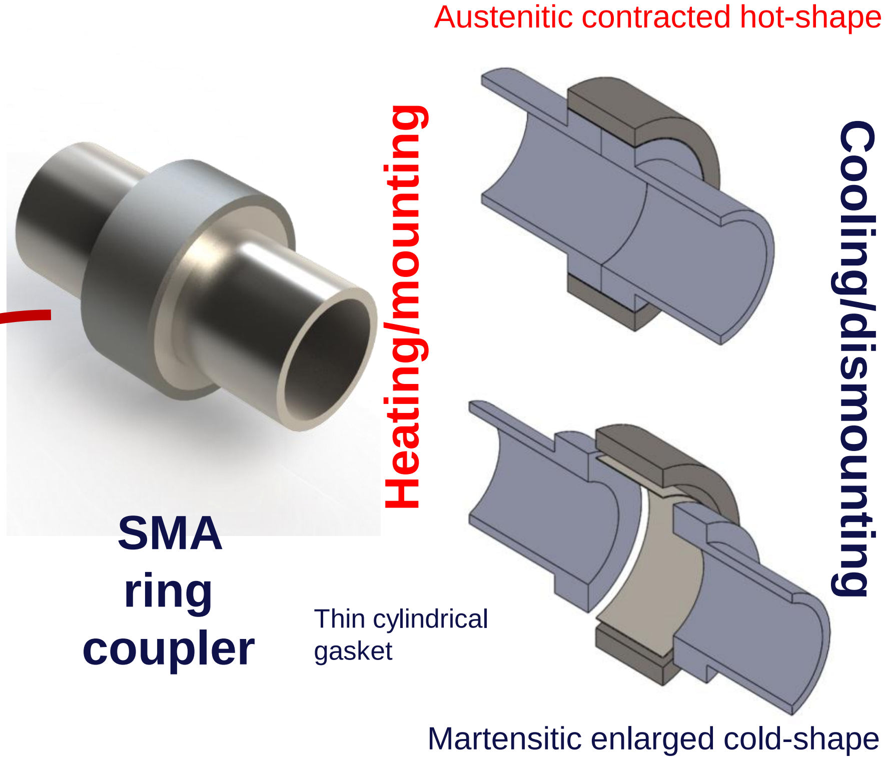
Open questions – Remote Vacuum Connection

- Mechanical solution, as used in Super KEKB, require a lot of space
- SMA connection (FCC_ Week 2022) thanks to the compact dimensions could be the perfect solution to fit inside the available space.

- We may start a collaboration to investigate if the use of this solution is compatible with our design



Shape memory alloy couplers



Soft/hard materials + temperature control

C. Garion FCC Week 1st June 2022

In progress → Road to milestone 07/2023

- Study of the **reduced diameter bellows** solution: to complete the assembly strategy, where the bellows integration is crucial
- Complete **buckling analysis** of the central chamber
- Hypothesize **supports** for IR components: even if the detector geometry is not defined, a first guess can be done
- **Finalise** the preliminary **assembly strategy**
- **Complete integration** of components available

Collaborations

- An effective collaboration has been started with **INFN-Pisa** on tracker and vertex of IDEA detector, in order to integrate 3D parts inside the IR CAD and study the assembly feasibility
- A productive collaboration with Alexander Novokhatski, from **SLAC**, who is calculating the thermal contribution due to the wake fields.
- Vibration mitigation: we are in contact with the **LAPP** group (Laurent Brunetti, Stanislas Grabon, Eva Montbarbon), to optimize the behaviour of the structure from a vibrational point of view.
- **CERN** groups for vacuum, alignment, magnet.
- Mogens Dam, from **Niels Bohr Institute**, for LumiCal

Conclusions

- The current structure (chamber, cylinder) can assure a **good stiffness**, maintaining stress and strain low.
- The thermal simulation is quite preliminary but still effective. In the next future we are going to **update the thermal load** with Alexander calculation, then we intend to **built a prototype** to **test the system.**
- What has been showed is a “conceptual strategy” for assembly, but it is effective anyway, especially to understand the issues and to design the assembling tools.
- IR strongly depends on detector, an iterative collaboration started only on the IDEA vertex detector but not inputs from other detectors proposal.
- There is still a lot to be done and many aspect needs to be implemented/designed/improved and defined but the process can be speeded up if an engineering counterpart is defined. (LumiCal, detectors, etc.…).
- Prototyping phase has to start soon to demonstrate the technical feasibility of proposed solutions.

THANK YOU FOR YOUR ATTENTION

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