MECHANICAL DESIGN OF FCC IR

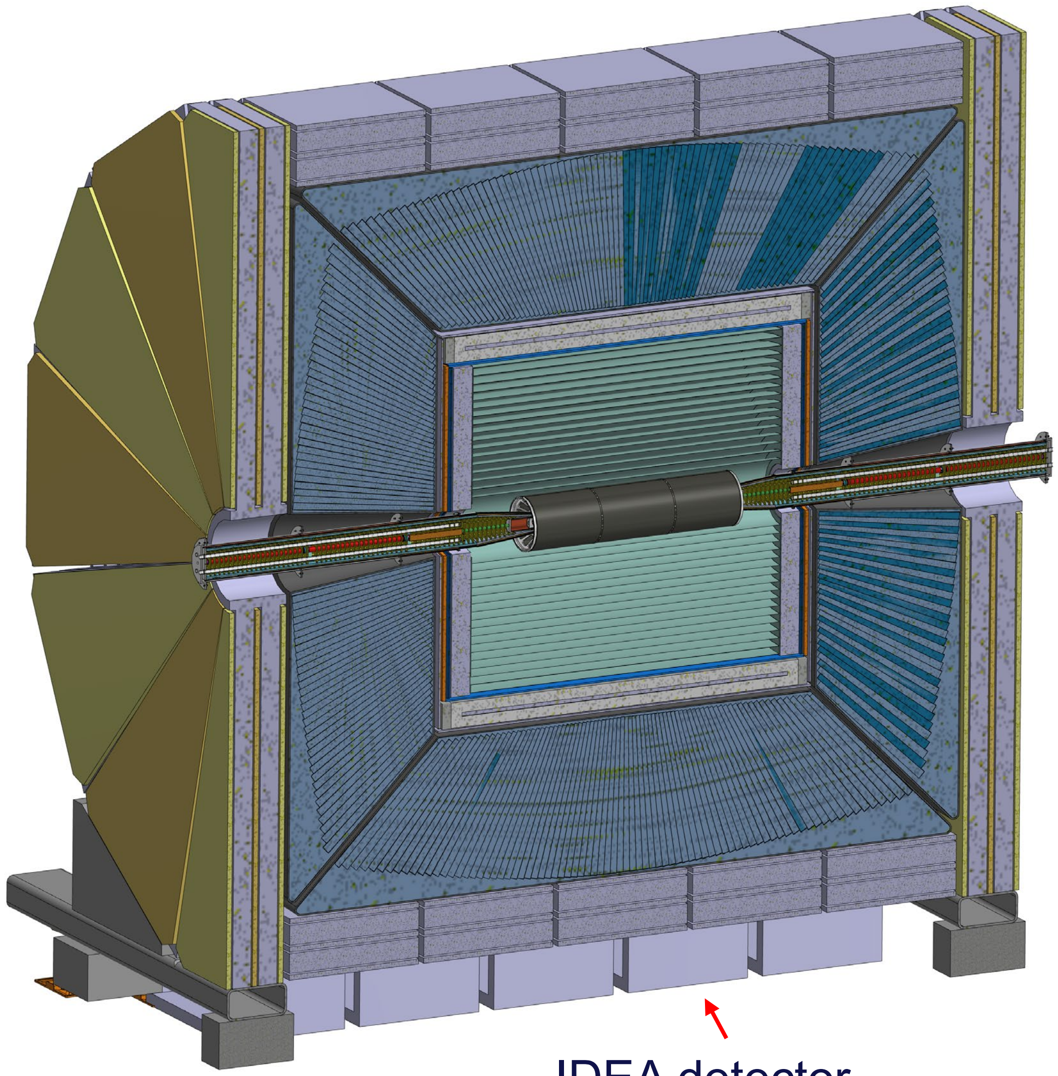
Speaker: Francesco Fransesini

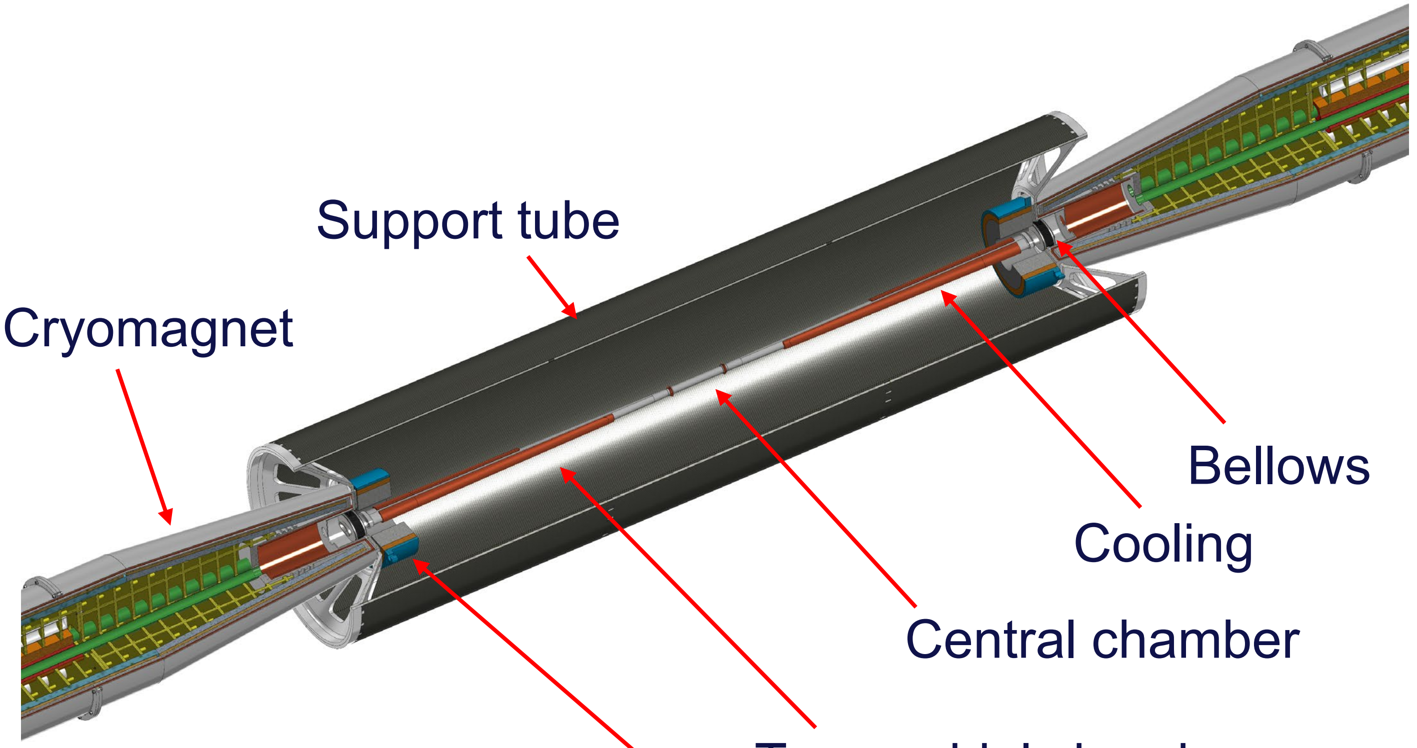
Thanks to Manuela Boscolo, Stefano Lauciani, Luigi Pellegrino, Fabrizio Palla, Filippo Bosi

This project has received funding from the **European Union's Horizon 2020** research and innovation programme under the **European Union's Horizon 2020** research and innovation programme under grant agreement No 951754

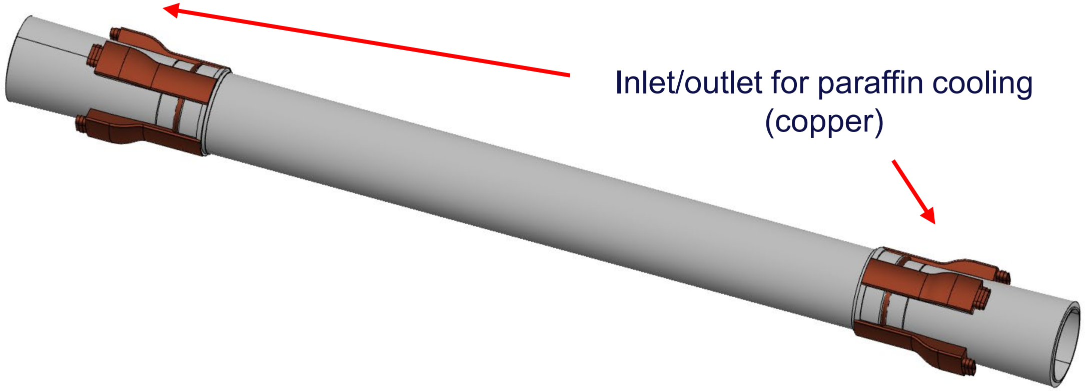
FCC IR region

This design is based on the IDEA detector concept, in fact we are working in close contact with INFN-Pisa integrating their Vertex and Tracker detector design.



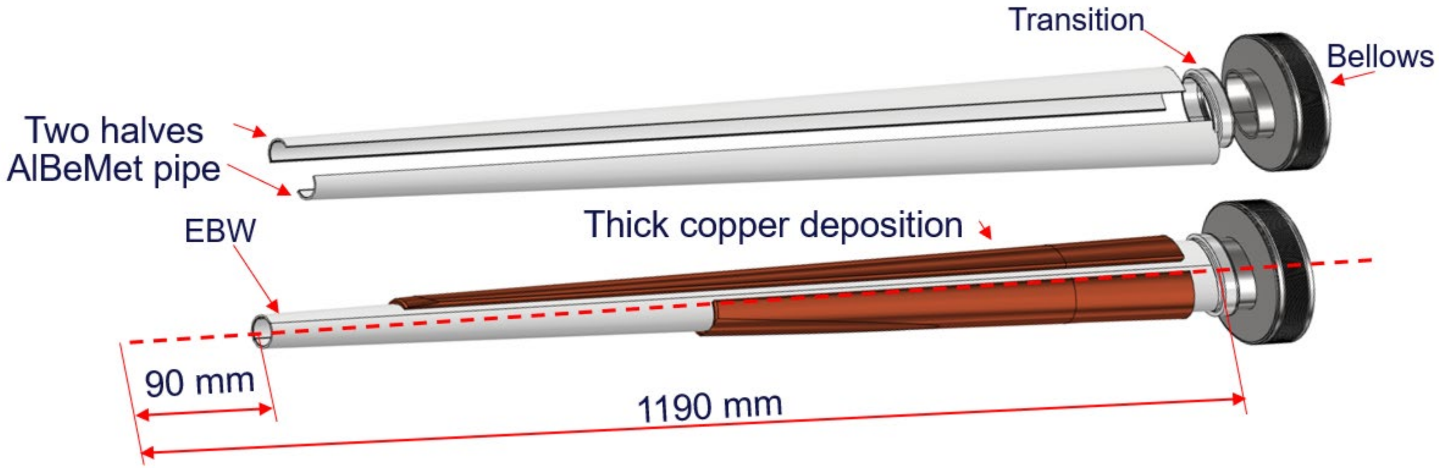


Central chamber



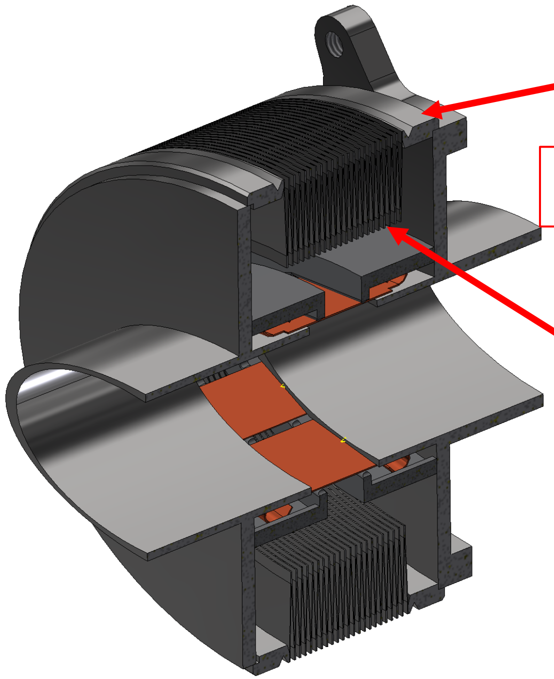
- Three layers from 0-90 mm from IP
  - 0.35 mm of AlBeMet162 (62% Be, 38% Al)
  - 1 mm gap for Paraffin
  - 0.35 mm of AlBeMet162

Trapezoidal chamber

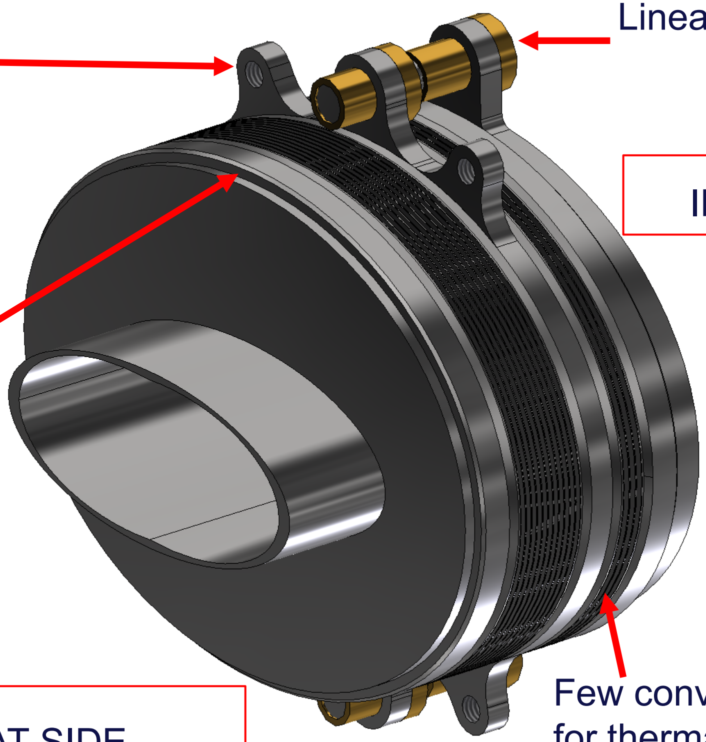


- Starting from 90 mm to 1190 mm from IP
- AlBeMet162 as main material
- Chamber in two halves and assembled using electron beam welding (EBW)
- Copper cooling system

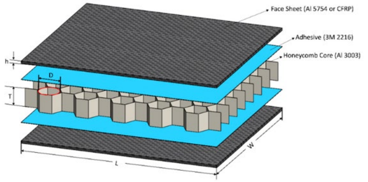
1st Bellows (Single bellows)



2nd Bellows (Double bellows)



Support tube



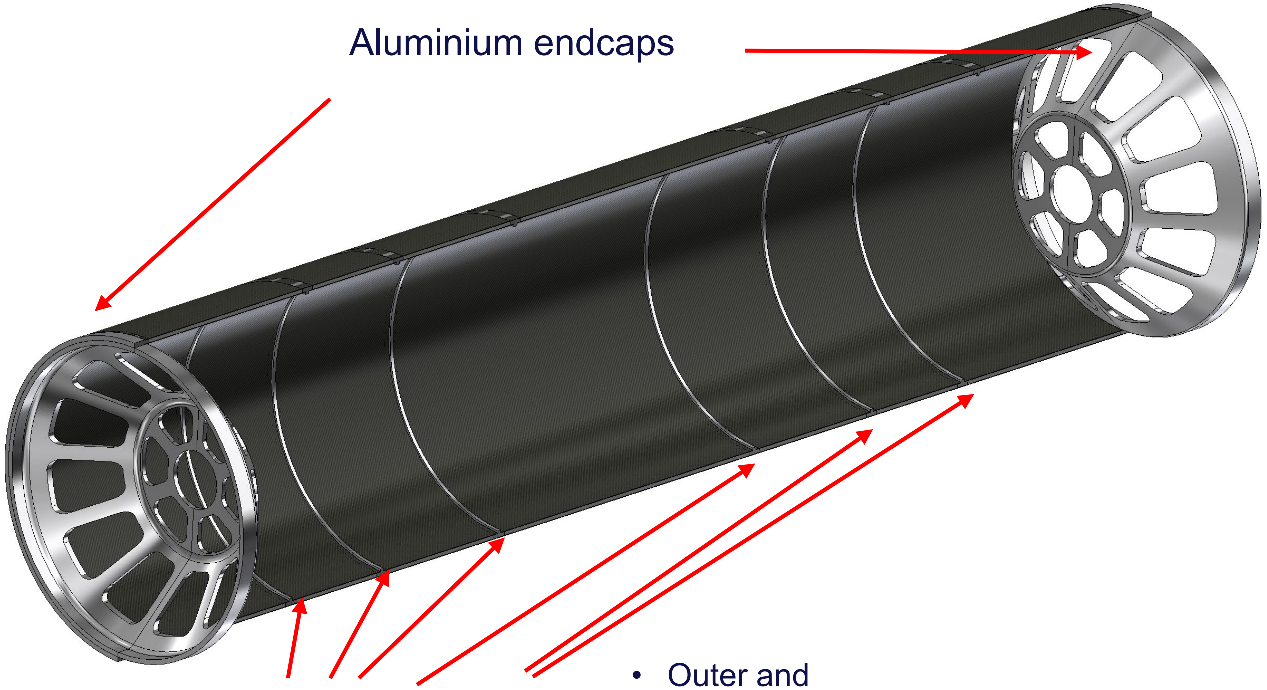
The **support tube** aims to :

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

The structure is made with a multiple layer structure:

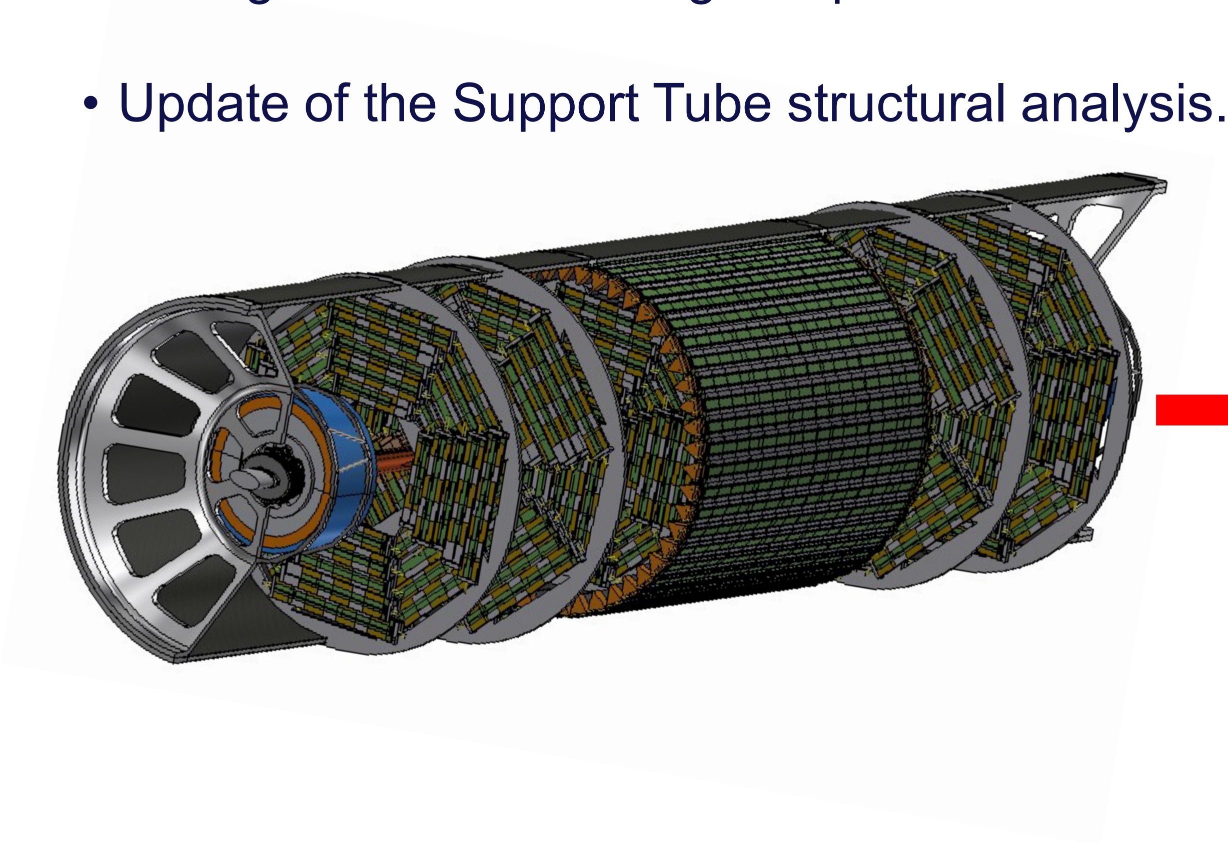
- ➢ 1mm CF + 4mm HC + 1mm CF

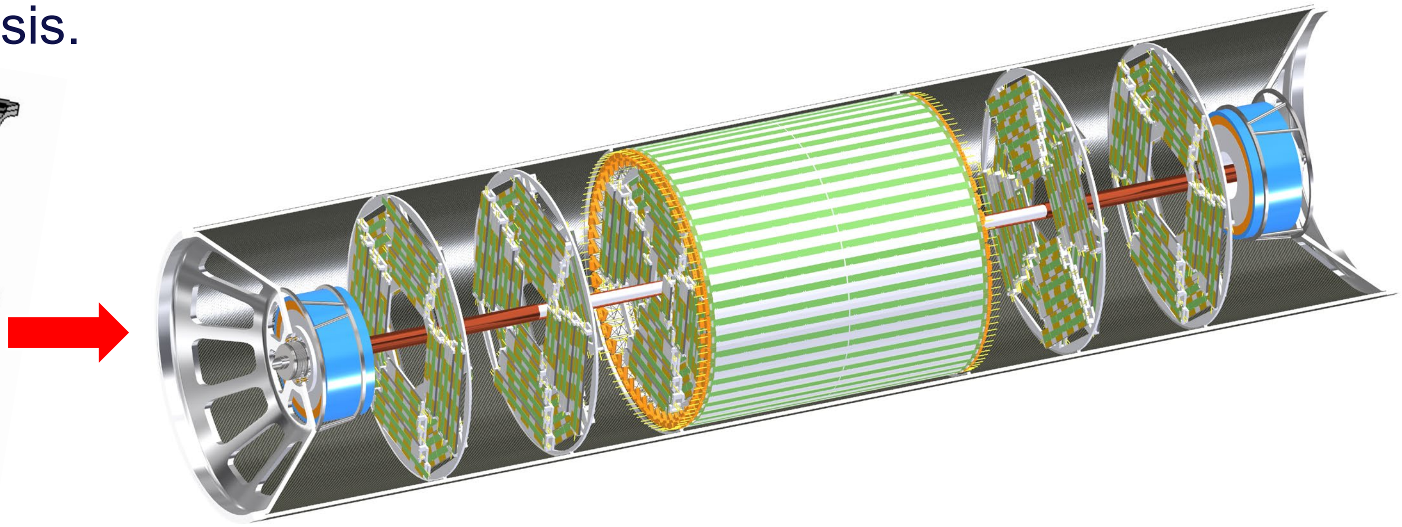
- To allow the support of the disks are necessary 6 reinforcement ribs.
- The cylinder is split in two halves to simplify the assembly procedure
- The Aluminium endcaps support the LumiCal and the beampipe



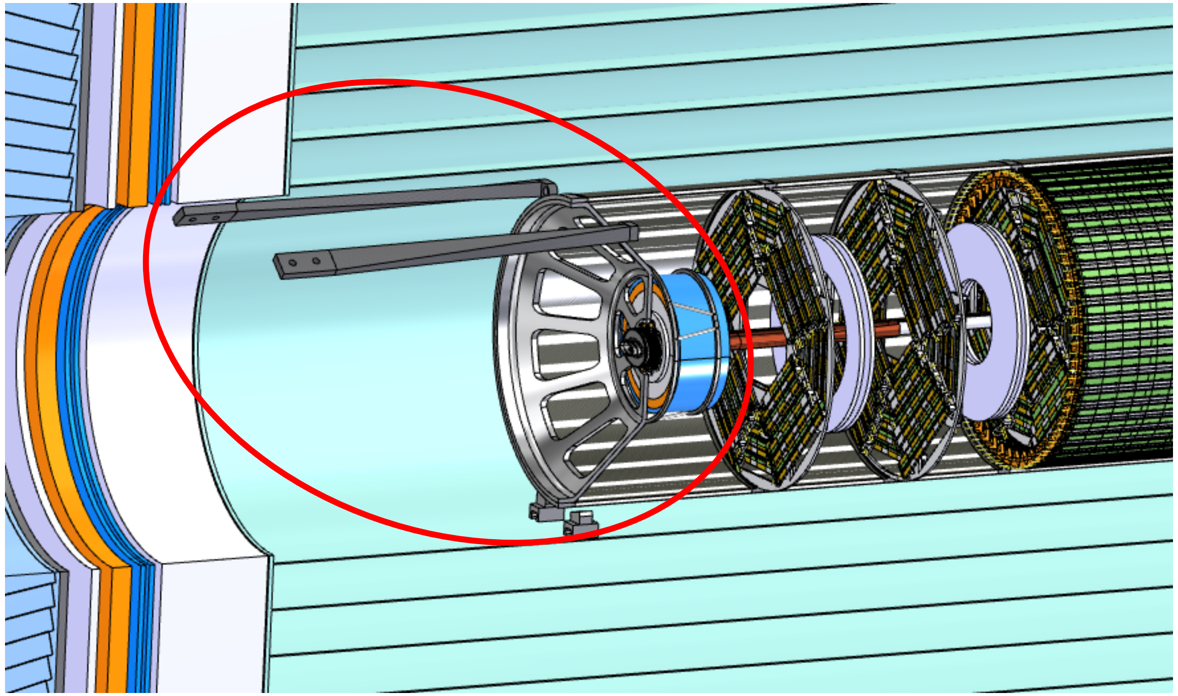
Update of the vertex detector, disks and barrels integration

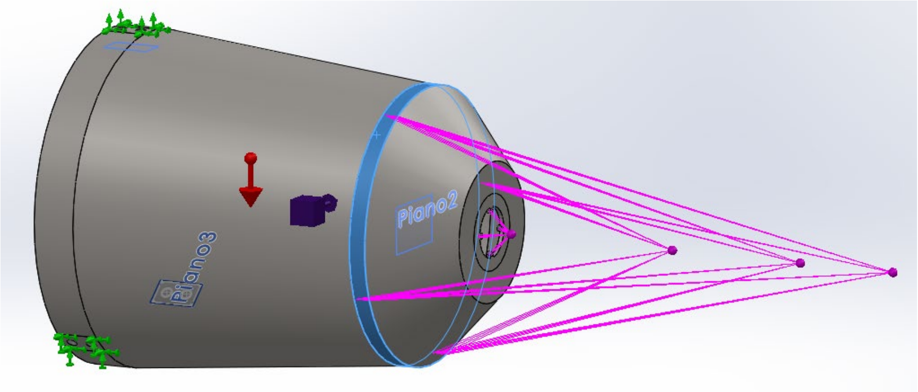
- Update of the diameters of disks and outer barrel.
- Change of the disks' position according to the last layout version from INFN-Pisa group.
- Change of the reinforcing ribs position.
- Update of the Support Tube structural analysis.



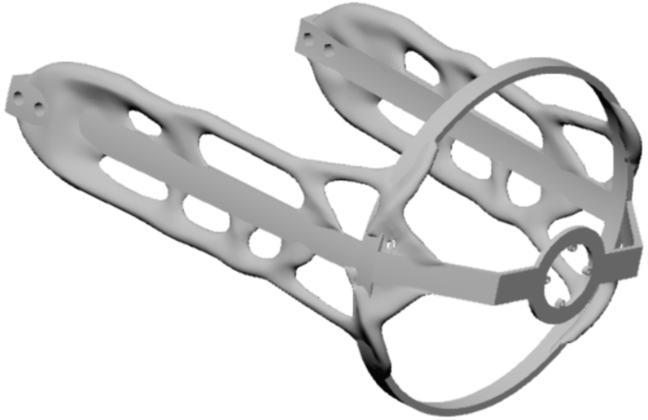


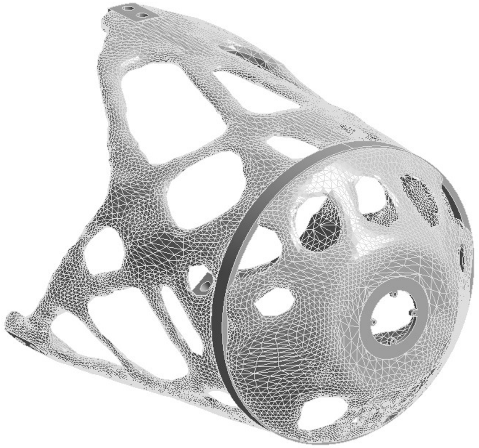
Structural optimization of Support Tube flanges

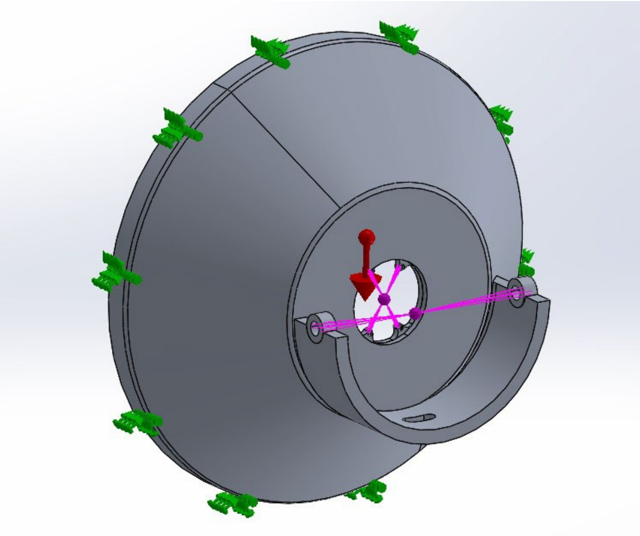


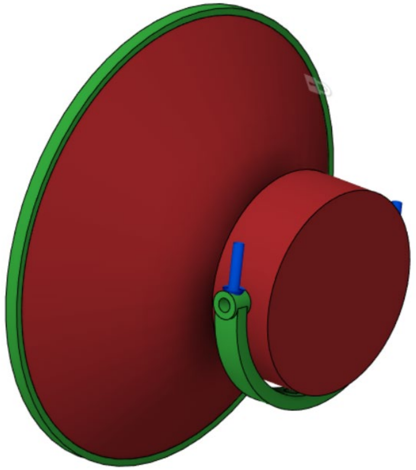


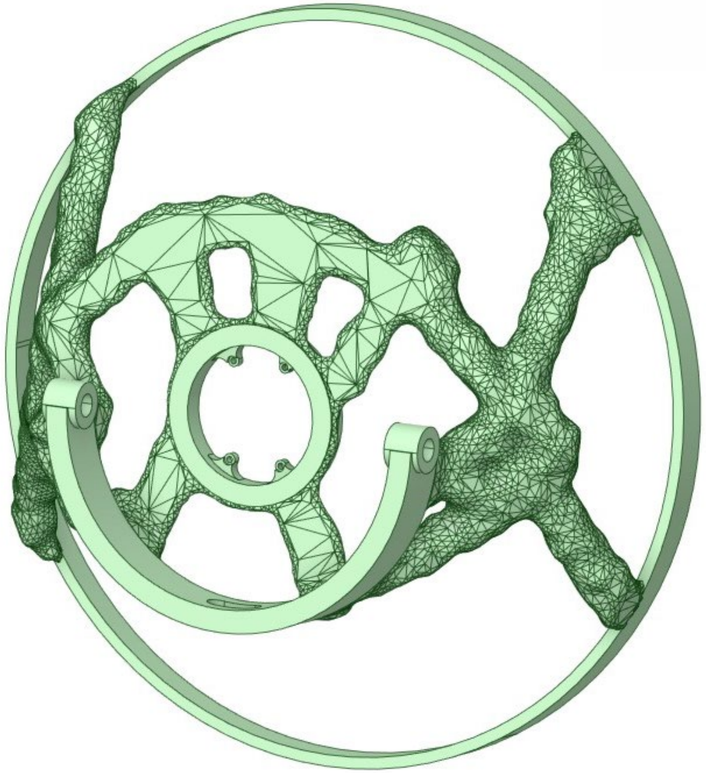
At the moment, the **SIMP** algorithm has been used, based on the concept of penalty, and the **Generative Design** method, capable of creating a structure from an initial shape and from imposed spatial constraints.



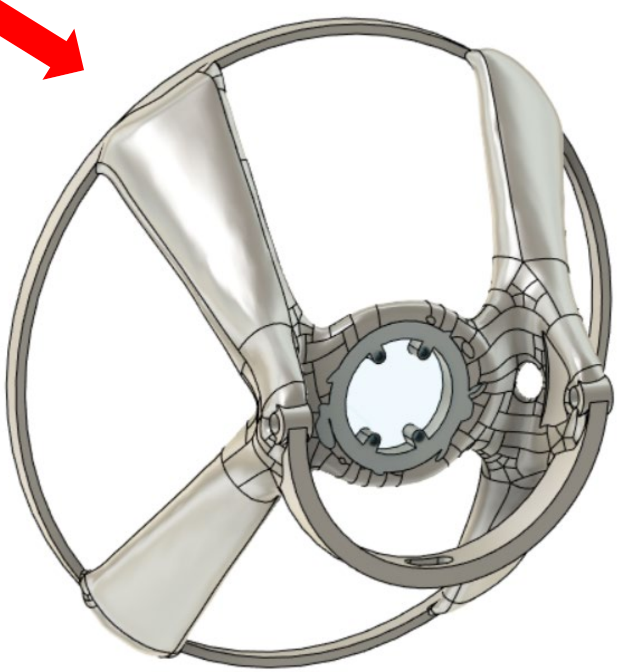




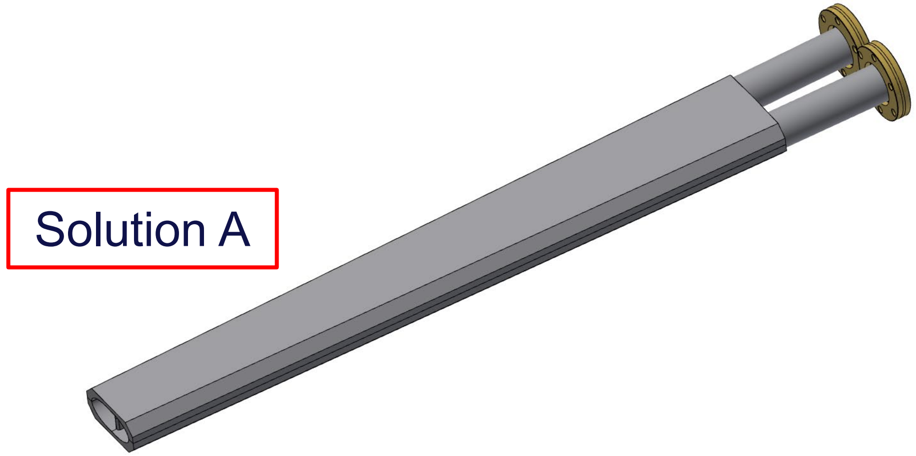


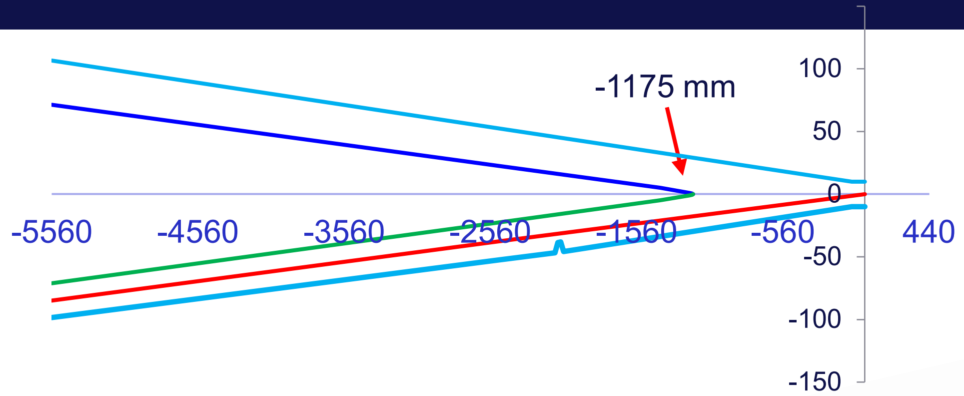


- Constraints in term of stress and displacement
- Minimizing of the mass
- No design zone where the constraint and loads are applied and in functional area

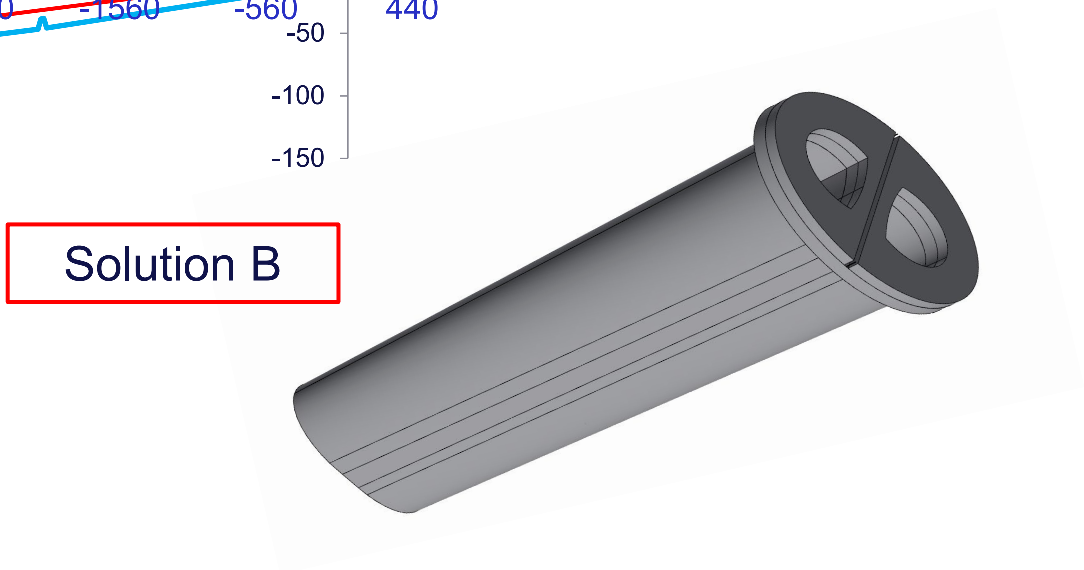


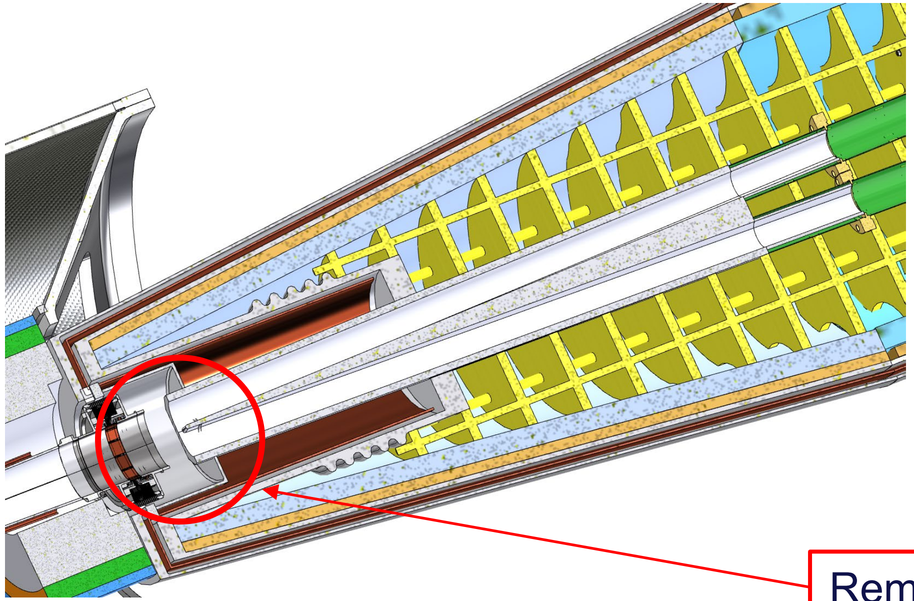
Crotch chamber





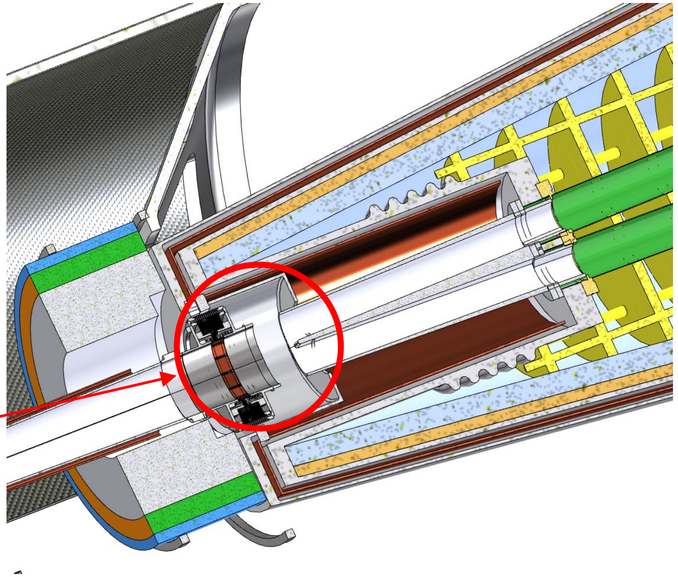
Work in progress





Solution A:
- Standard flanges
- More space available for the crotch
- Flanges in Helium

Solution B:
- Flanges not in contact with Helium
- Shorter chamber than solution A
- No standard flanges



Remote vacuum connection

Accelerator division internal notes

- Calculation of the paraffin flow parameters needed to remove the heat load
- Published17-04-2023

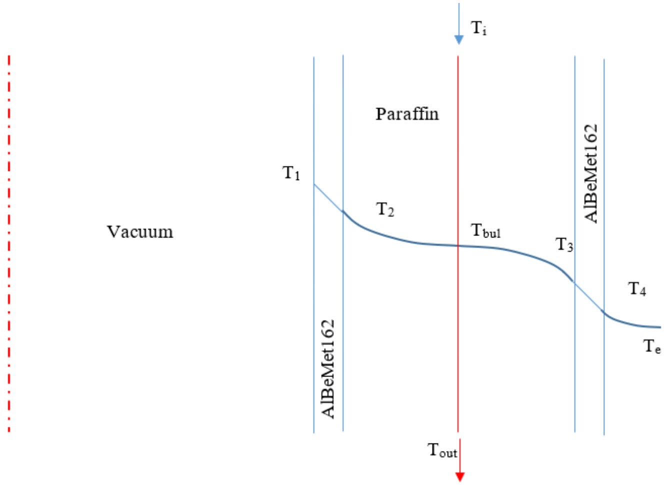


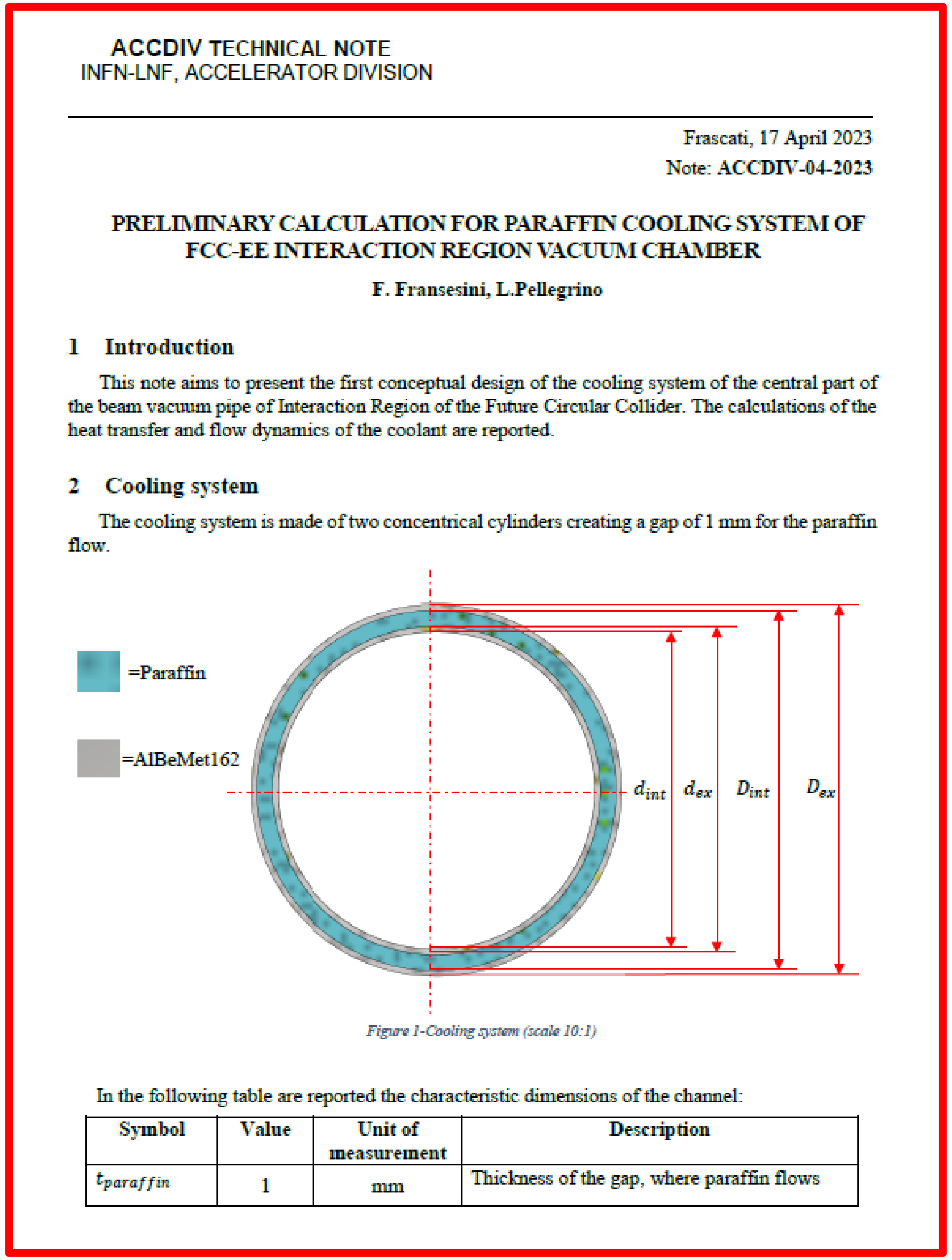
Figure 5 - Temperature diagram

Case	A	B
Velocity	V=0.3 m/s	V=0.5 m/s
T_{out}[°C]	18.5	18.3
T_{bulk}[°C]	18.3	18.2
T_2[°C]	23.4	23.0

$$\Delta p_{v=0.3} = f \frac{L}{D_{eq}} \frac{v^2}{2} \rho = 24 \frac{0.180}{2 * 10^{-3}} \frac{0.3^2}{2} 734\ Pa = 71.34\ kPa$$

$$\Delta p_{v=0.5} \frac{L}{D_{eq}} \frac{v^2}{2} \frac{0.180}{10^{-3}} \frac{0.5^2}{2} 734\ Pa = 192\ kPa$$

https://da.lnf.infn.it/documentation/accelerator-division-technical-notes/accelerator-division-technical-notes/


ACCDIV TECHNICAL NOTE
INFN-LNF, ACCELERATOR DIVISION

Frascati, 17 April 2023
Note: ACCDIV-04-2023

PRELIMINARY CALCULATION FOR PARAFFIN COOLING SYSTEM OF FCC-EE INTERACTION REGION VACUUM CHAMBER

F. Fransesini, L.Pellegrino

1 Introduction

This note aims to present the first conceptual design of the cooling system of the central part of the beam vacuum pipe of Interaction Region of the Future Circular Collider. The calculations of the heat transfer and flow dynamics of the coolant are reported.

2 Cooling system

The cooling system is made of two concentrical cylinders creating a gap of 1 mm for the paraffin flow.

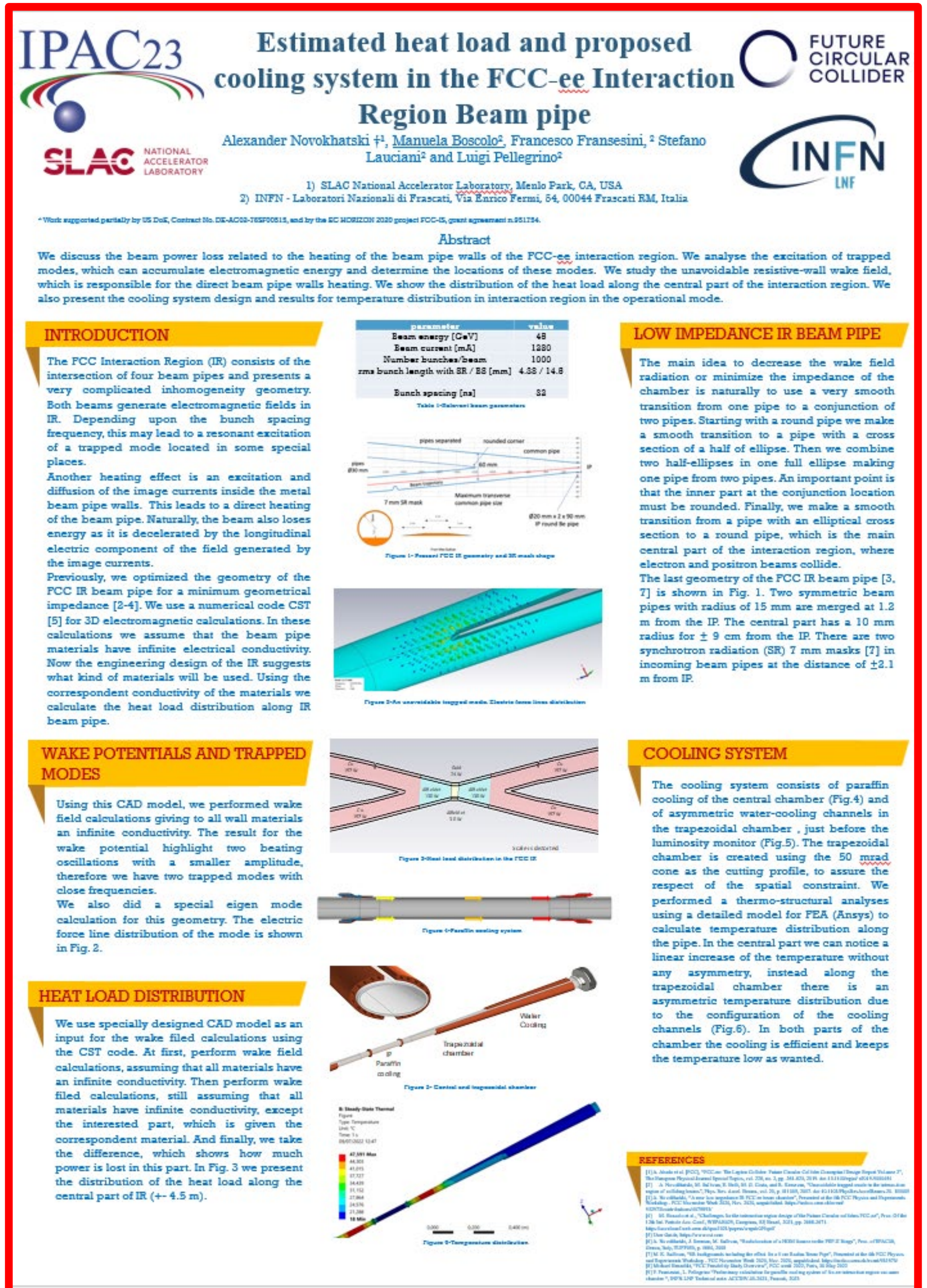
Figure 1-Cooling system (scale 10:1)

In the following table are reported the characteristic dimensions of the channel:

Symbol	Value	Unit of measurement	Description
$t_{paraffin}$	1	mm	Thickness of the gap, where paraffin flows

IFAE 2023

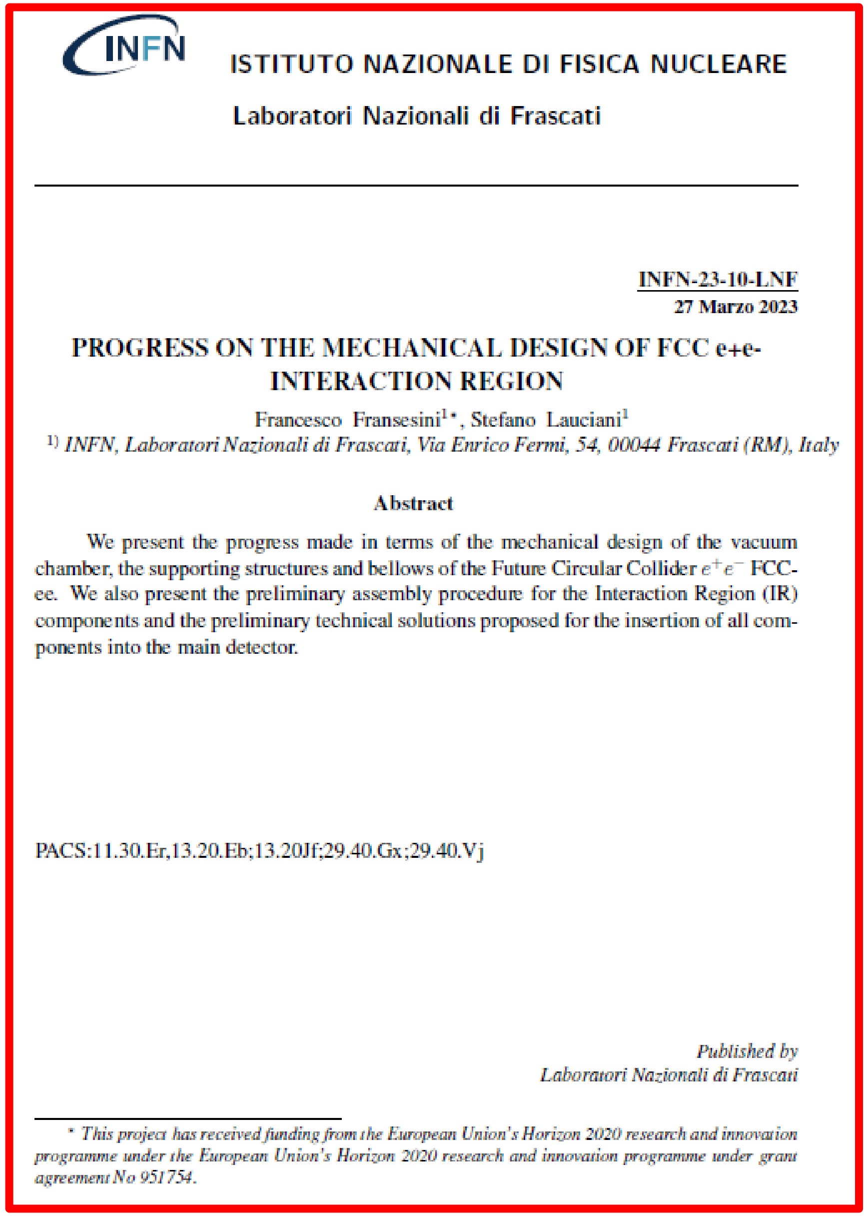
IPAC 2023



INFN note

Main themes:

- Mechanical Model of the Beam Pipe and structural analysis
- Mechanical Model of the IR Bellows
- IR Carbon-fibre Support tube
- Assembly sequence and alignment
- Future plans



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Laboratori Nazionali di Frascati

INFN-23-10-LNF
27 Marzo 2023

PROGRESS ON THE MECHANICAL DESIGN OF FCC e+e- INTERACTION REGION

Francesco Fransesini[1]*, Stefano Lauciani[1]
[1]) *INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi, 54, 00044 Frascati (RM), Italy*

Abstract

We present the progress made in terms of the mechanical design of the vacuum chamber, the supporting structures and bellows of the Future Circular Collider e^+e^- FCC-ee. We also present the preliminary assembly procedure for the Interaction Region (IR) components and the preliminary technical solutions proposed for the insertion of all components into the main detector.

PACS:11.30.Er,13.20.Eb;13.20Jf;29.40.Gx;29.40.Vj

Published by
Laboratori Nazionali di Frascati

* *This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.*

- Published on 28-03-2023

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THANK YOU FOR YOUR ATTENTION

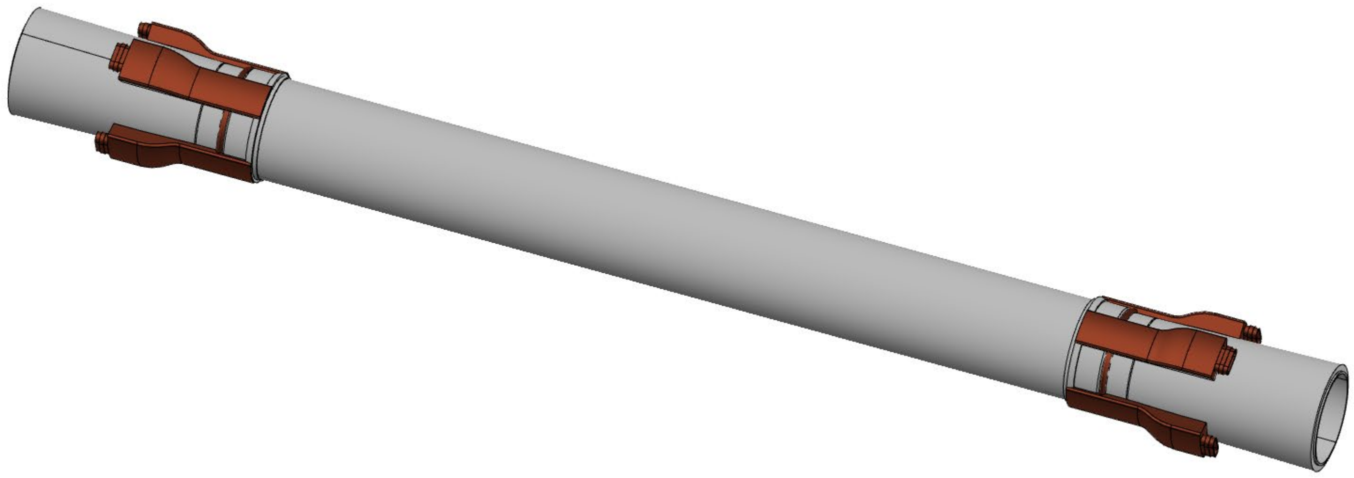
Contact: francesco.fransesini@lnf.infn.it

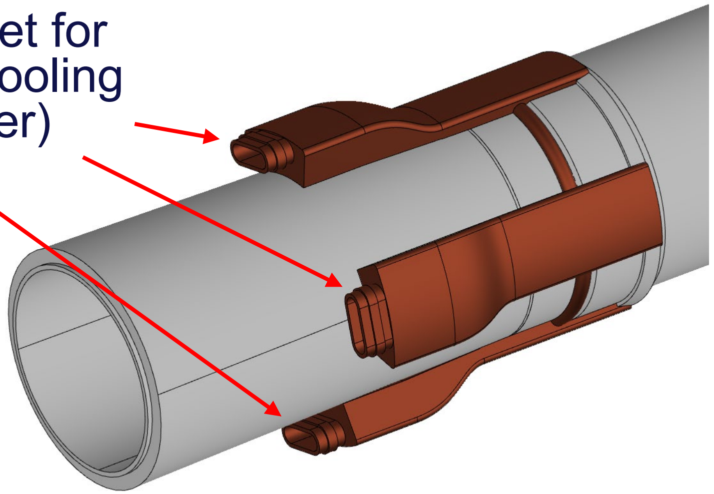
BACK UP SLIDES

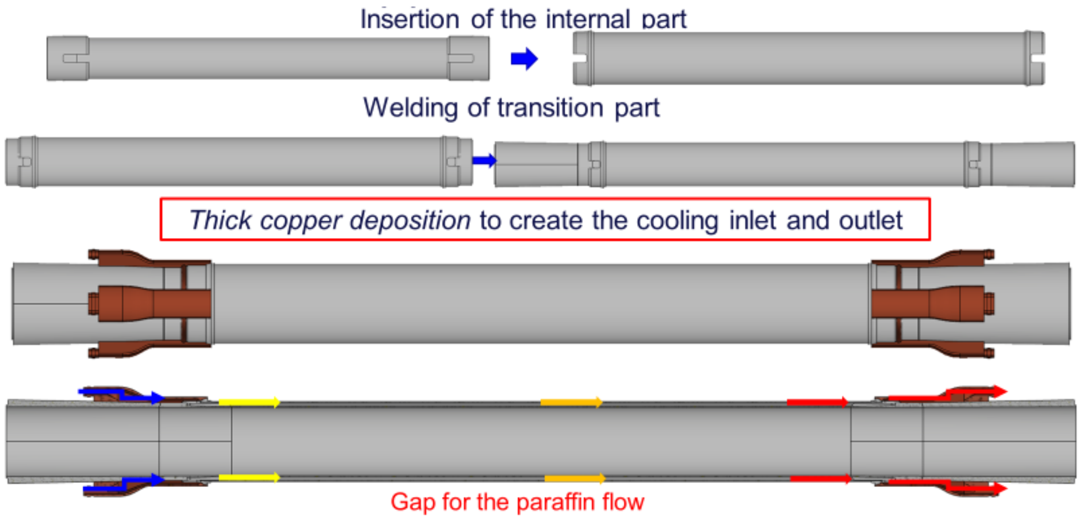
Chamber design – central chamber

The central has the following characteristics:

- AlBeMet 162 as main material
- Three layers from 0-90 mm from IP
  - 0.35 mm of AlBeMet162 (62% Be, 38% Al)
  - 1 mm gap for Paraffin
  - 0.35 mm of AlBeMet162
- Paraffin as coolant
- Geometry studied to integrate the central chamber with the vertex detector



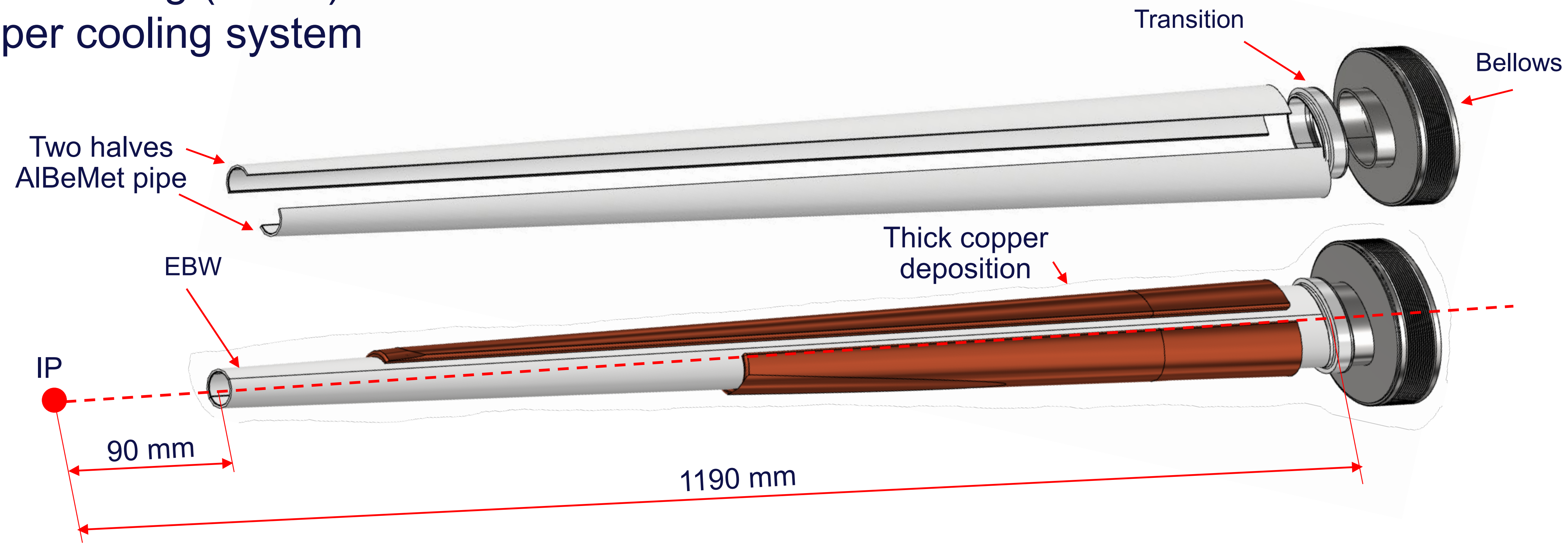




Chamber design – trapezoidal chamber

Main characteristics:

- Starting from 90 mm to 1190 mm from IP
- AlBeMet162 as main material
- Chamber in two halves and assembled using electron beam welding (EBW)
- Copper cooling system



Structural analysis – central chamber

Loads, constraints, characteristic parameters, design ➡ FEA (Ansys) ➡ **Temperature distribution, stress and displacement** 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

\+

Chamber design

\+

- Heat load → From CST calculations (**Alexander Novokhatski (SLAC)**)
  - 54 W central
  - 130 W AlBeMet162 for each part
- Weight
  - chamber
  - Vertex detector first layer
- Constraint
  - Cantilevered, simply supported configuration
- Hypothesis:
  - Perfect thermal contact between the materials

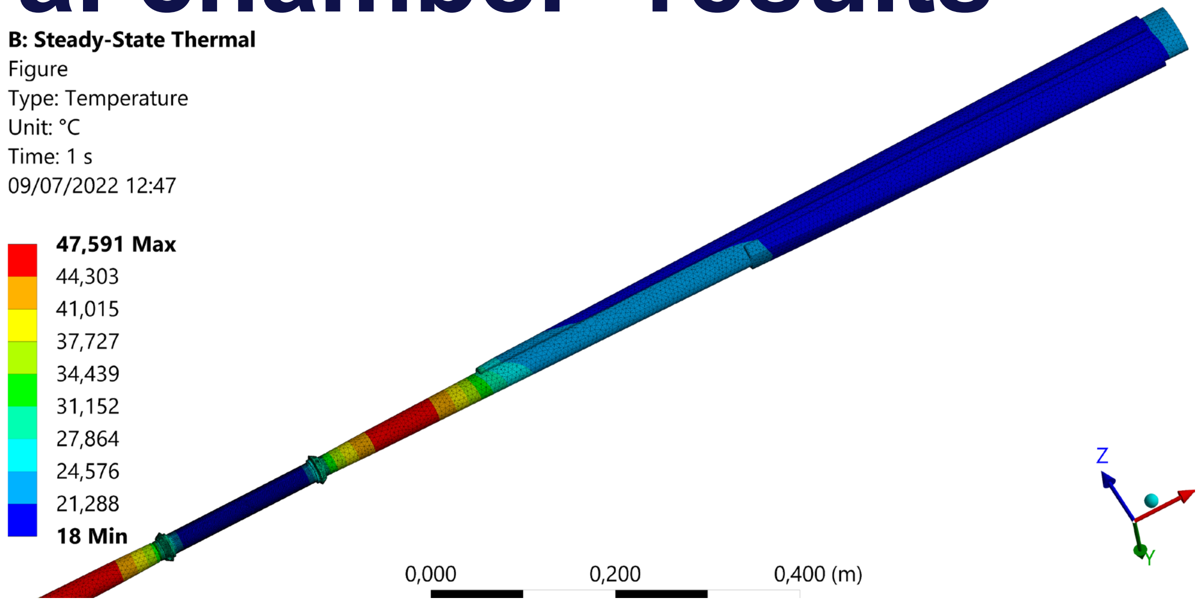
➡ RESULTS

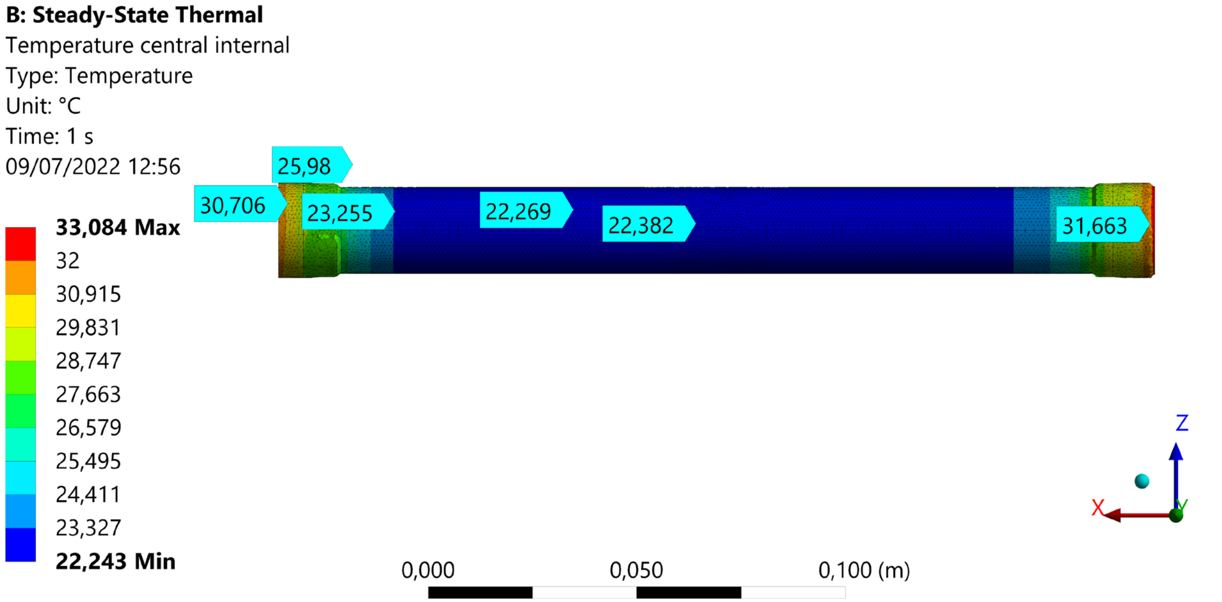
Structural analysis – central chamber- results

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

Von Mises stress [MPa]					
		Trapezoidal SX	Trapezoidal DX	Central IN	Central EX
BEAM	Fixed ends	22,07	21,86	46,8	38,9
	Fixed+displ	14,65	10,63	9,69	17

Maximum displacement [mm]			
		X	Y
BEAM	Fixed ends	0,031	0,07
	Fixed+displ	0,1	0,29





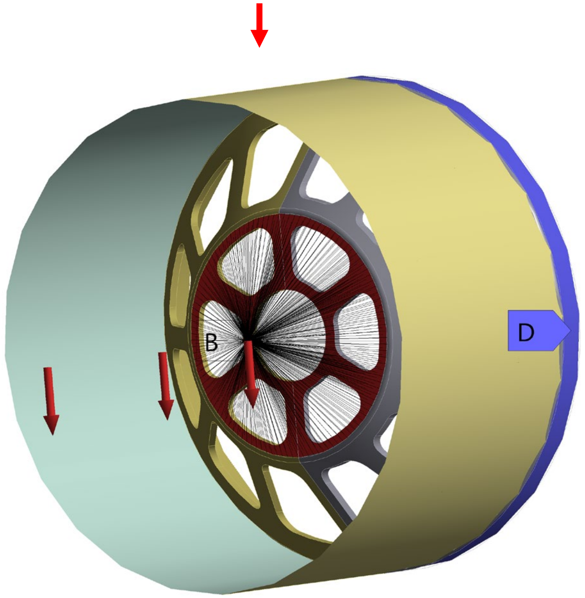
Support tube – Structural analysis

The aim of this analysis is to calculate the stress and displacement in each part of the cylinder (Al reinforcement, carbon fiber, honeycomb).

It is necessary to set:

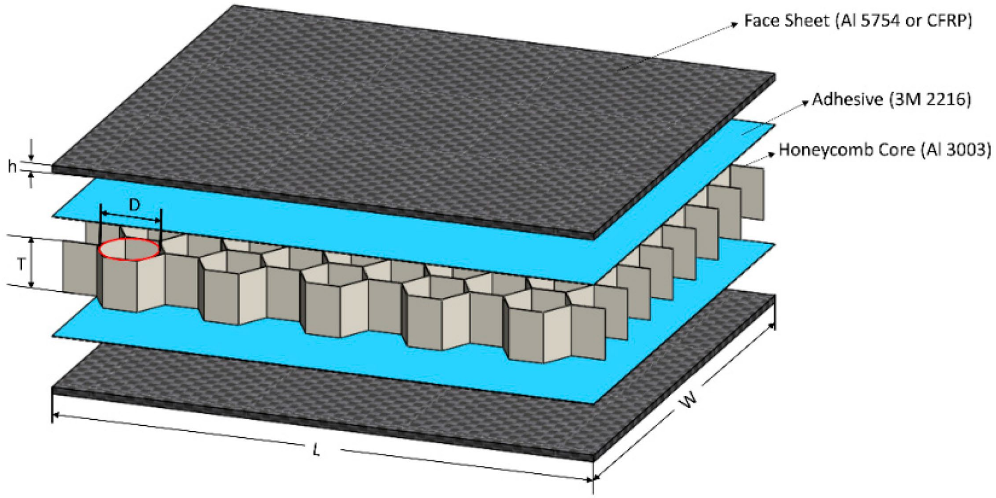
- Constraint configuration → double fixed ends
- Loads configuration →

Chamber	50 kg
LumiCal	70 kg + 70 kg
Disk tracker	6*10 kg
Outer tracker	15
Medium tracker	7
First guess loads (overestimated)	

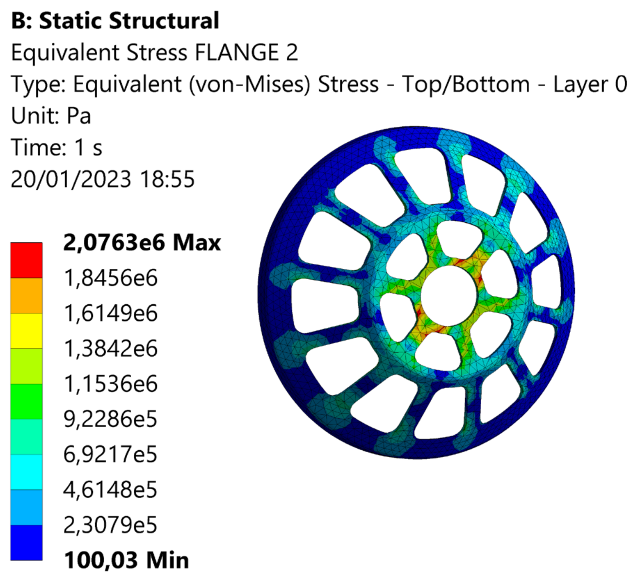


Loads applied to remote point to distribute

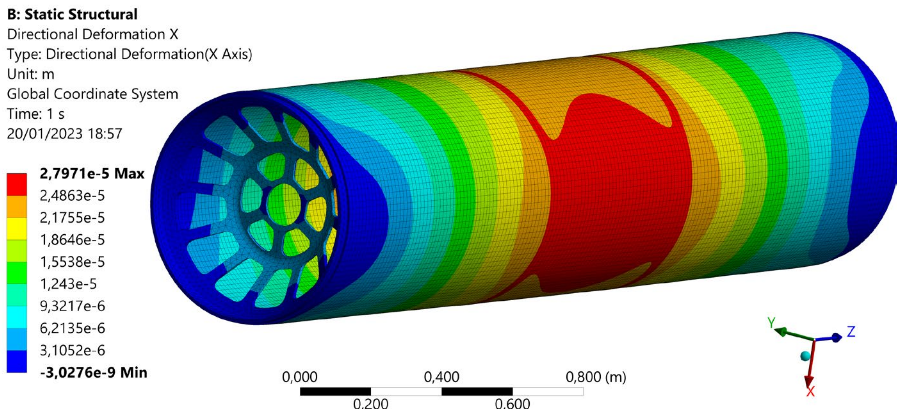
- Carbon fiber/ honeycomb creation → layered section

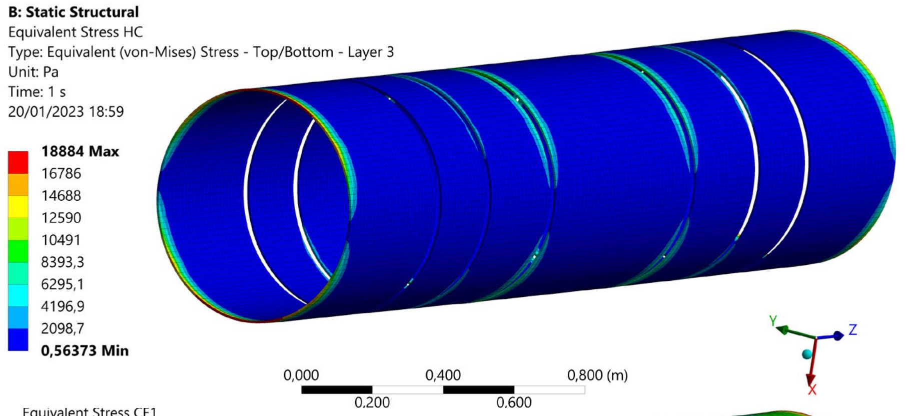


Support tube – Structural analysis – results

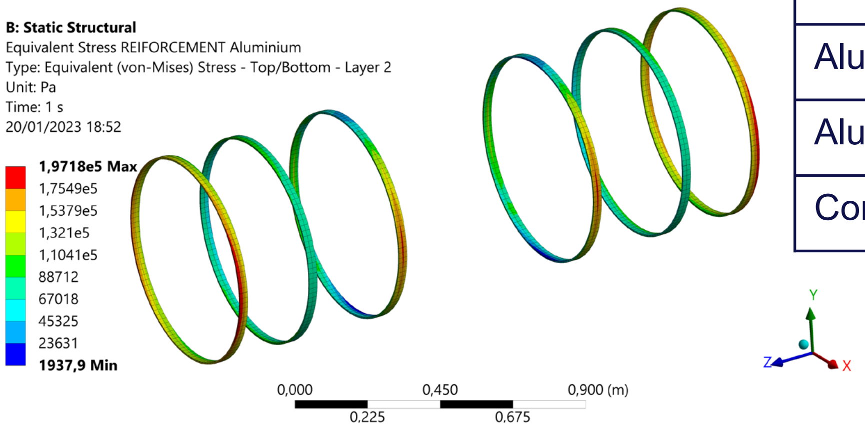


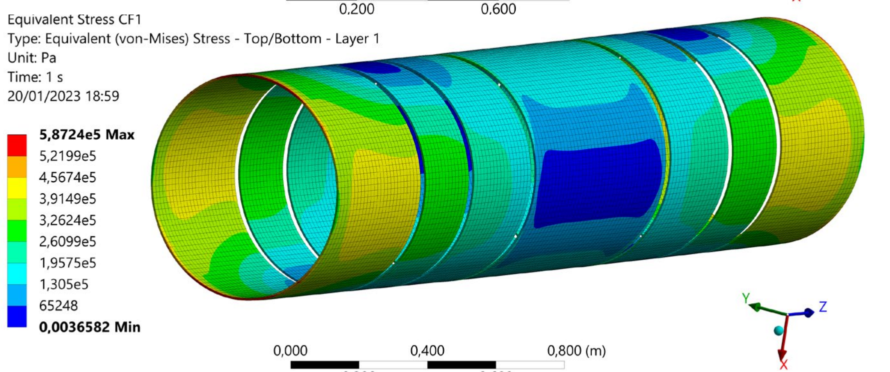
	Maximum stress [MPa]
Aluminium flanges	2.08
Aluminium ribs	0.20
Honeycomb	0.02
Carbon fiber	0.60





	Maximum displacement X [mm]
Aluminium flanges	1.34 e-2
Aluminium ribs	2.62 e-2
Composite	2.80 e-2



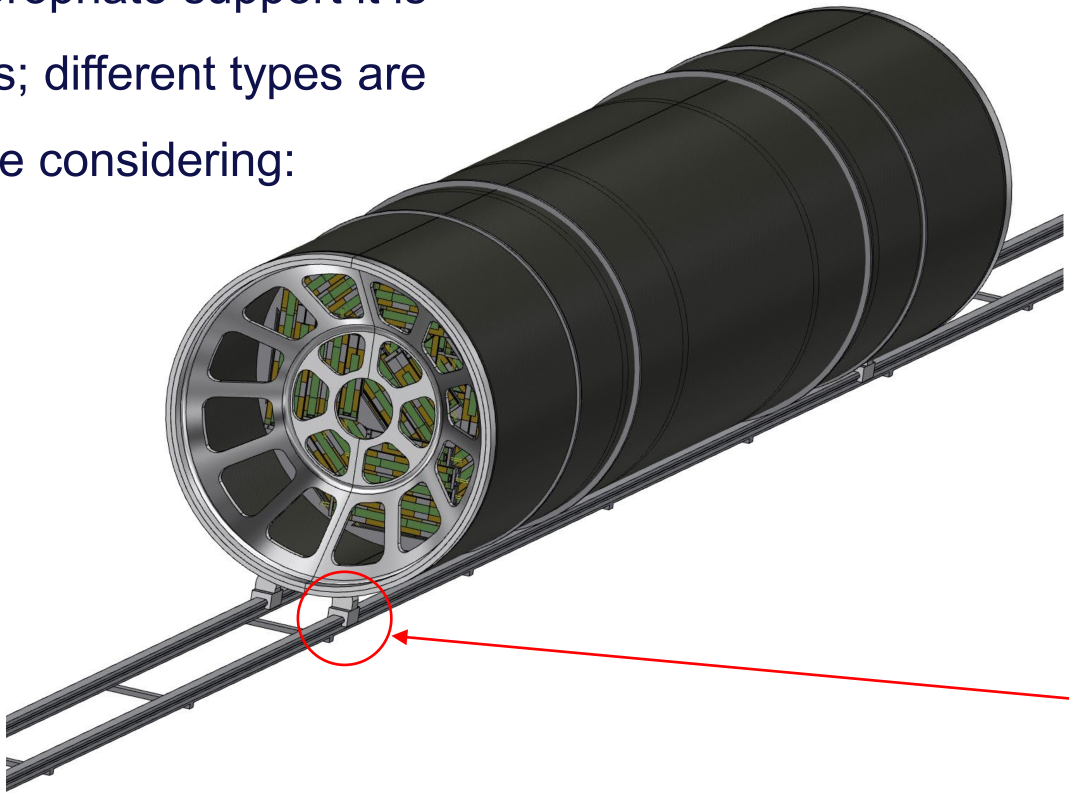


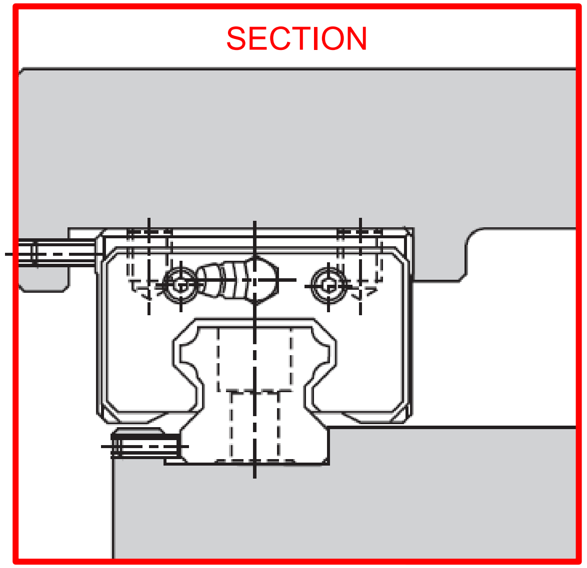
Support tube – Rail

The support tube needs to be inserted into the main detector; the idea is to use a rail, starting from the outside of the detector to allow the sliding of the cylinder.

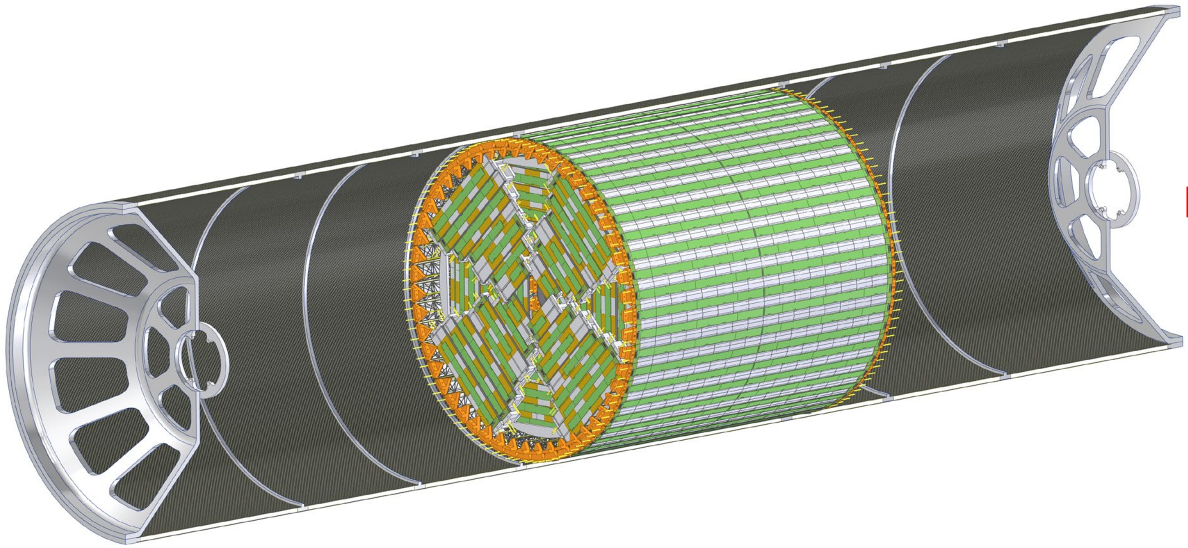
To assure a good precision and appropriate support it is necessary to use the linear bearings; different types are available, the choice has to be made considering:

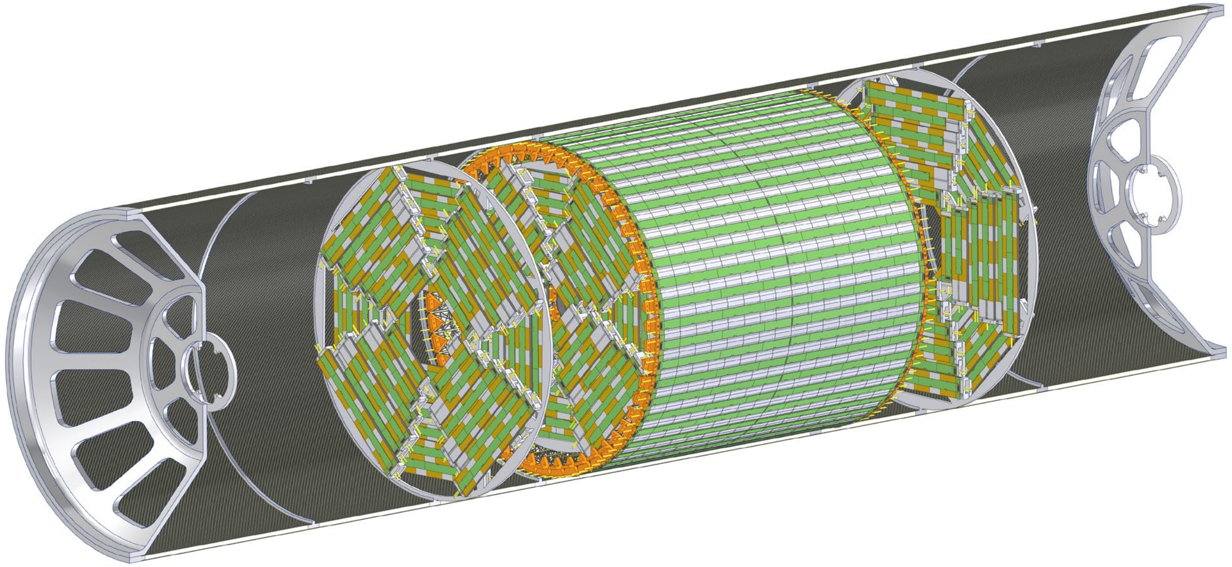
- Required positioning precision
- Weight of the whole structure
- Necessary degrees of freedom





Assembly procedure

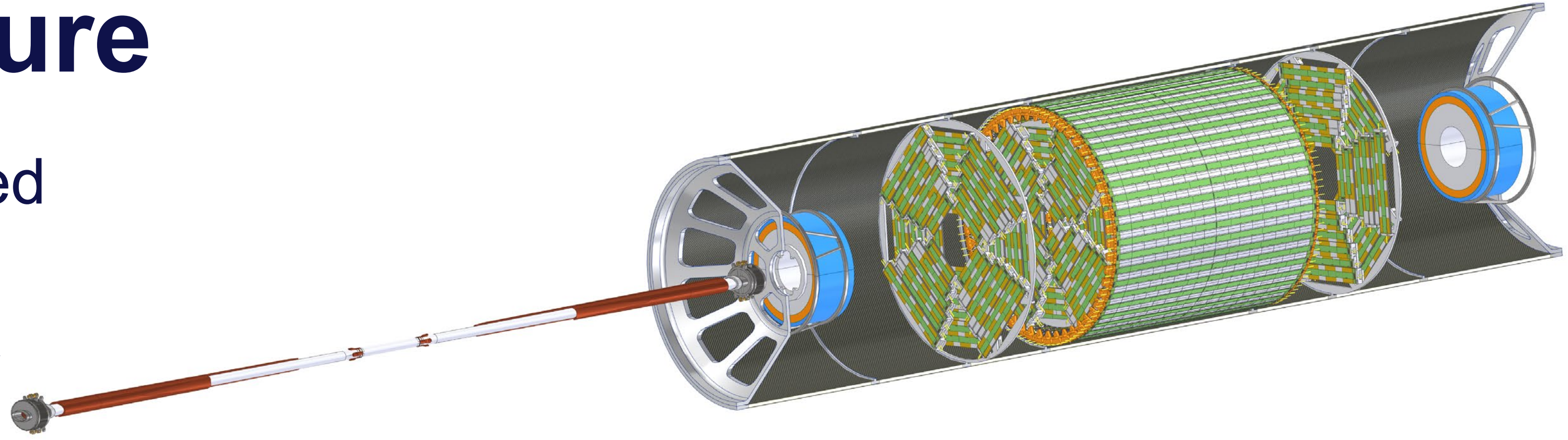




1) Outer tracker, Medium tracker and disks 1 are installed as a rigid structure inside the support tube

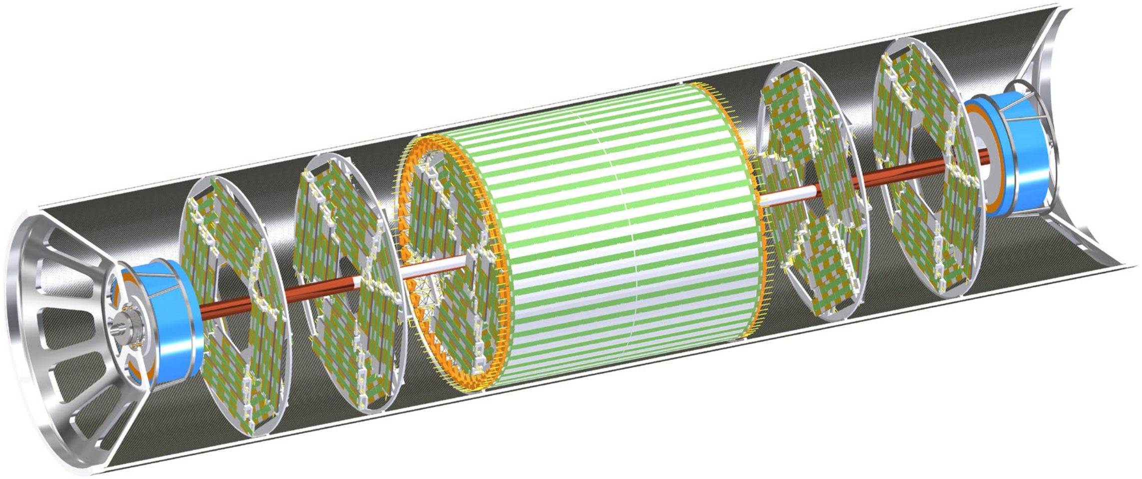
2) Disks 2 and 3 are installed inside the support tube

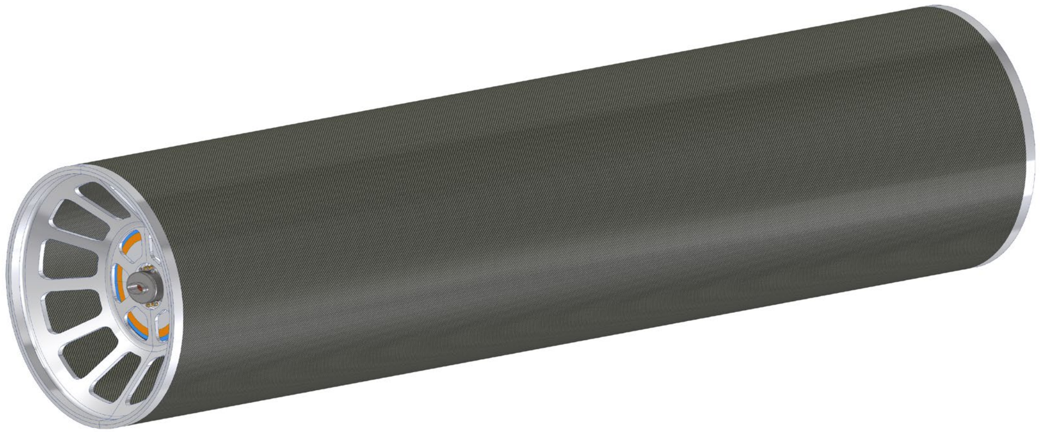
Assembly procedure



3) LumiCal is installed in centered position, then beam pipe with vertex detector is inserted with a dedicated tool inside disks and outer tracker, then fixed to both endcaps

4) LumiCal can be aligned in the correct position on the outgoing beams

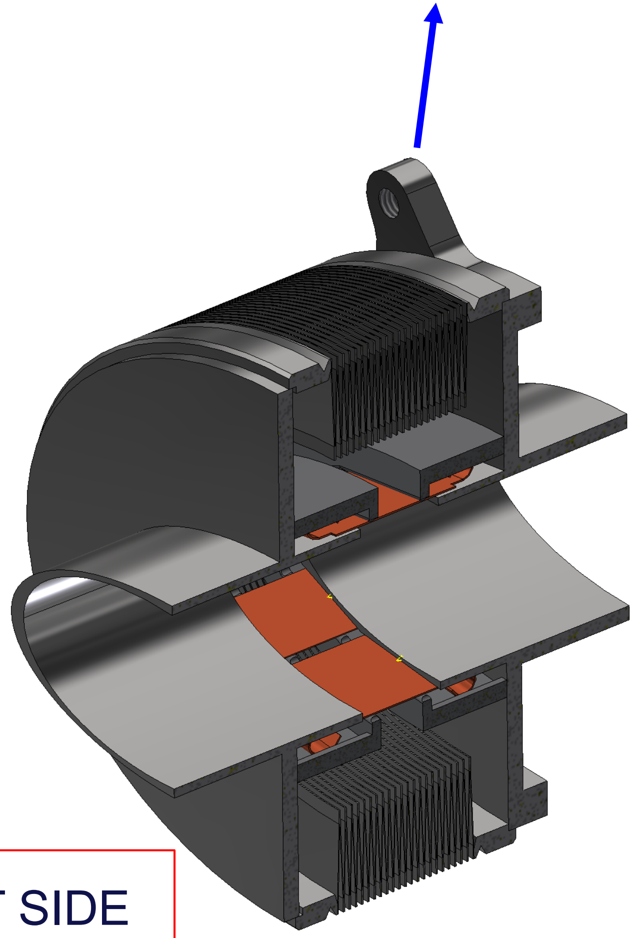




5) Support tube can be closed

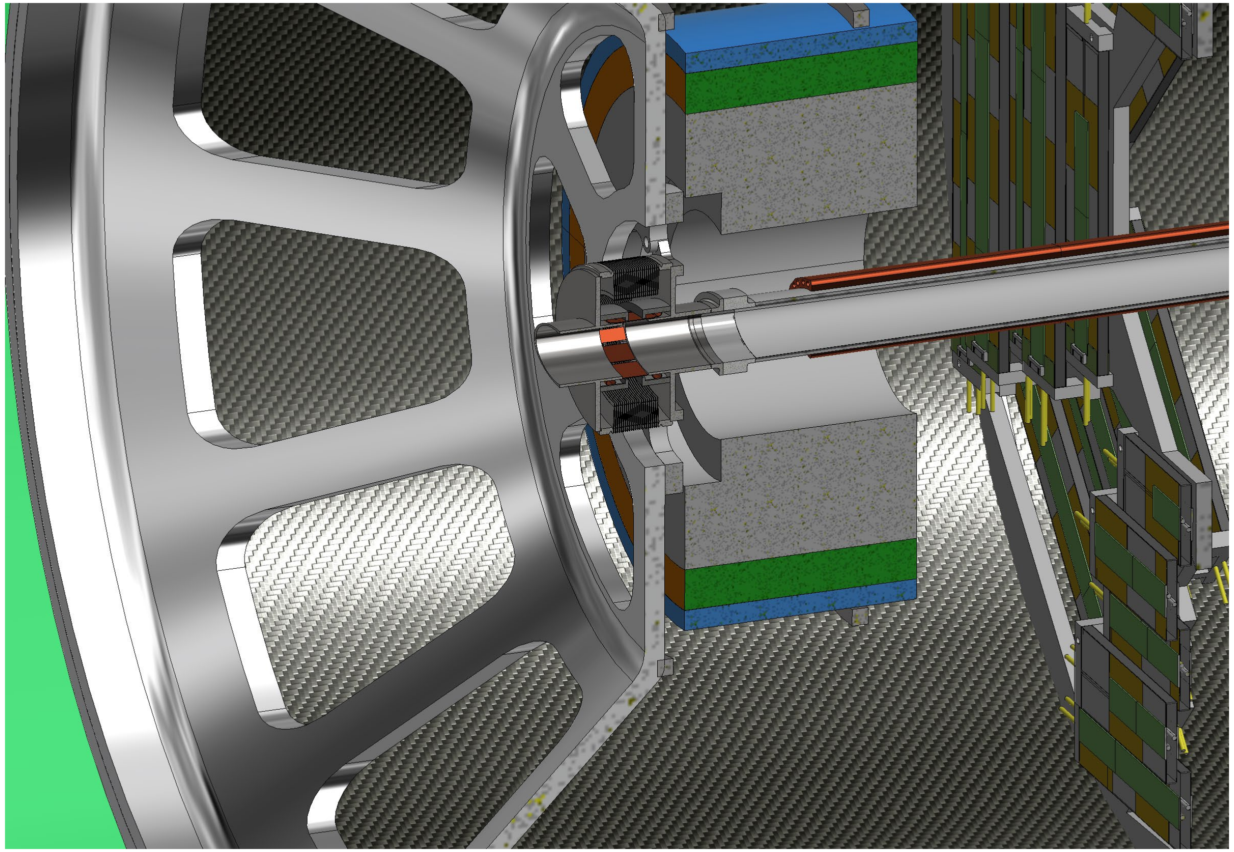
1st Bellows (Single bellows)

Anchoring flange to support tube

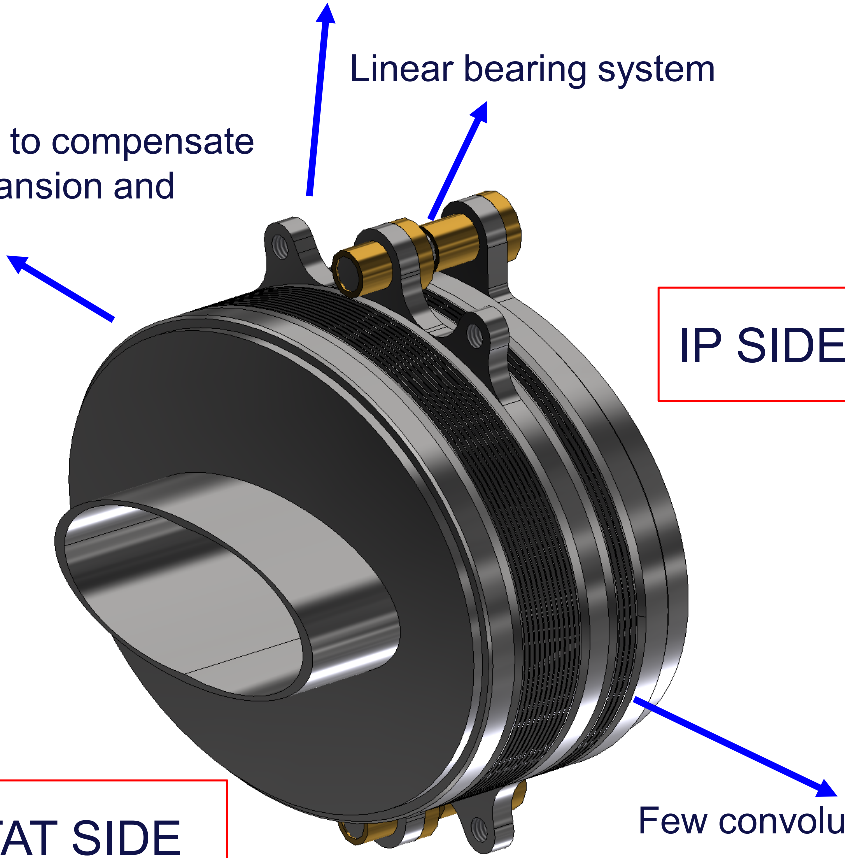


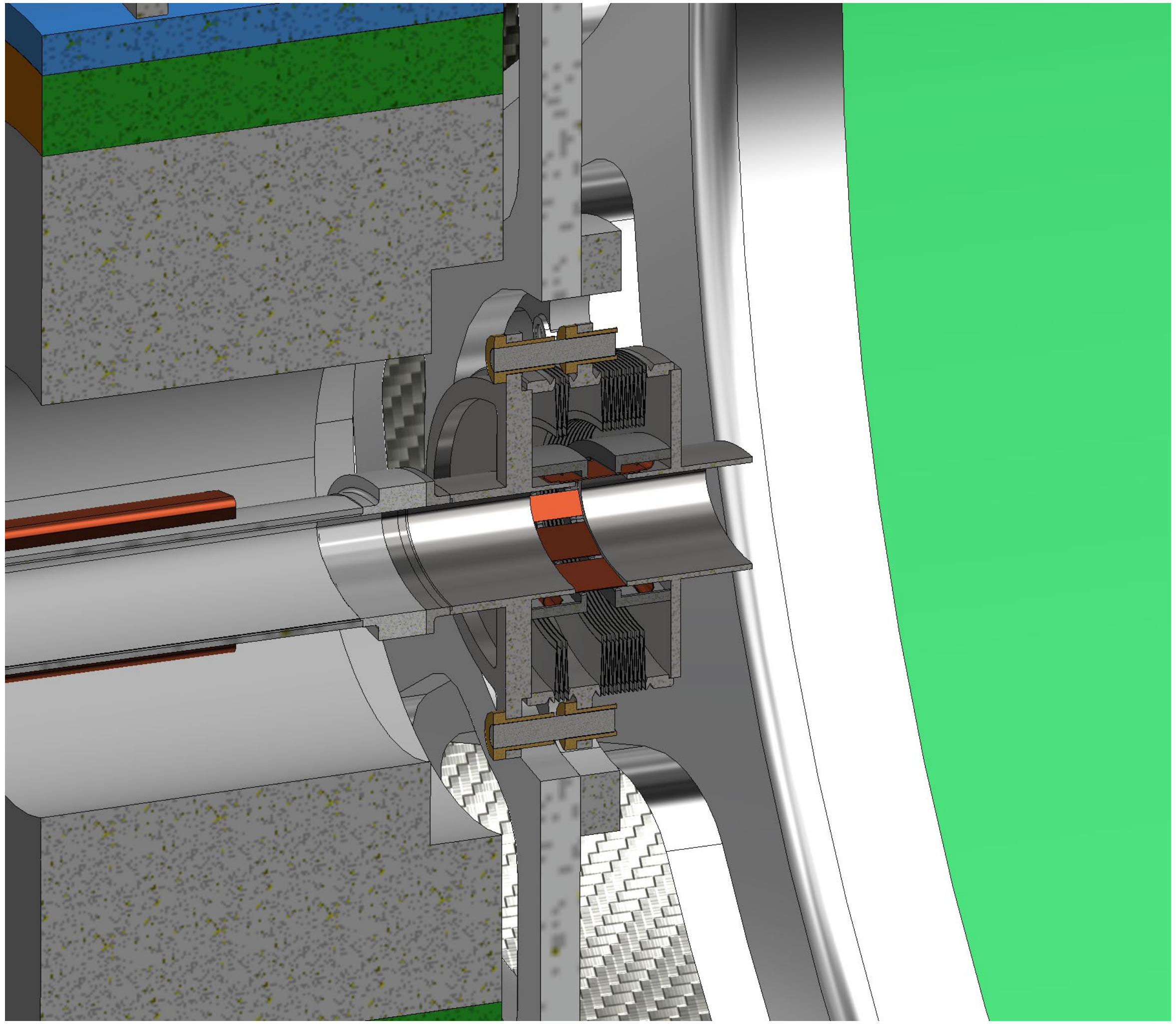
IP SIDE

CRYOSTAT SIDE



2nd Bellows (Double bellows)

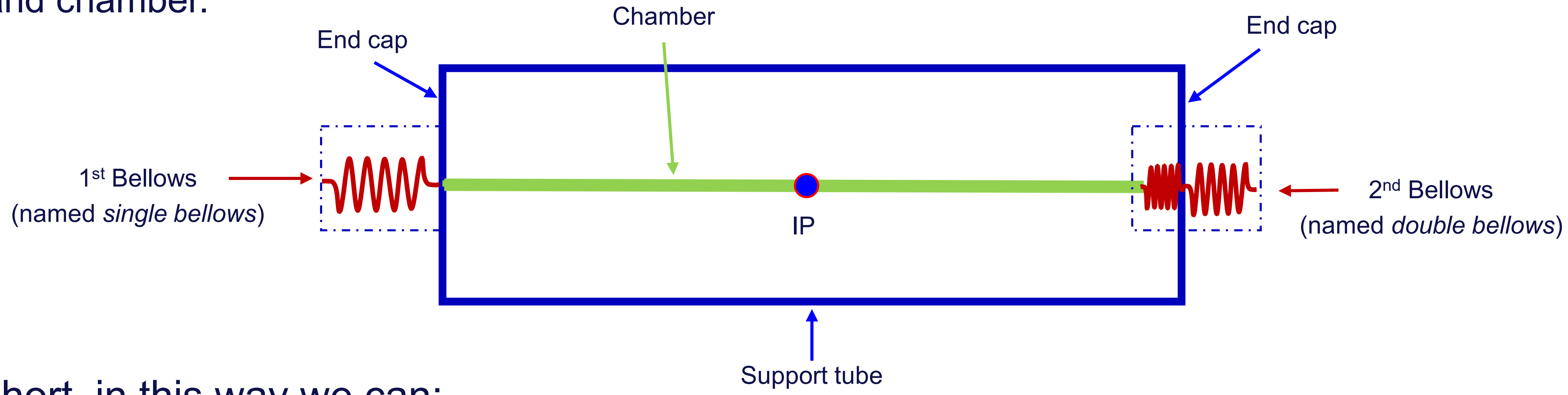




Bellows – constraint configuration

The use of support tube is designed to avoid overloads on central chamber during assembly and operation (thermal expansion). This solution has been obtained using different kind of bellows for the two side of the support tube.

To understand the constraint configuration, it is useful to create a simplified schema with bellows, support tube and chamber.



In short, in this way we can:

- Protect the central chamber during the assembly procedure
- Support properly the chamber bellows-to-bellows, containing the deformation
- Allow the thermal deformation without compromising the chamber