PROGRESS ON THE MDI MECHANICAL DESIGN

Speaker: Francesco Fransesini

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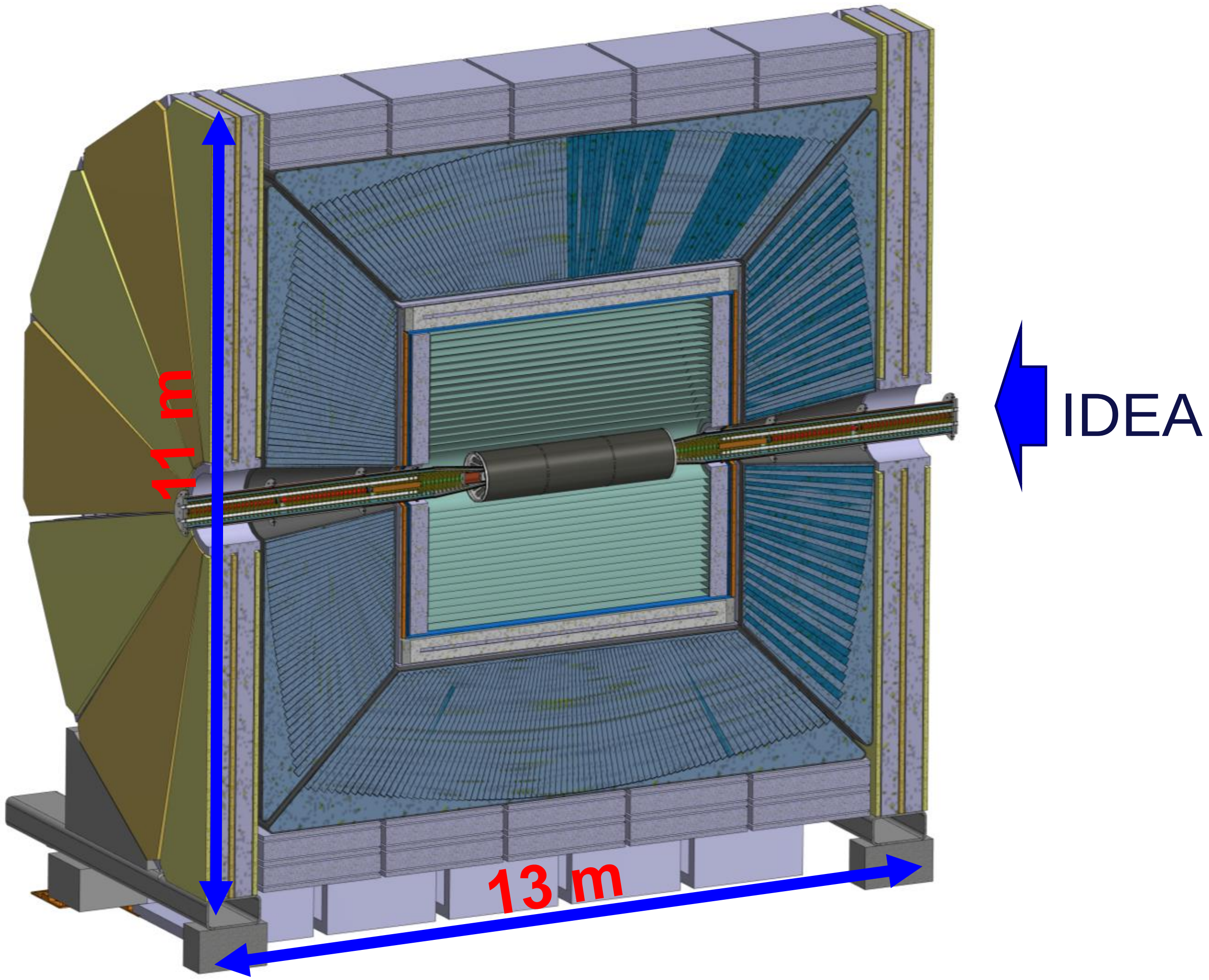
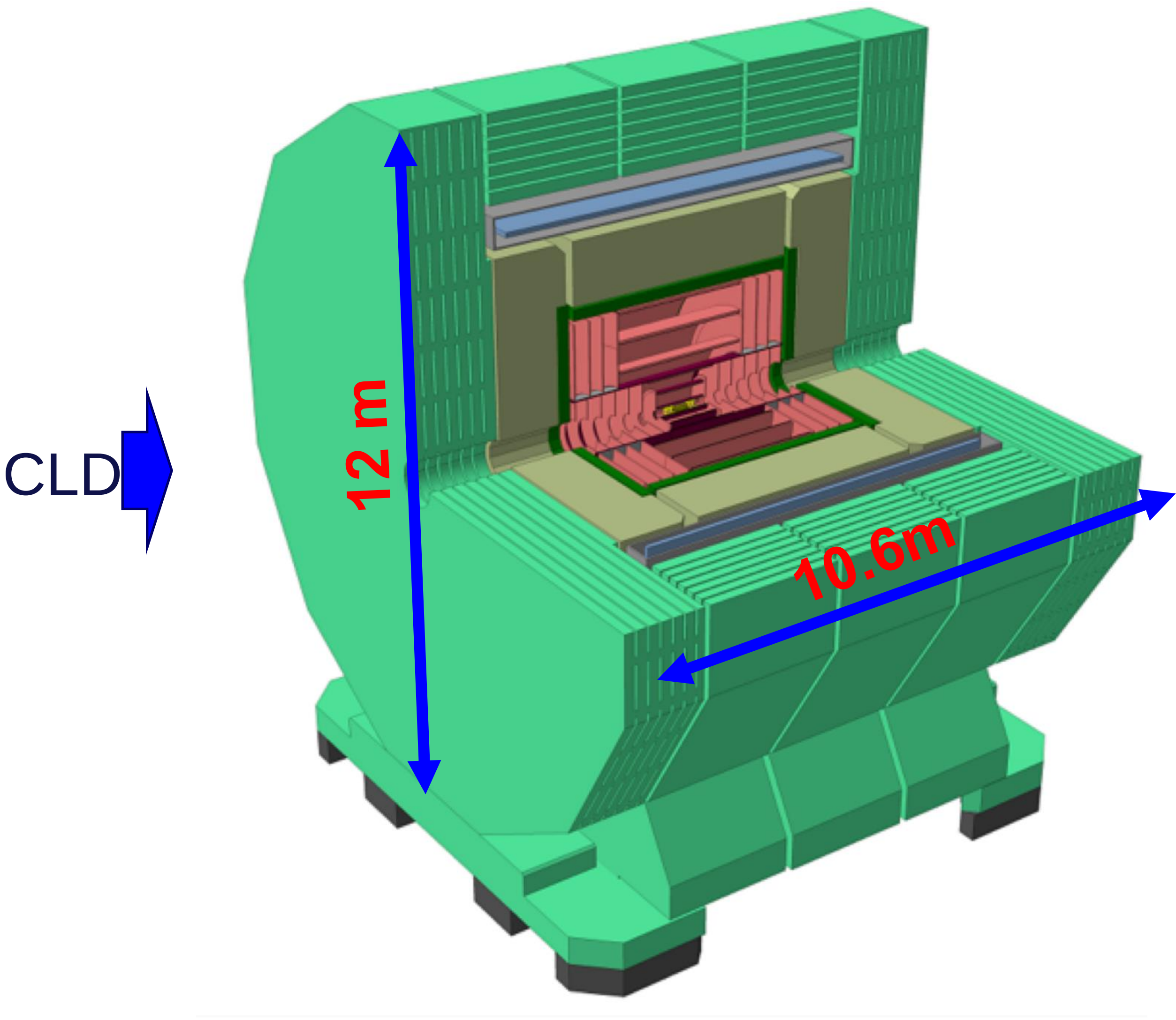
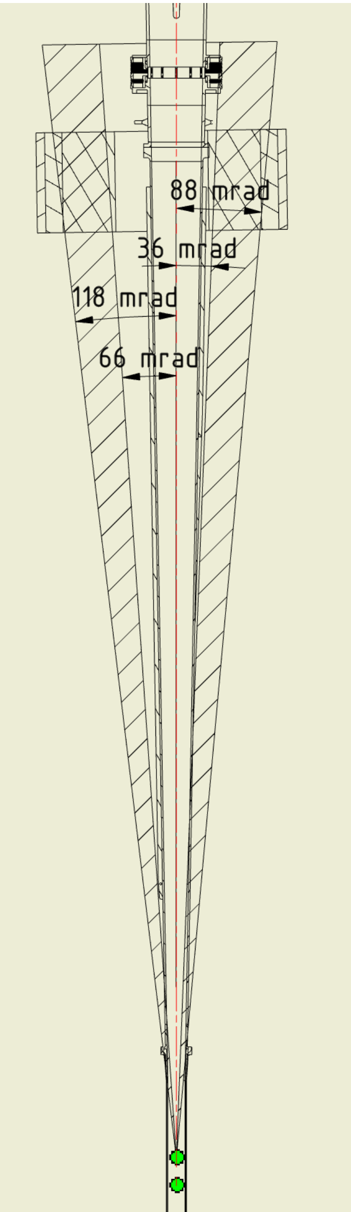
- At the moment a detector concept has not been defined. The two main philosophy are based on the IDEA concept and the CLD concept,
- Any design shown in this presentation for now is based on IDEA detector; the design compatible with CLD will be start in the next months.



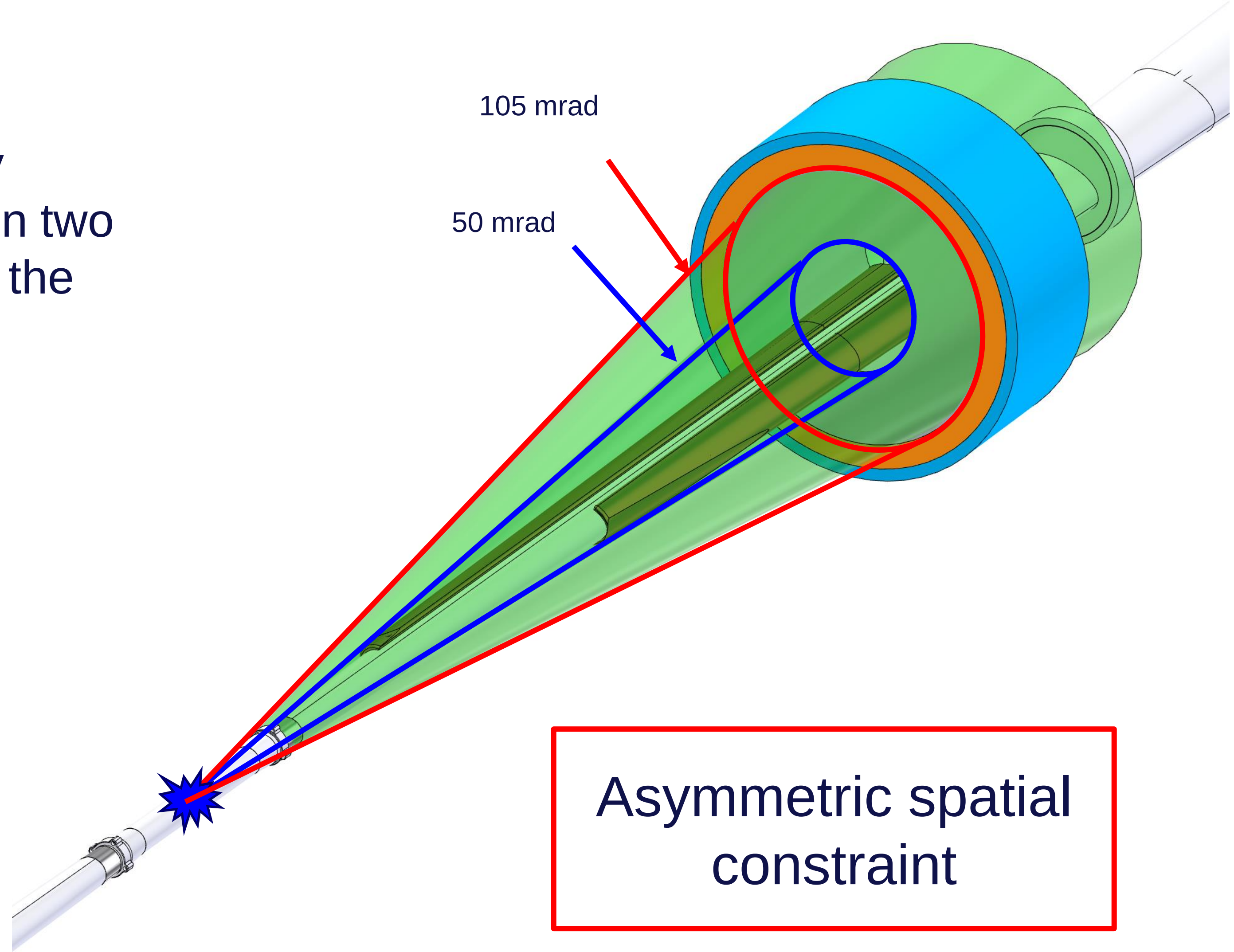


Spatial constraints - LumiCal Cones



The Lumical is centred on the outgoing beam pipe.
The device to perform properly needs an empty space between two cones, the 50 mrad cones and the 105 mrad cone.

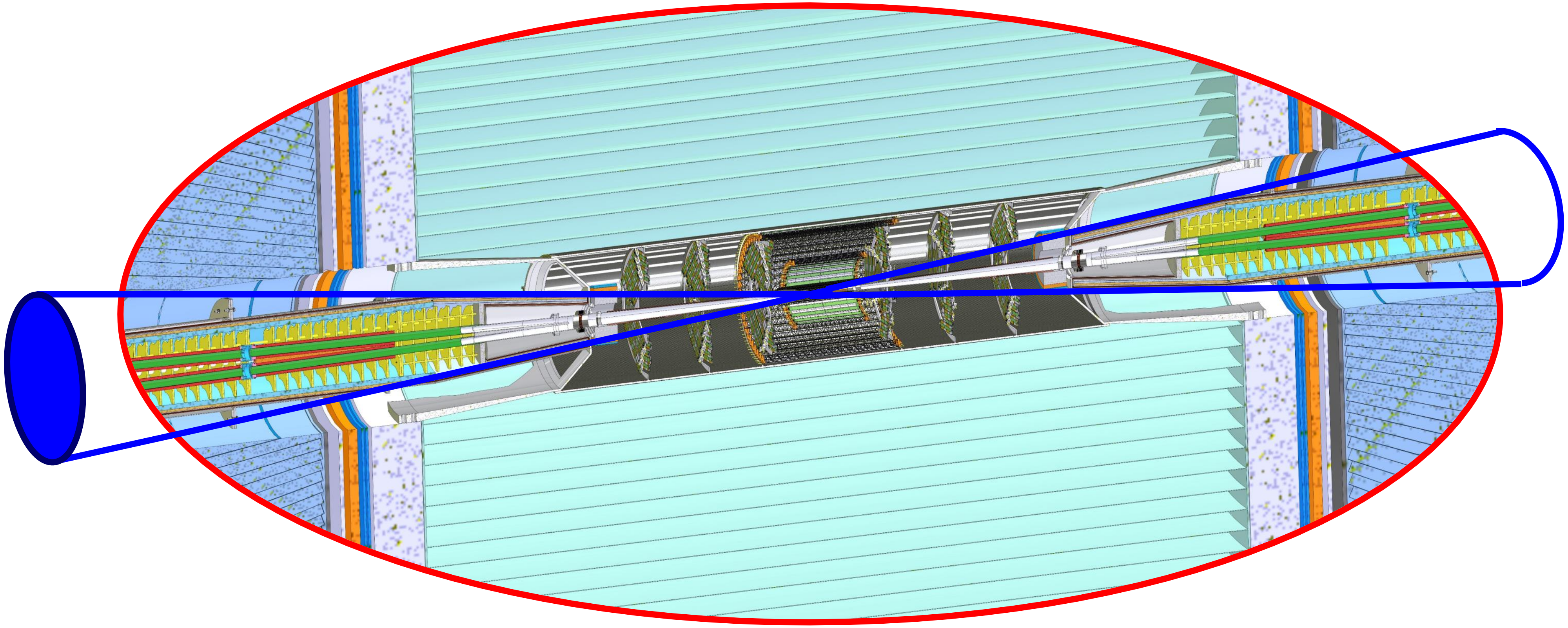
The components integration and each component (i.e. the conical chamber) have been designed to keep everything out of this range, or the thickness has been optimized to achieve the maximum transparency possible.

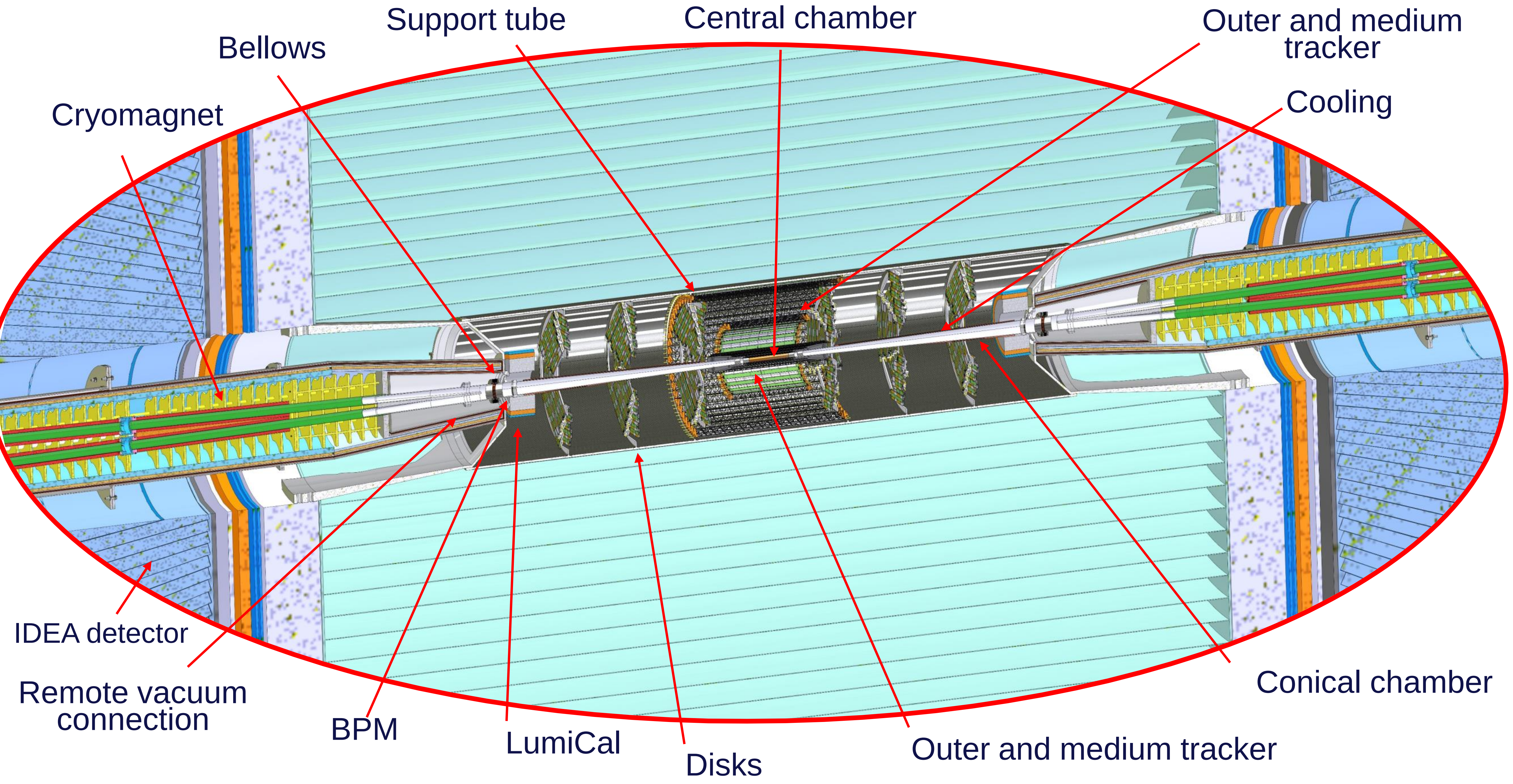


Asymmetric spatial constraint

Spatial constraints – Detector Cone

- Another important constraint imposed over the IR from the detector is the respect of a 100 mrad cone, centered on the detector axis.
- This constraint is symmetric and, therefore, is less problematic if compared with the Lumical Constraint




Support tube
Central chamber
Outer and medium tracker
Bellows
Cooling
Cryomagnet
IDEA detector
Remote vacuum connection
BPM
LumiCal
Disks
Outer and medium tracker
Conical chamber

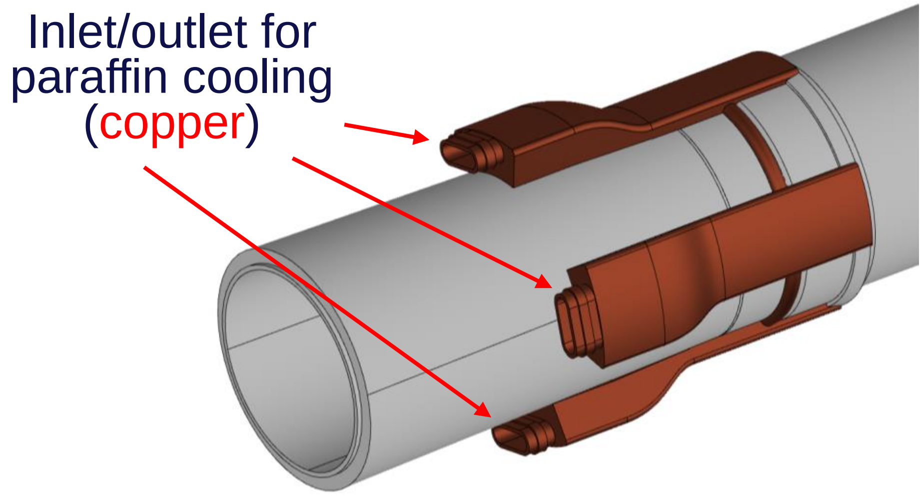
Central chamber– change of the design

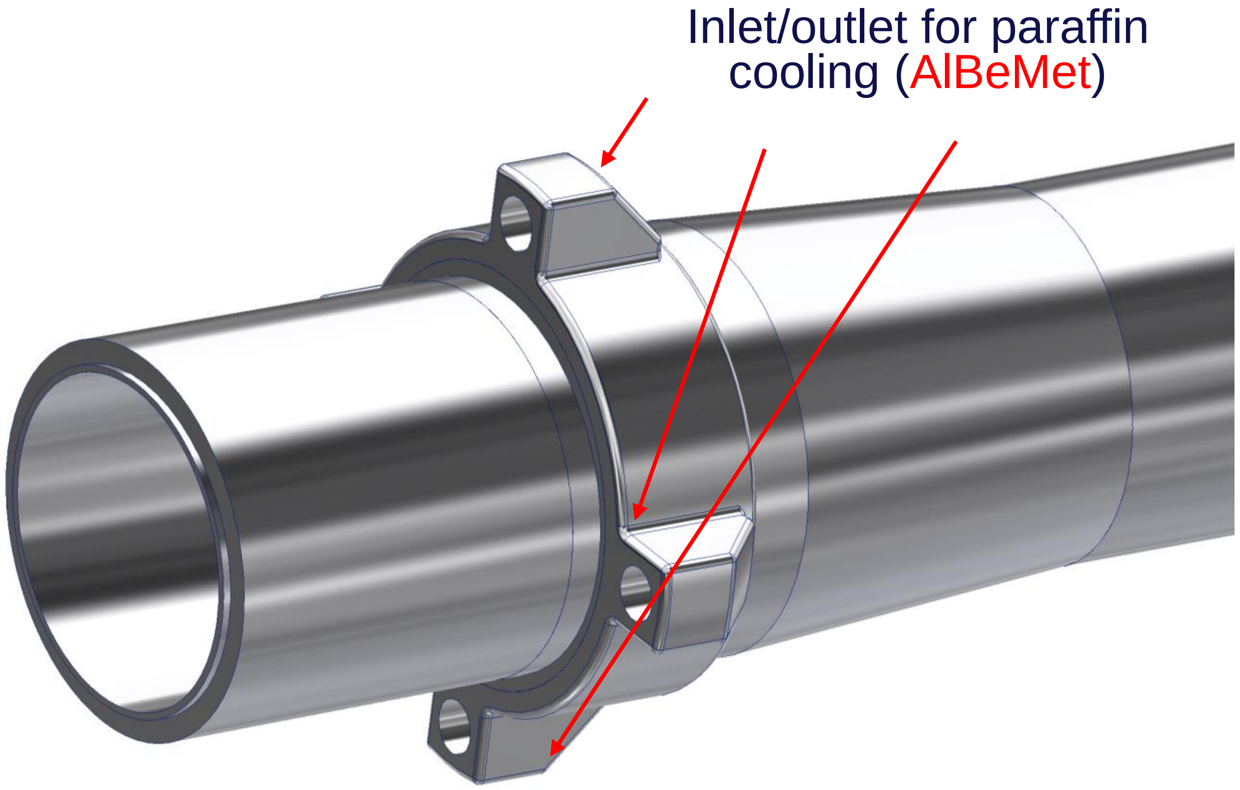
The main characteristics are maintained:

- 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

Change of the inlet and outlet material

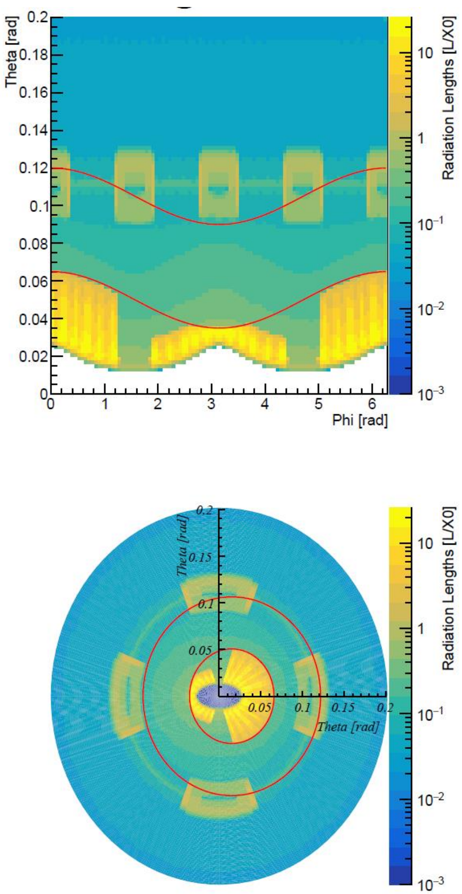
- Reduction of the material budget, avoiding any manifold in copper

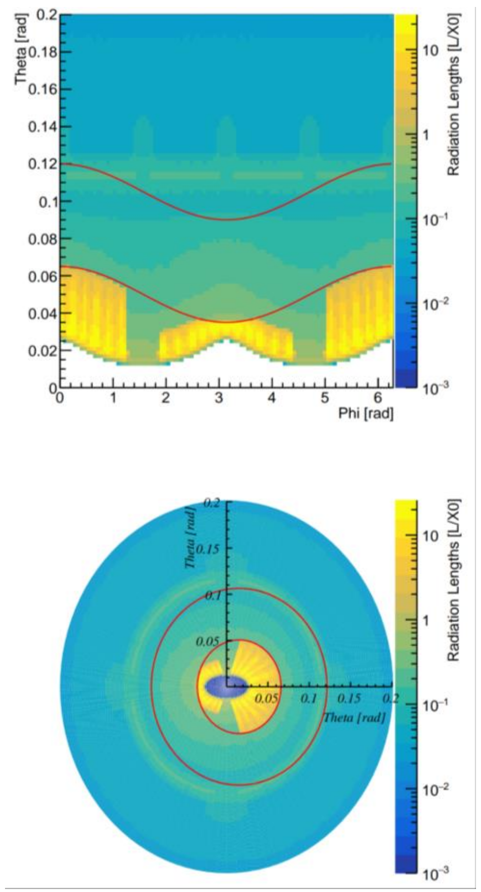




Comparison of the material budget calculations

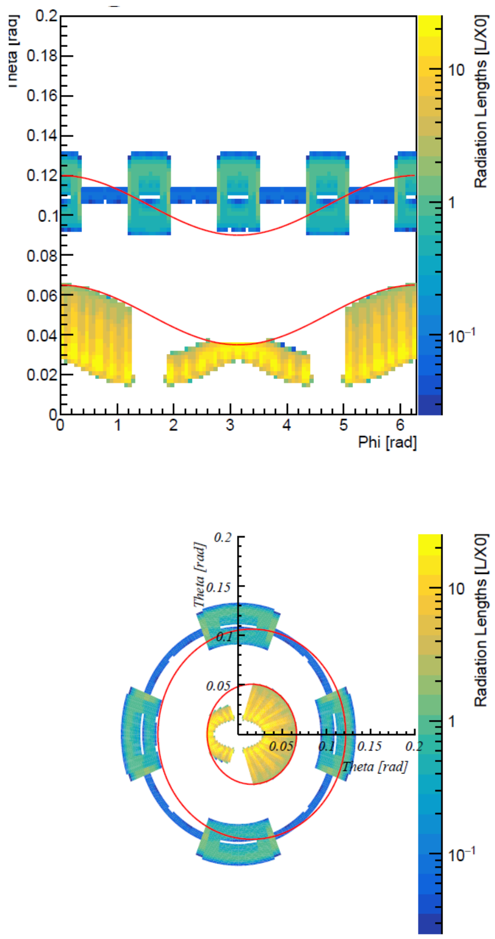
Total Material budget



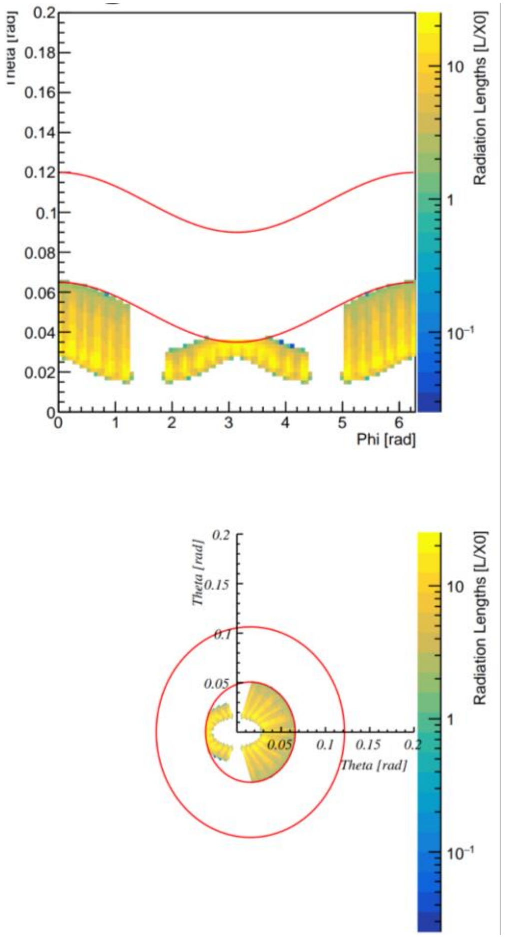


After

Copper Material budget



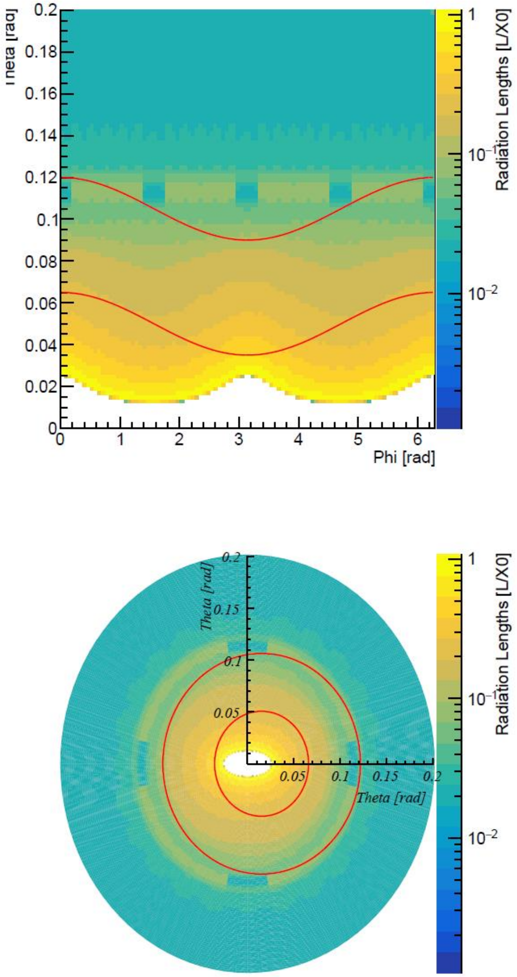
Before



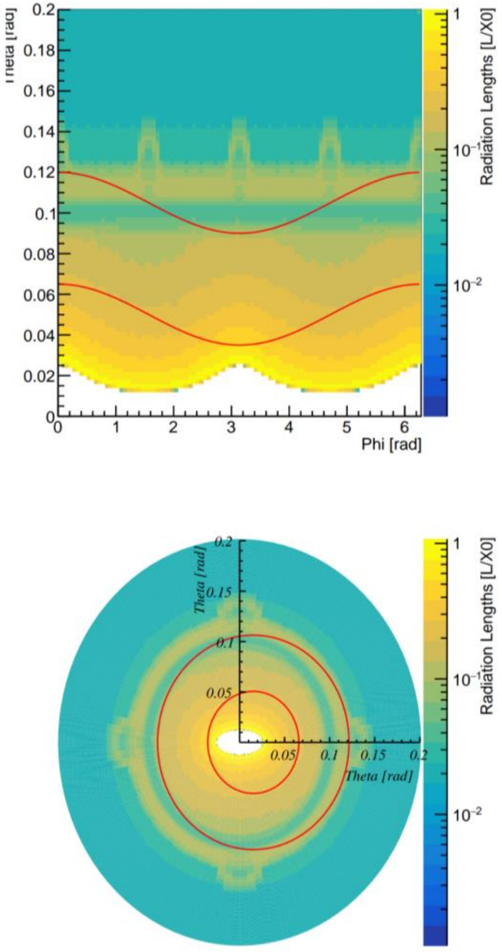
After

Simulations and plots by Andrea Ciarma

AlBeMet Material budget



Before



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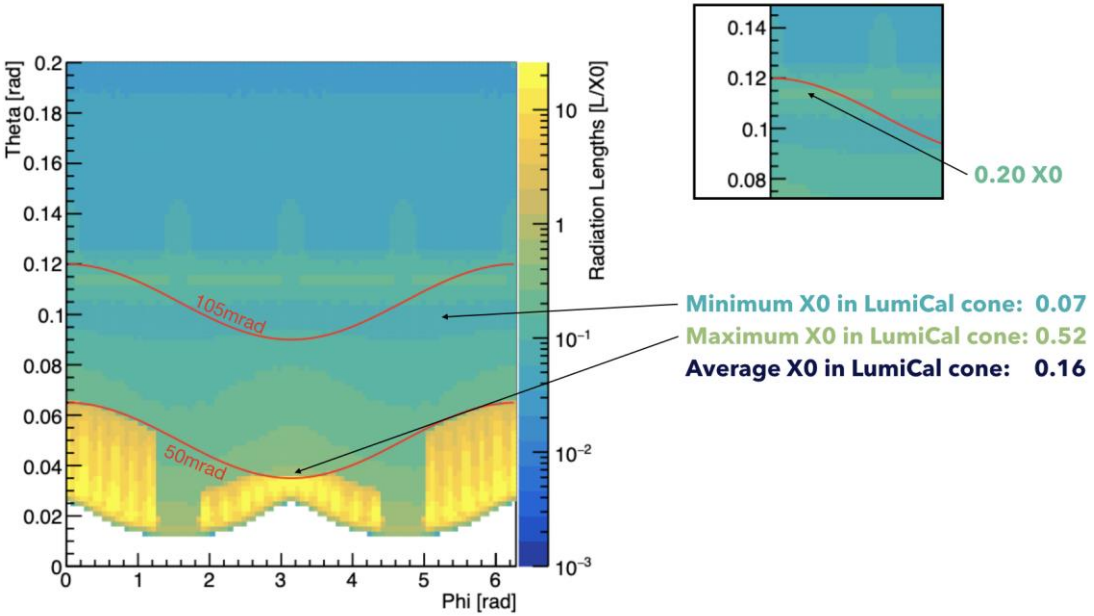


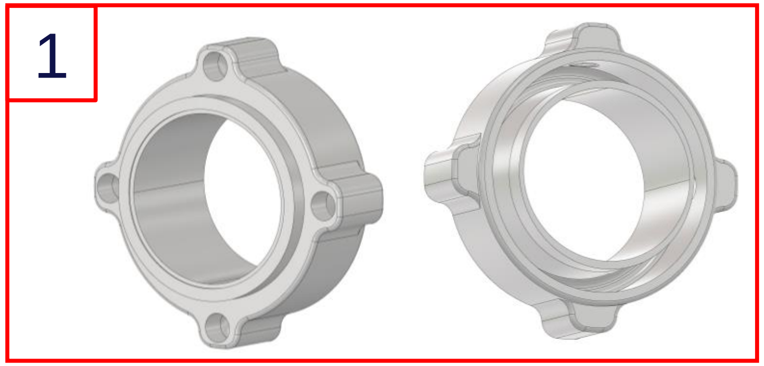
	Value of L/X0	
	Previous design	Current design
Minimum	0.06	0.07
Maximum	1.8	0.52
Average	0.2	0.16

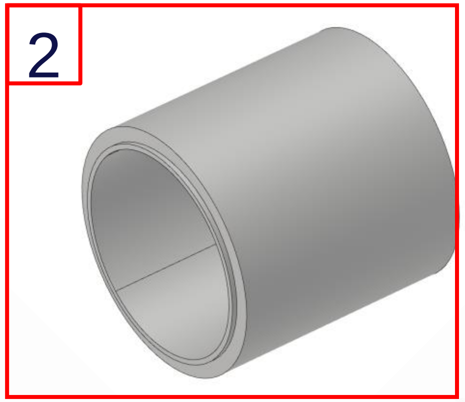
Simulations and plots by Andrea Ciarma

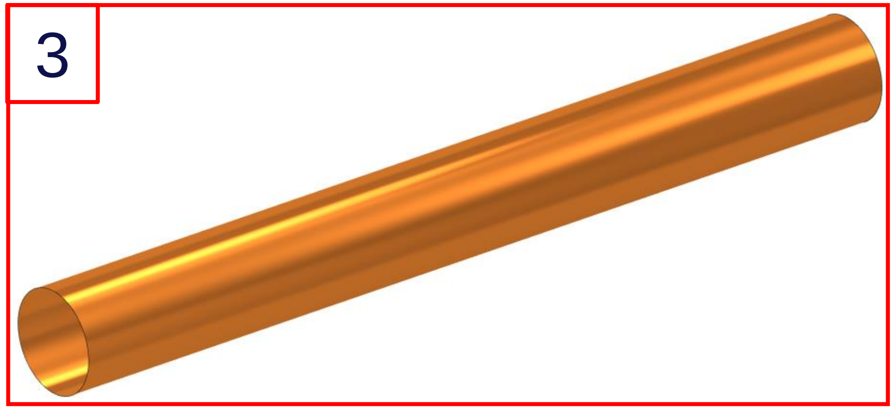
Central chamber

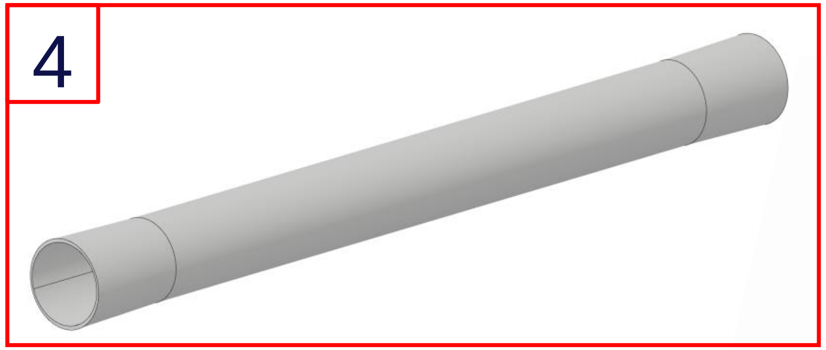
The central has the following characteristics:

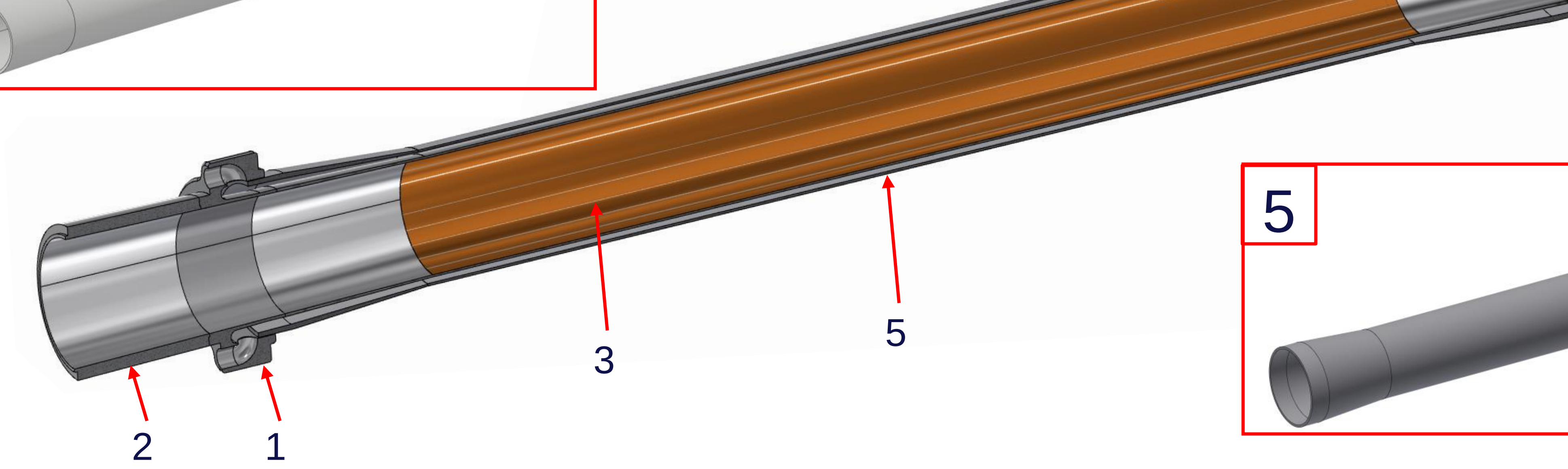
- **AlBeMet** 162 as main material
- **Three layers** from 0-90 mm from IP
  - 0.35 mm of AlBeMet162
  - 1 mm gap for Paraffin
  - 0.35 mm of AlBeMet162





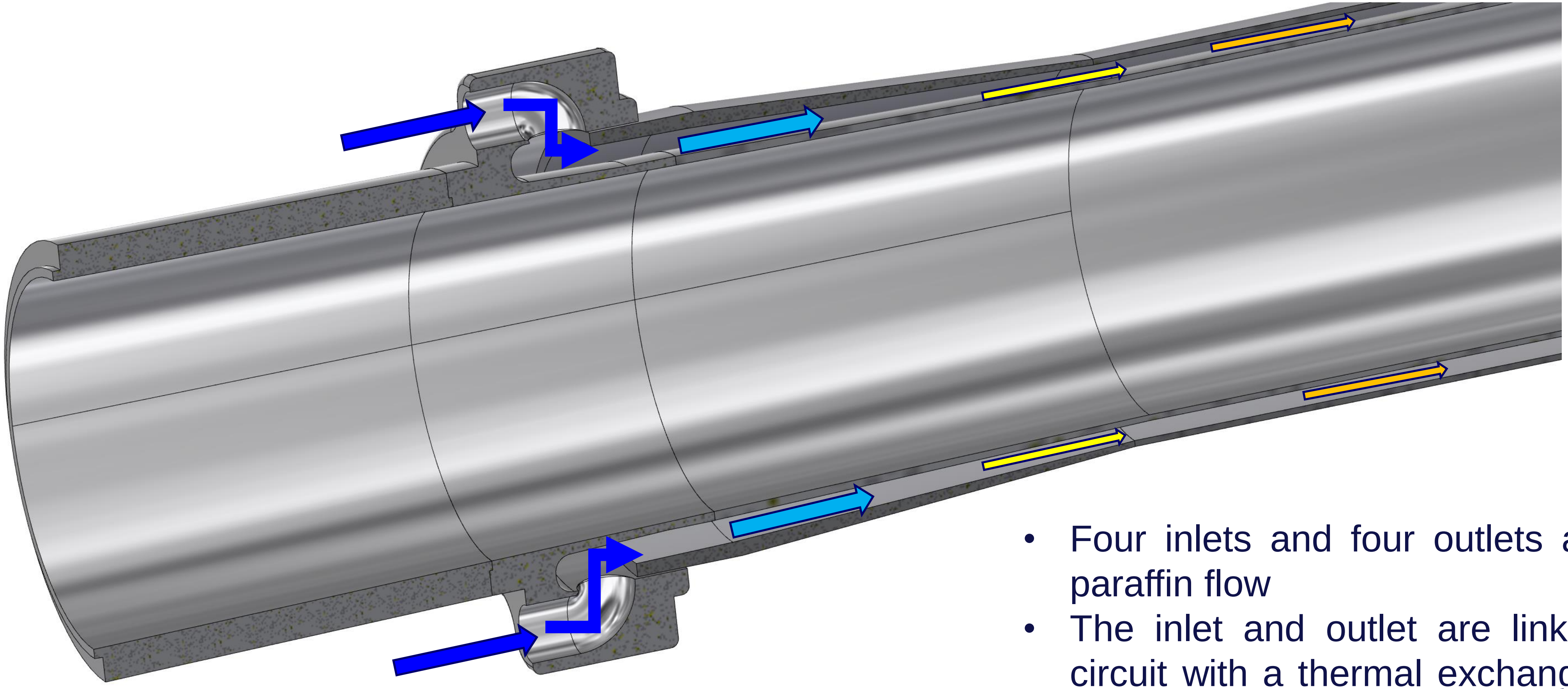






Central chamber – cooling system

To remove the heat calculated by wakefield calculation it is necessary a cooling system. The paraffin has been chosen as coolant for its good transparency. The cooling system consists of the flow of the paraffin inside a channel created by the double layer of the central chamber.



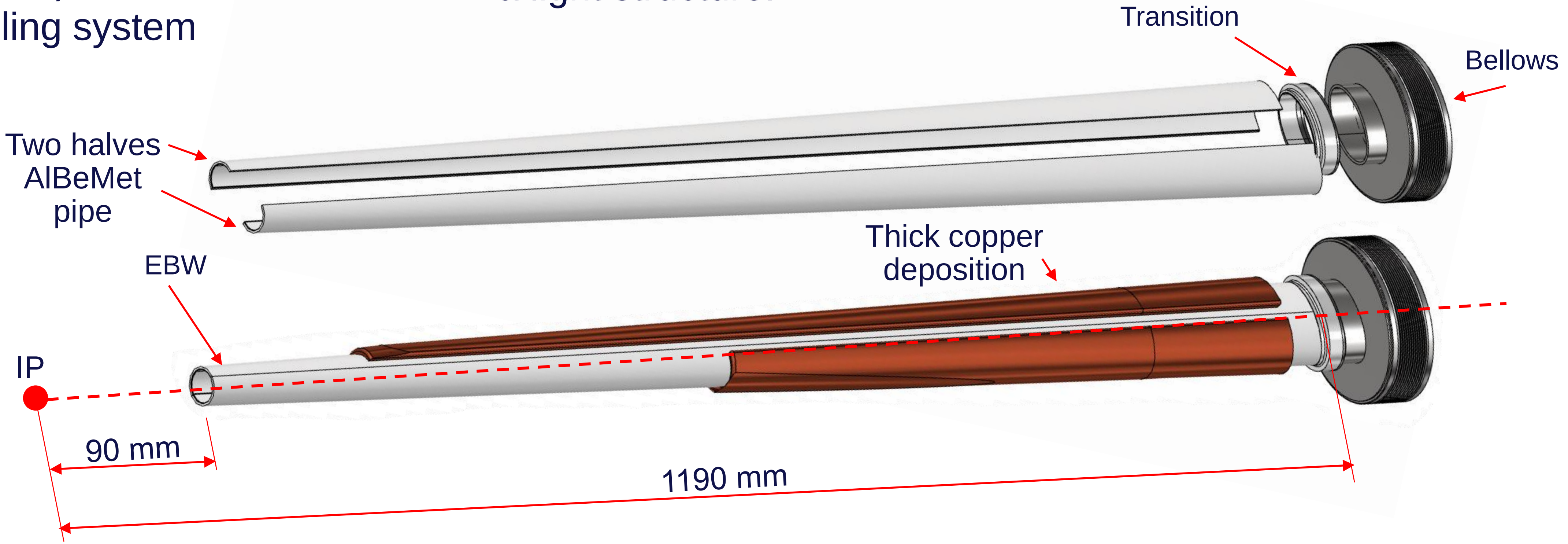
- Four inlets and four outlets are foreseen for the paraffin flow
- The inlet and outlet are linked with an external circuit with a thermal exchanger to cool down the paraffin.

Conical chamber

Main characteristics:

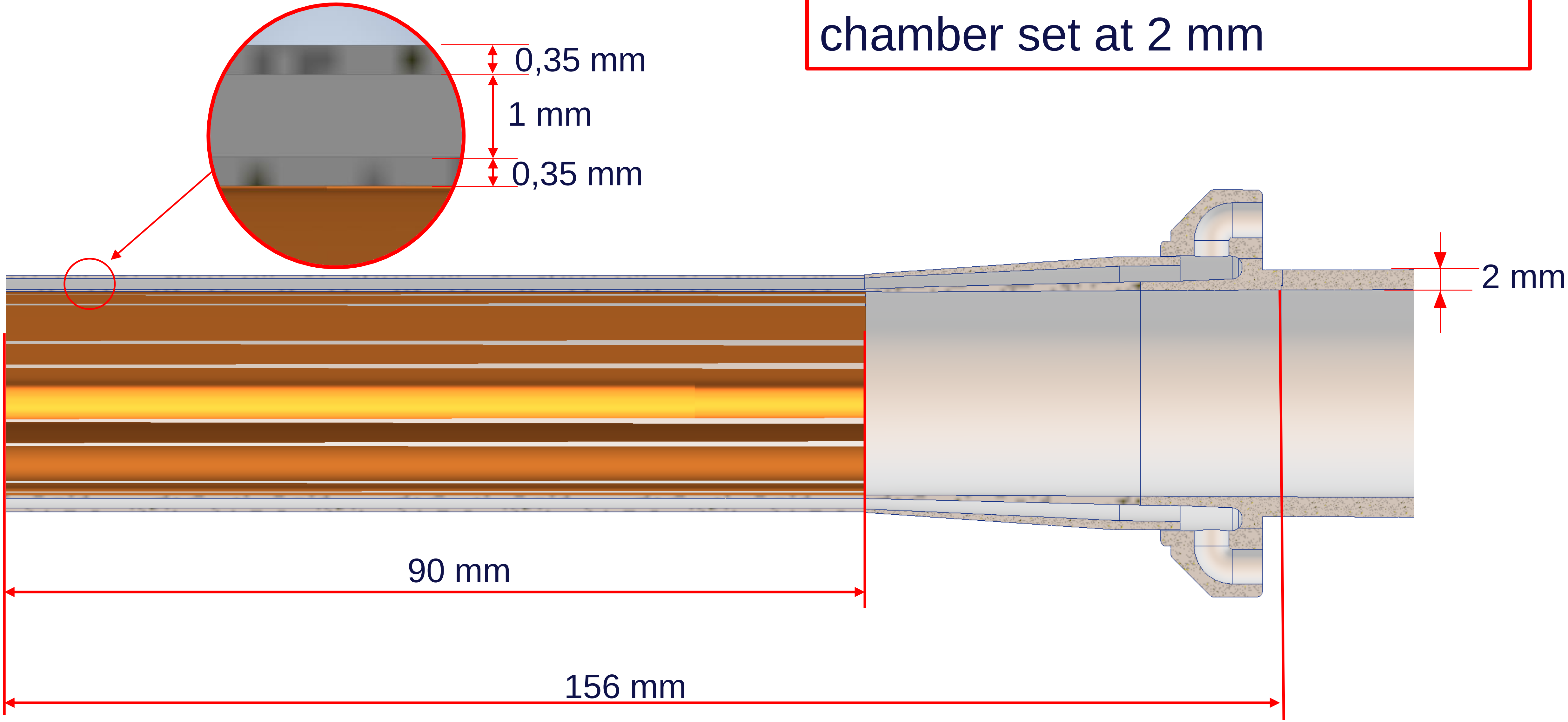
- Starting from 90 mm to 1190 mm from IP
- AlBeMet162 as main material
- Chamber in two halves and assembled using electron beam welding (EBW)
- Copper cooling system

- 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 requirement**.
- To reduce the cooling material, the design provides **five channels** for each side; in this way is possible to use the needed quantity of coolant and reduce the material, creating a light structure.



Thickness of the chamber

Uniform thickness of the conical chamber set at 2 mm



LumiCal BPM

In order to insert the LumiCal BPM:

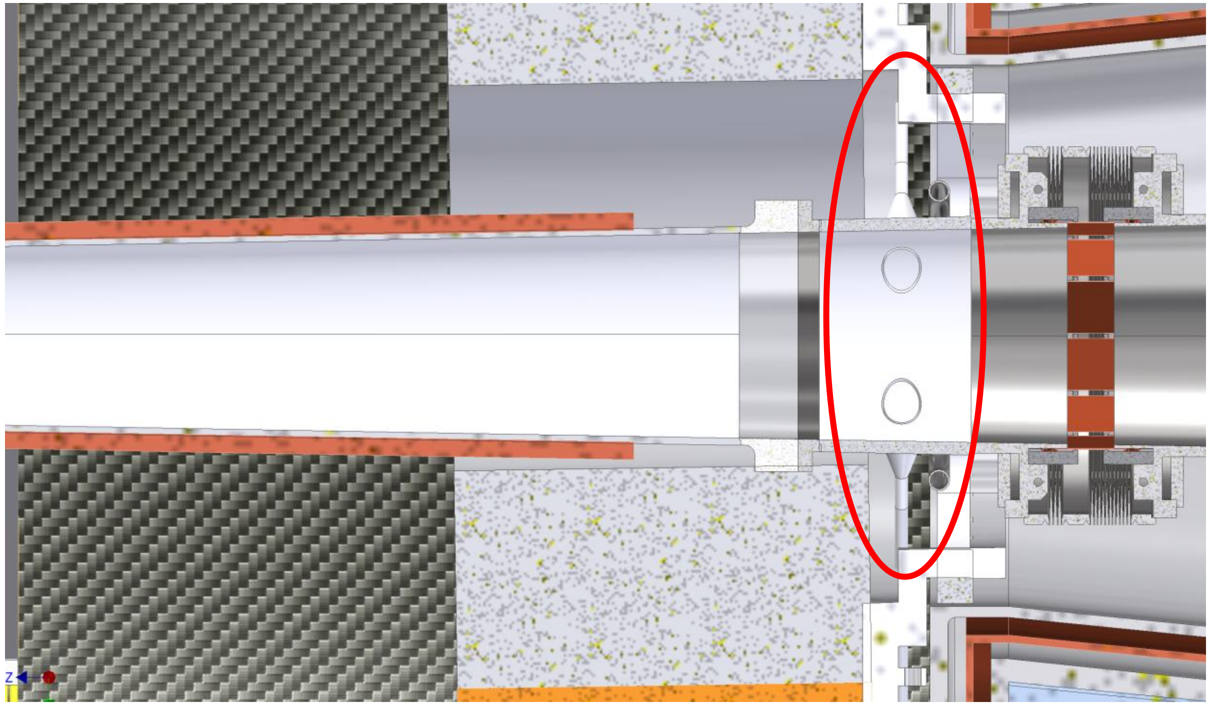
- the crotch has been moved forward about 30 mm.
- The transition has been moved backward.
- The bellows has been moved foward.
- The BPM has been inserted, considering che coaxial cable.

The impedence of the new chamber has been checked by Alexander Novokhatski and it works fine.

New geometry is possible to use

- The heat distribution does not change much in new geometry, even we got two trapped modes, but less interaction with the beam
- So, now we can try to place IR BPMs
- However, a proposal for a new SR mask comes and we decided to check the difference between old and new masks

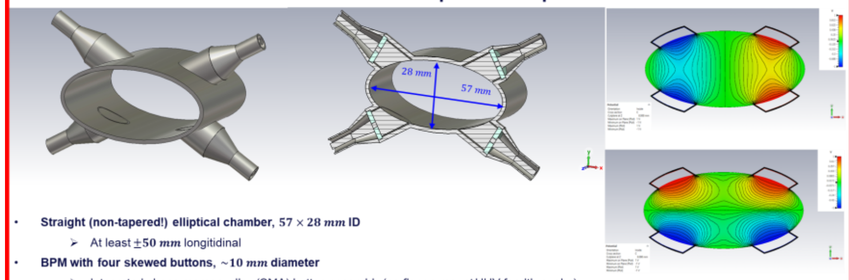
SLAC *A. Novokhatski 11/16/23* 14 FUTURE CIRCULAR COLLIDER FCC-ee MDI & IR mockup Workshop



Preliminary LumiCal BPM made by Manfred Wendt

E. Howling & M. Wendt (CERN) – FCC Week 2023, London (UK). - 5th–9th June 2023

LumiCal BPM Pickup: A Proposal



- Straight (non-tapered!) elliptical chamber, $57 \times 28\ mm$ ID
  - At least $\pm 50\ mm$ longitidinal
- BPM with four skewed buttons, $\sim 10\ mm$ diameter
  - Integrated shape memory alloy (SMA) button assembly (no flange-mount UHV feedthroughs)
  - Requires optimization, RF & impedance studies, etc.
- Needs real-estate!
  - $\sim 15\ mm$ length for the buttons, more space in radial directions
  - Also, space for the as-short-as-possible(!) $50\ \Omega$ semi-rigid SiO_2 RF signal cables
  - If located at $\sim \pm 1150\ mm \Rightarrow \sim 7.67\ ns\ e^+$-$e^-$ bunch signal separation

Structural analysis – chamber

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

- ❑ Cooling system
- Paraffin for central chamber
- Water for conical chamber

+

Chamber design

+

- ❑ Heat load → 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

	Conical 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]					
		Conical SX	Conical 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 – description

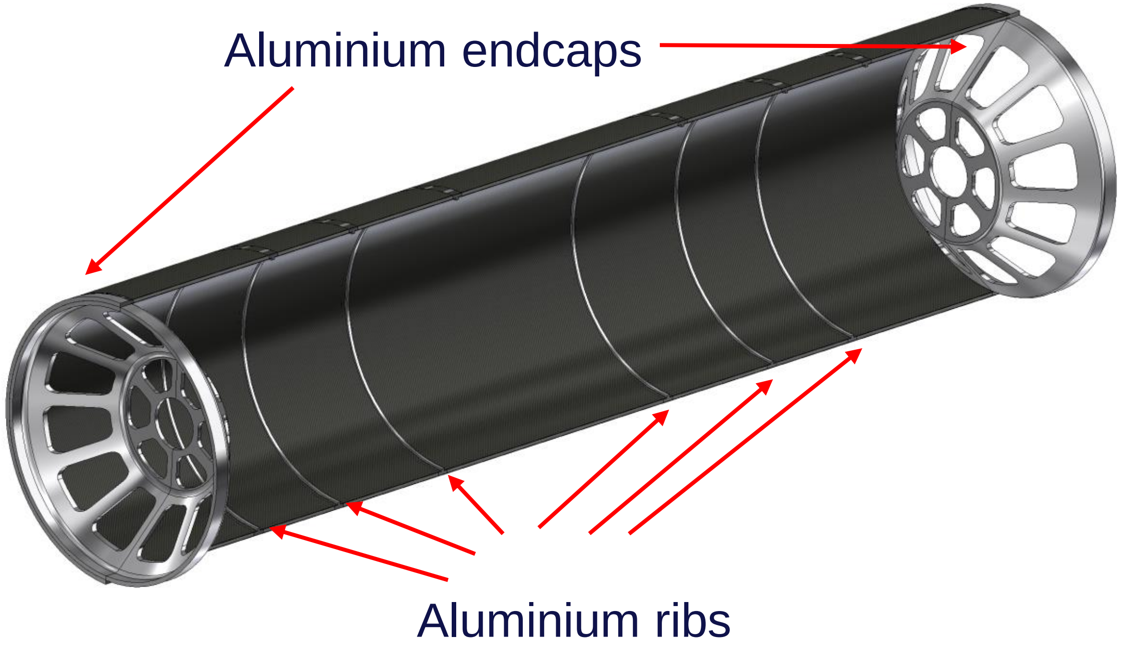
The **support tube** aims to :

- 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

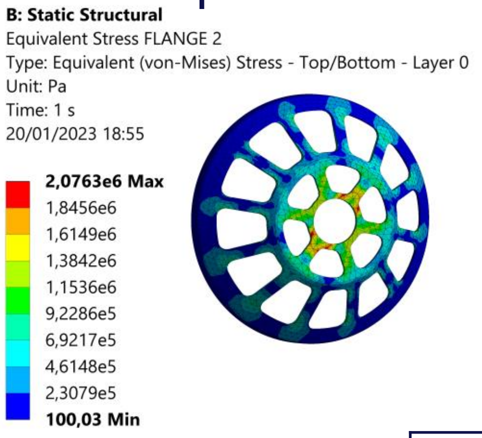


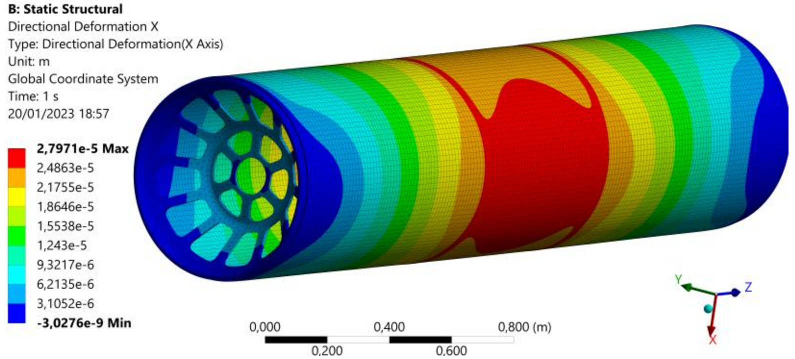
CF=carbon fibre
HC=honeycomb

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

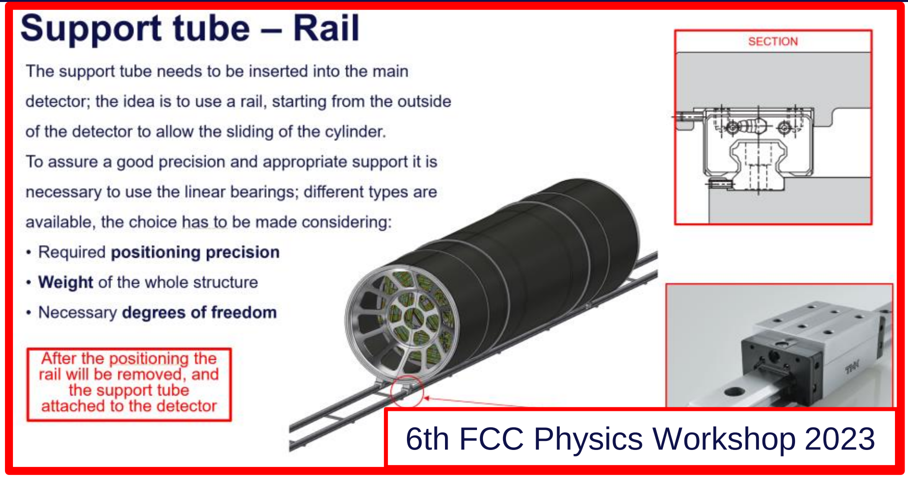
Chamber	50 kg
LumiCal	70 kg + 70 kg
Disk tracker	6*10 kg
Outer tracker	15
Medium tracker	7
First guess loads (overestimated)	

+

- ❑ Carbon fiber/ honeycomb creation → layered section

	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 – How to insert it

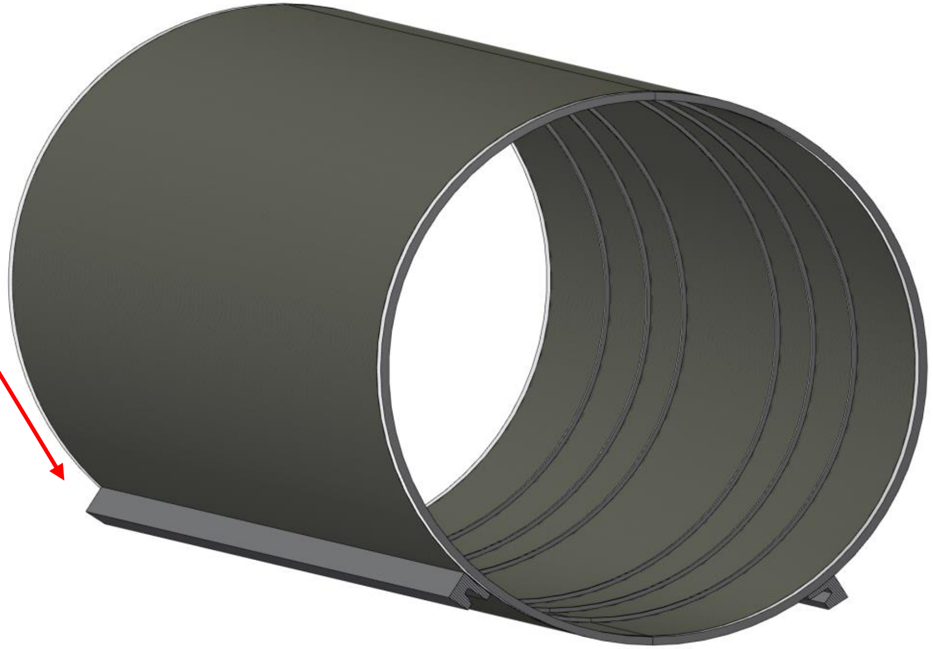


After a discussion with Andrea Gaddi (thanks for your help), a new idea came out

- The idea presented during the *6th FCC Physics Workshop* consists of a rail, mounted only the sliding procedure, then removed. In this way the Support Tube should have been attached to the detector in order to remove the rail, a supplemental operation.
- The new idea is based on the creation of a Carbon Fiber rail embedded on the support tube, and placing some guides in the detector, to allow the sliding.

Understudy:
- Rail support
- Rail anchoring
- Rails length
- Geometry of the rail section
- Linear bearing type
- Positioning system

To continue the design, it is necessary to know:
- **Allowable anchoring** point from detector side
- **Allowable space** (internal detector diameter and geometry)



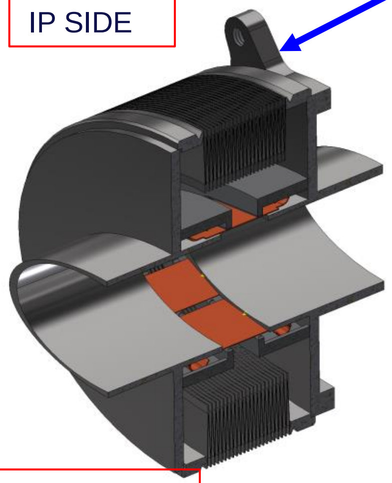
Bellows

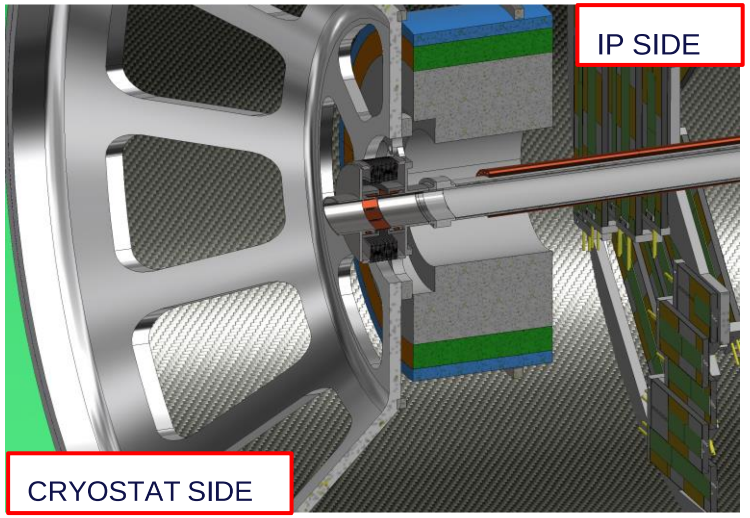
The use of Support Tube is designed to avoid overloads on central chamber during assembly and operation (thermal expansion). This solution has been obtained using **two kind of bellows** for the two sides of the support tube.

In short, in this way we can:

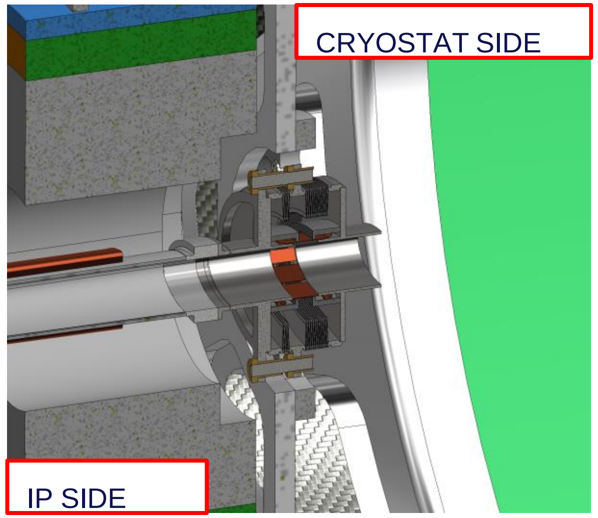
- **Protect the central chamber** during the assembly procedure
- **Support properly the chamber** bellows-to-bellows, containing the deformation
- **Allow the thermal deformation** without compromising the chamber

1st Bellows (Single bellows)



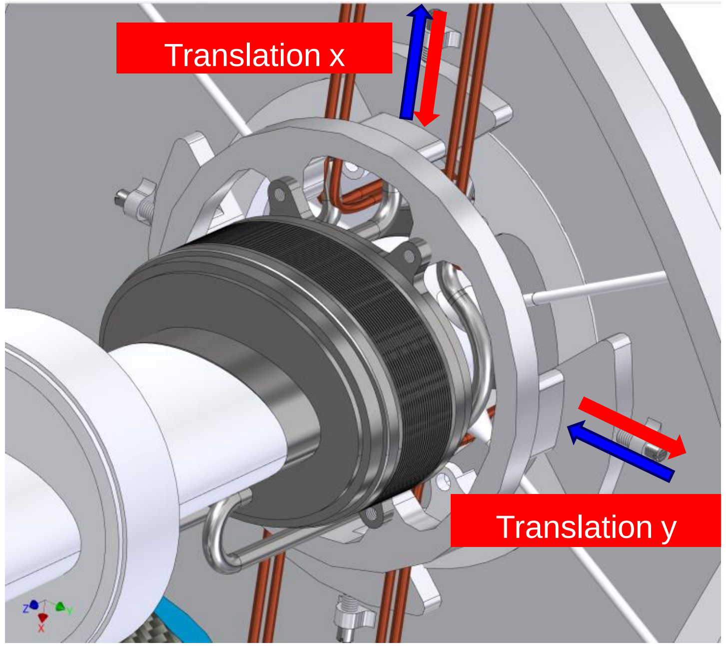


2nd Bellows (Double bellows)



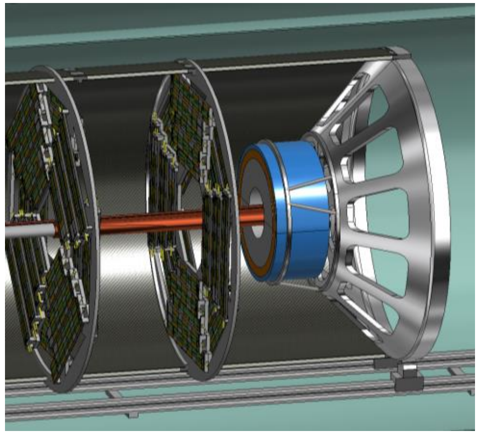
Interface between the bellows and the Support Tube

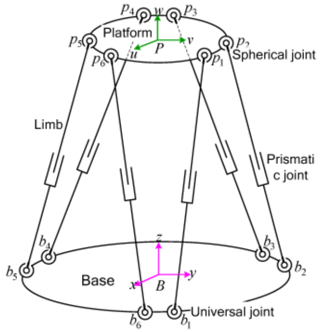
- The bellows will be attached to a flange that will be linked to the Support Tube using a system with two degrees of freedom (trasl x and trasl y).
- This system can be modified to add more degree of freedom (rotation) or modified into an active one, it depends on the needs.
- The design is still preliminary but what matters is the concept, so the possibility to adjust the position of the bellows and the chamber.
- This flange has been designed creating some holes for the services, needed to go outside the end cap of the Support Tube.



LumiCal – Support proposal

- LumiCal are held by the two support tube endcaps.
- A hexapod structure allows to limit the axial footprint.
- Hexapod positioner has 6 DOF and high-precision positioning.
- Actuators could be manual or automatic for a remote positioning.



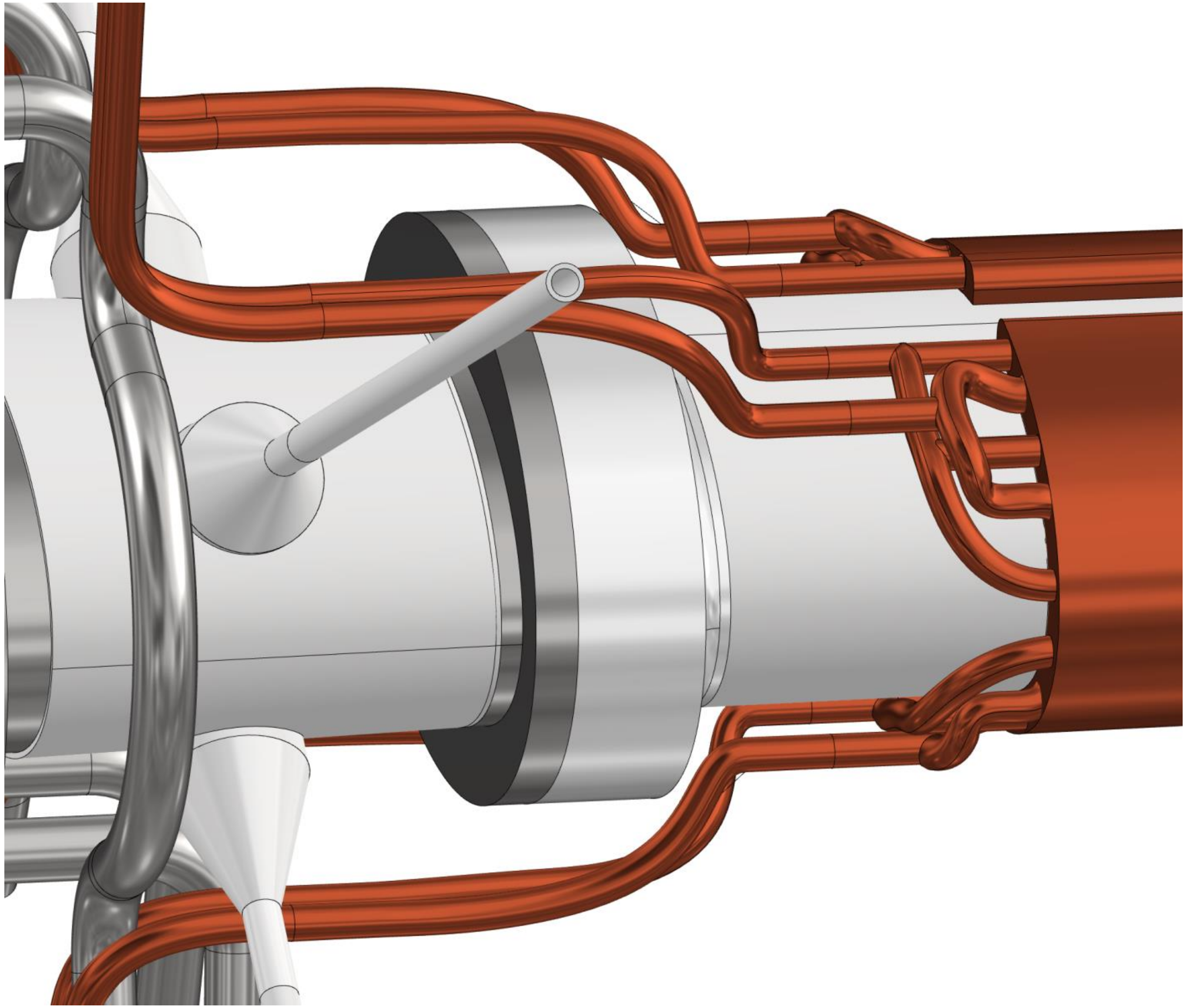


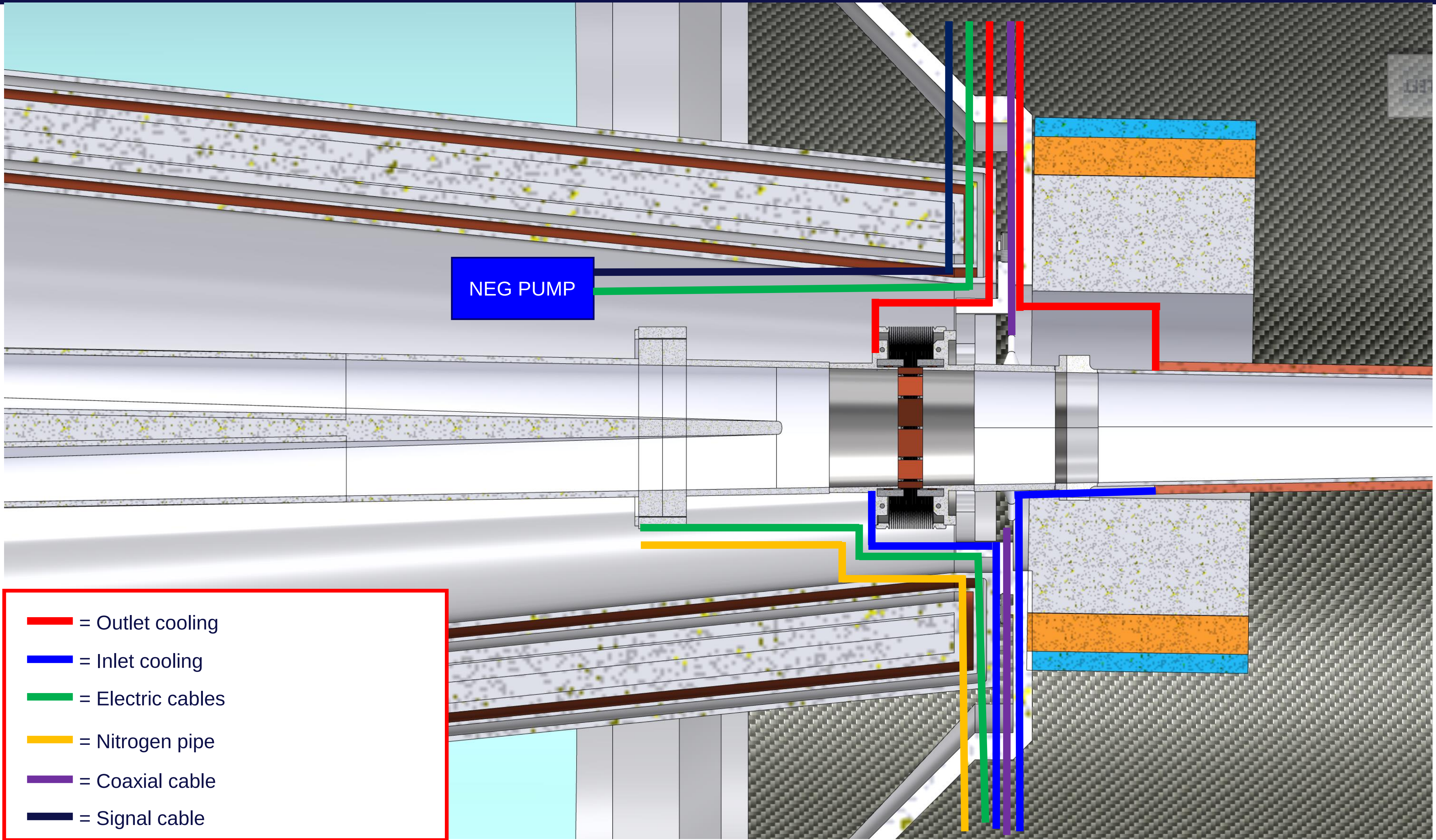
To proceed with this design, it is necessary an engineered design of the LumiCal

Space for services - Pipes for conical chamber water-cooled

- To reduce the space for conical chamber service we intend to use a system of 3D printed pipe to converge and connect different inlets and outlet to reduce the number of tubes that have to come out from the Support Tube

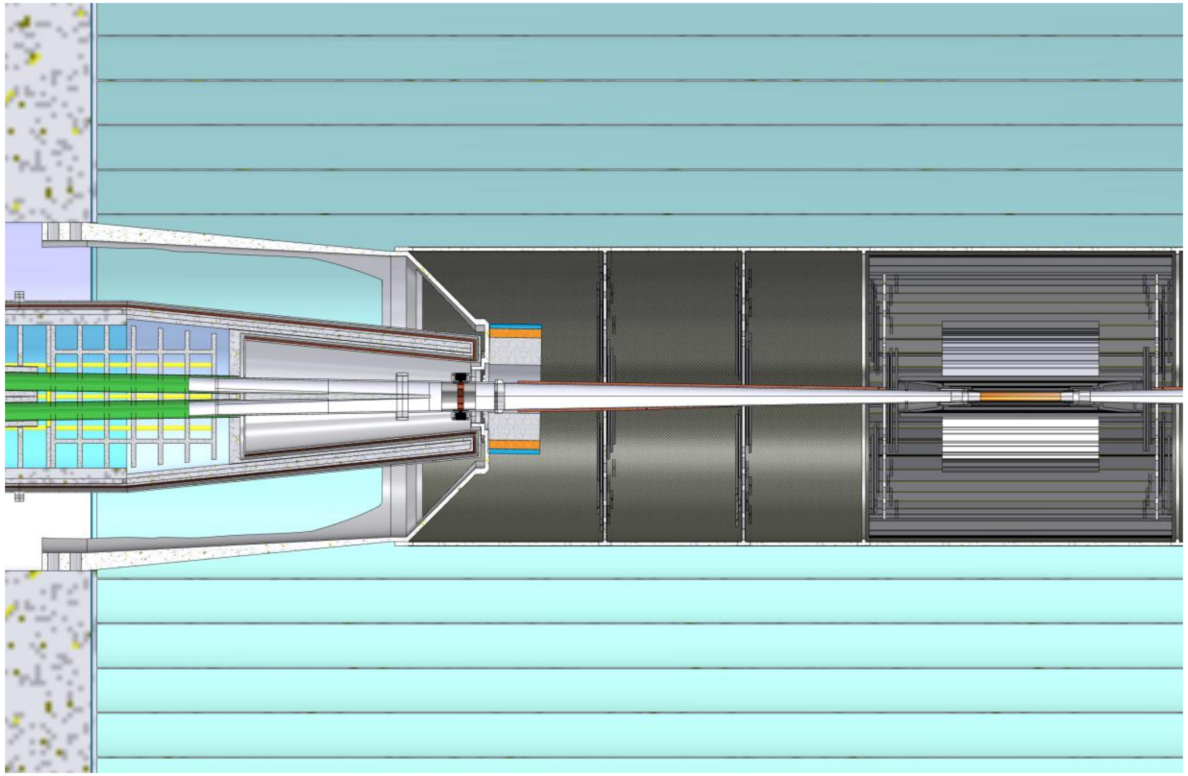
- This system is under design and the feasibility has not been checked yet but it is still necessary optimize the space needed for services.




NEG PUMP
= Outlet cooling
= Inlet cooling
= Electric cables
= Nitrogen pipe
= Coaxial cable
= Signal cable

Space for services - list

Components	Type of service	Number
Central chamber	• Inlet for paraffin • Outlet for paraffin	1 1
Bellows	• Inlet for water • Outlet for water	1 or 2 1 or 2
Conical chamber	• Inlet for water • Outlet for water	2 2
Remote vacuum connection	• Electric power for heating • Nitrogen tube • Temperature sensor	1 1 1
NEG pump	• Electric power for heating • Temperature sensor	1 1
BPM	• Coaxial cables	4



Prototypes

Inside the mockup project that it has started in Frascati, we will create a series of prototypes to study the main aspects of the desing.

Central chamber

1. To Check the feasibility of the **assembly strategy**

Due to the double layers for the paraffin flow and the non regular internal shape of the chamber, it necessary to use a sequential assembly procedure, that needs some delicate steps.

2. To check the feasibility of the **Electron Beam Welding** along an **elliptical shape**.

3. Test the **cooling system**

The paraffin flow can be simulated with Fluidodinamical analysis, but a prototype is necessary to verify the correct operation.

In particular, we want to verify the pressure drop needed, the maximum temperature reached and set the external circuit for the paraffin cooling down.

Conical chamber

1. To Check the feasibility of the **assembly strategy**
2. To check the feasibility of the **Electron Beam Welding** along **an elliptical shape**.
3. To check the feasibility of the "**Thick copper deposition technique**".
4. To test the **transition AlBeMet162-Stainless Steel**

Bellows

1. Test the **constraint schema**:
   - Demonstrate the double bellows' capability to absorb thermal loads and stress on central chamber.
   - Measure the loads on the central chamber (intermediate dummy prototype of the bellow and central chamber may be necessary).
2. Measure the **stiffness of bellows** with CuBe blades.
3. Measure the **cooling performance.**

Next steps

- The anchoring points detector side are still not defined; therefore, the insertion strategy of the Support Tube and the interface structures are still preliminary.

- The LumiCal design has not be engineered yet, therefore there is only an idea for the LumiCal support. As soon as we have a more detailed design we will start a deeper study of the support structure.

- The space for the services is important and we are open to add other services we forgot. It is important not to forget the services in terms of space and weight.

- In the next months the mockup with the different prototypes will be primary.

THANK YOU FOR YOUR ATTENTION

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