

MECHANICAL DESIGN OF FCC IR

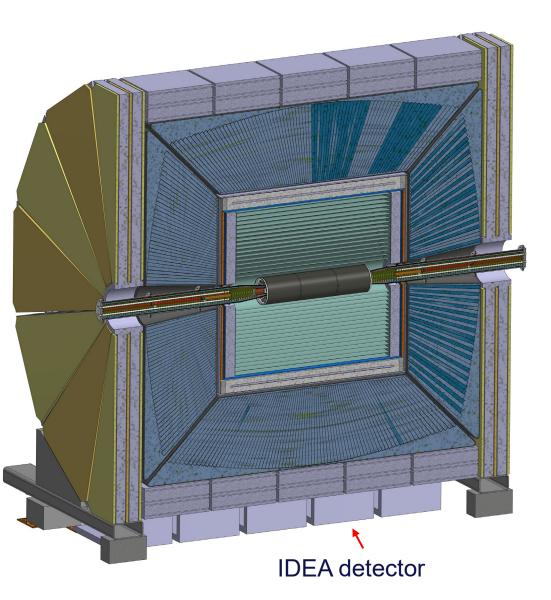
Speaker: Francesco Fransesini

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

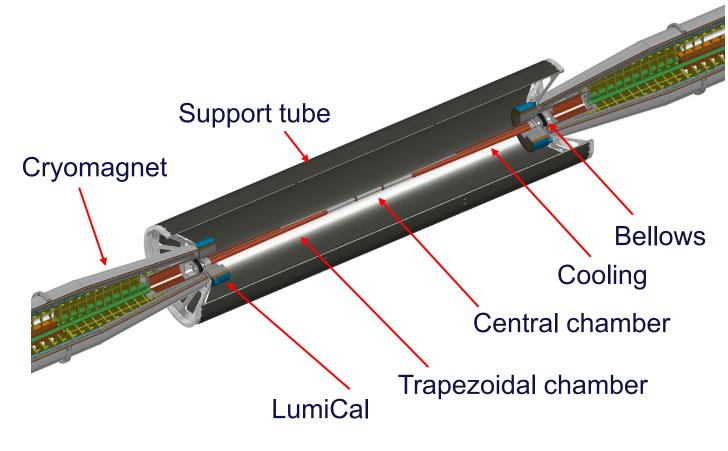




FCC IR region



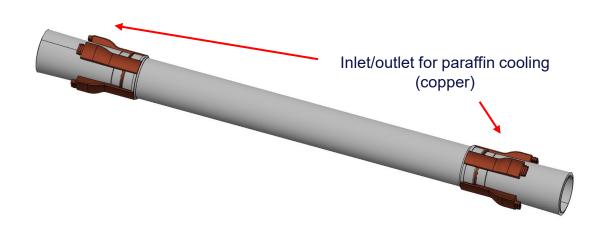
This design is based on the IDEA detector concept, in fact we are working in close contact with INFN-Pisa integrating their Vertex and Tracker detector design.





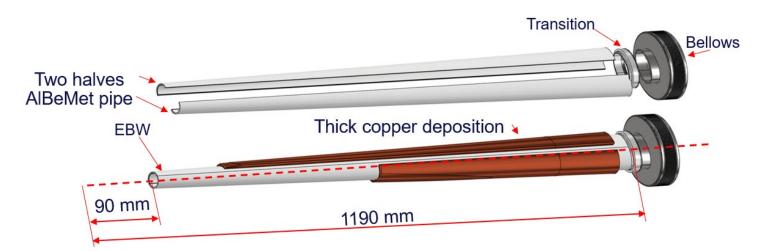


Central chamber



- 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



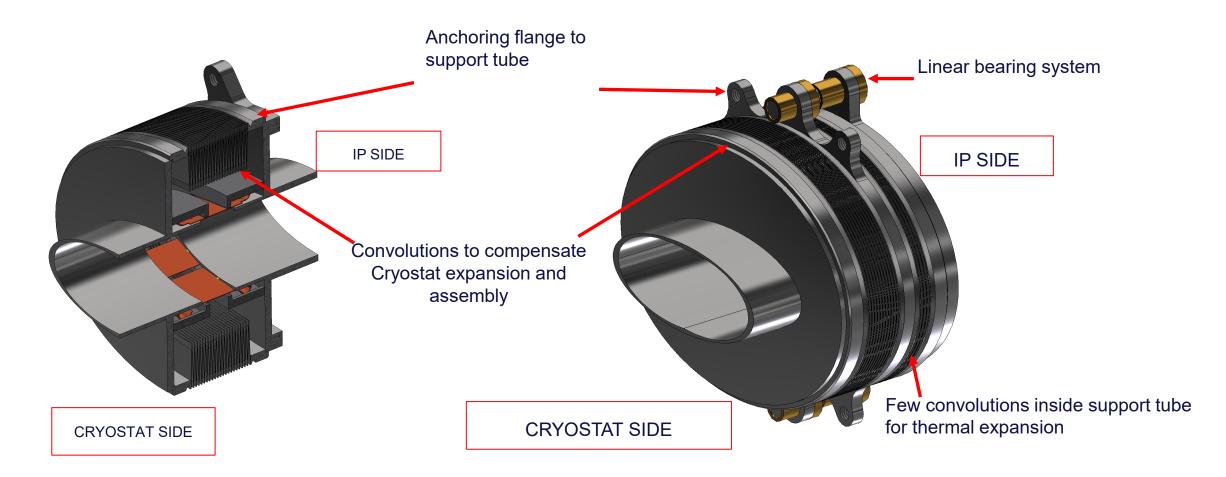
- Starting from 90 mm to 1190 mm from IP
- AlBeMet162 as main material
- Chamber in two halves and assembled using electron beam welding (EBW)
- Copper cooling system





1st Bellows (Single bellows)

2nd Bellows (Double bellows)







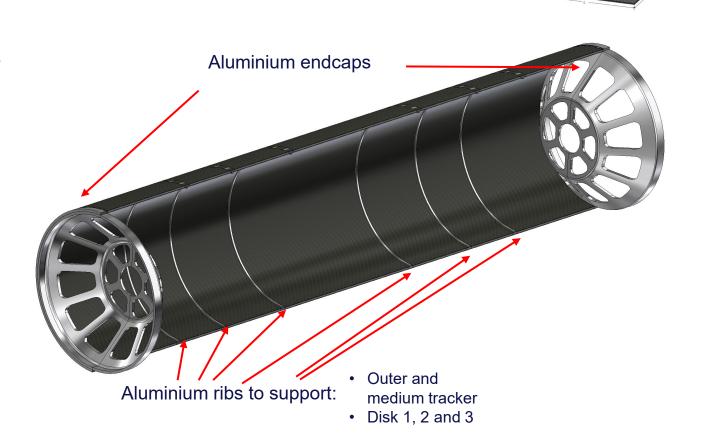
Support tube

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

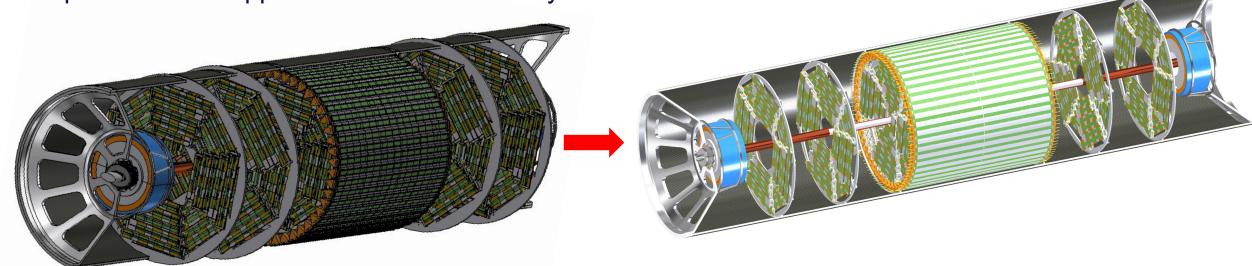




Update of the vertex detector, disks and barrels integration

- 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.

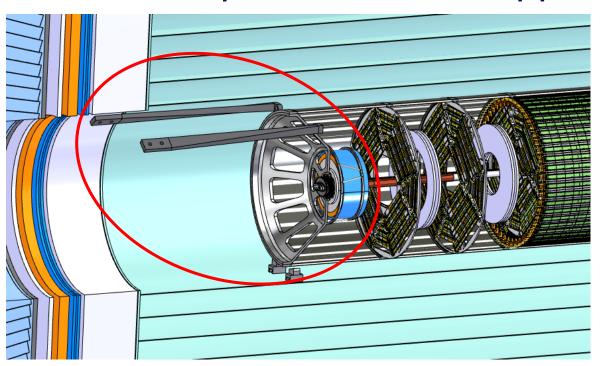


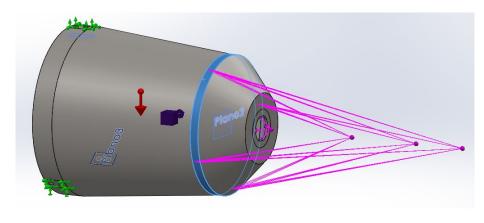
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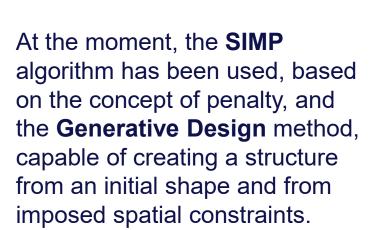




Structural optimization of Support Tube flanges

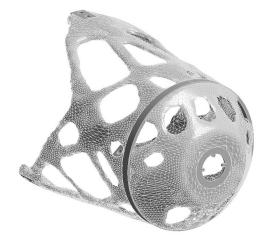




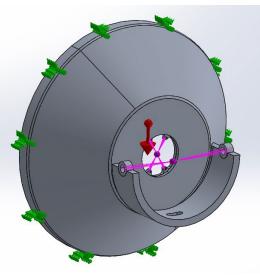


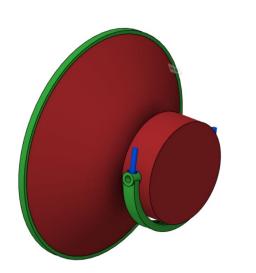


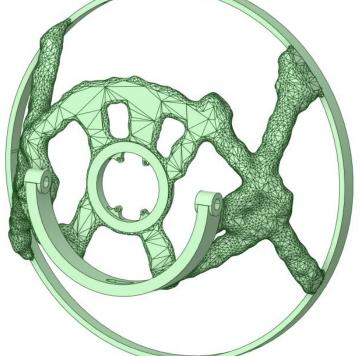












- Constraints in term of stress and displacement
- Minimizing of the mass
- No design zone where the constraint and loads are applied and in functional area



Solution A



Work in progress

Crotch chamber



Solution B

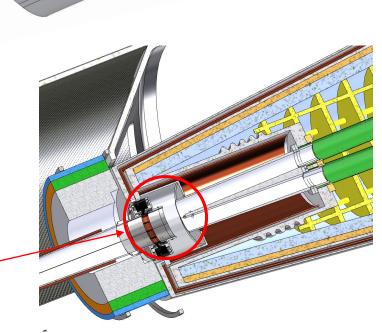
Solution A:

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

Solution B:

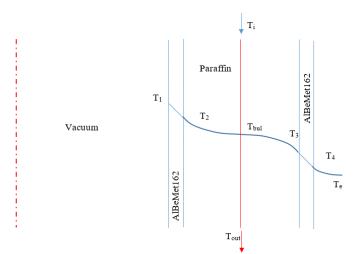
- Flanges not in contact with Helium
- Shorter chamber than solution A
- No standard flanges

Remote vacuum connection



Accelerator division internal notes

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



Case	Α	В
Velocity	V=0.3 m/s	V=0.5 m/s
<i>T</i> _{out} [° C]	18.5	18.3
T _{bulk} [°C]	18.3	18.2
<i>T</i> ₂ [°C]	23.4	23.0

Figure 5 - Temperature diagram

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

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

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

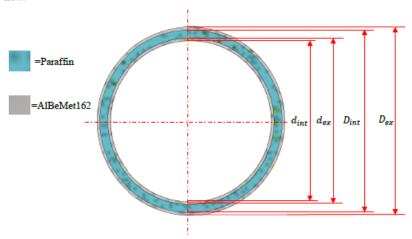


Figure 1-Cooling system (scale 10:1)

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

FUTURE

CIRCULAR

COLLIDER







PROGETTAZIONE MECCANICA DELLA REGIONE DI INTERAZIONE DEL FUTURE CIRCULAR COLLIDER e+ e-

CIRCULAR

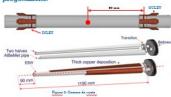
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INTRODUZIONE

Il Future Circular Collider e+ e- rappresenta una grande sfida per la comunità scientifica mondiale; l'alto livello del progetto necessita di un alto livello di progettazione e previsione degli scenari che si presenteranno dalla fase attuale di feasibility study fino alla realizzazione della macchina. La regione di interazione, riportata in Figura 1 rappresenta la zona di lavoro e sui cui si sta concentrando la





DESIGN MECCANICO DELLA CAMERA DA VUOTO

La camera da vuoto progettata inizia dall'IP e si estende fino al soffietto (1.2 metri dall'IP) ed è divisa in due parti. La Central Chamber da 0 a 90 mm è costituita da due cilindri concentrici di spessore 0.35 mm distanziati di 1 millimetro radialmente per creare un gap per il flusso di paraffina, utilizzata come liquido di raffreddamento avendo una bassa radiation length. La seconda parte chiamata Trapezoidal Chamber si estende fino al soffietto ed è creata in due metà saldate con EBW. Attorno a quest'ultima, tramite una tecnica additiva, sono previsti dei condotti di raffreddamento in cui scorrerà l'acqua. Il design è asimmetrico in quanto deve essere rispettato il cono di misura del JumiCal, il quale è centrato sul fascio uscente e non sull'asse del detector.

DESIGN MECCANICO DEL SOFFIETTO

soffietto è di particolare importanza per evitare che durante montaggio ed esercizio possano creare problemi alla camera. In particolare quello raffigurato in figura è un soffietto con due serie di convoluzioni: quella più piccola ha il compito di compensare le deformazioni termiche della camera, mentre quella più grande compensare

disallineamenti di montaggio e di esercizio. Il soffietto verrà

supportato nella parte centrale tra le



DESIGN MECCANICO DEL CILINDRO

Al fine di supportare i componenti della zona di interazione è stato progettato un cilindro in due metà con costole di rinforzo e due endcaps. Questo cilindro verrà inserito all'interno del detector principale

La struttura del cilindro è costituita da layers di fibra di carbonio opportunamente disposti con al centro uno strato di honevcomb.

I dischi, medium e outer tracker verranno ancorati alle costole di rinforzo, mentre il huminometro e la camera agli endcaps.



due serie di convoluzioni. CALCOLI E RISULTATI

Per validare i modelli progettati è stata effettuata l'analisi termo-strutturale [1] della camera, utilizzando i carichi termici derivanti da calcoli di impedenza con CST [2,3] e condizioni di carico e vincolo di progetto. Il sistema di raffreddamento è stato dimensionato al fine di mantenere la temperatura massima della camera sotto i 60 gradi: una volta ottenuta la distribuzione di temperatura. questa è stata utilizzata nell'analisi strutturale per calcolare stress e deformazioni.

Un'analisi strutturale è stata eseguita sul cilindro in carbonio al fine di valutare le deformazioni e stress causati dai carichi. Sono state considerate le costole di rinforzo e gli endcaps al fine di ottenere dei risultati il più possibile vicini alla realtà. Entrambe le simulazioni hanno dimostrato pieno rispetto dei requisiti di rigidezza delle strutture.



ACKNOWLEDGMENTS

Questo lavoro ha ricevuto fondi dalla Comunità Europea con il programma di ricerca e innovazione Horizon 2020 con il grant n. 951754. Un ringraziamento al gruppo INFN di Frascati per il supporto e l'aiuto nel lavoro e al Gruppo INFN di Pisa per il lavoro

OTTIMIZZAZIONE STRUTTURALE Al fine di ottimizzare le strutture di supporto

della regione di interazione è in corso uno studio di ottimizzazione strutturale degli endcaps e della struttura di ancoraggio al detector. Lo studio sta interessando diversi metodi di ottimizzazione che verranno confrontati valutata l'efficacia di ocmuno e dopo una scelta del metodo più adatto alle strutture seguirà una più accurata ottimizzazione considerando le variabili di progetto ottimizzabili. Al momento è stato utilizzato l'algoritmo SIMP, basato sul concetto di penalizzazione, e il metodo del Generative Design, in grado di creare una struttura da una forma inziale e da vincoli spaziali imposti.

[1] Appro Mechanist Jamesharmannescom [3] N. NOSSMERIC, Villey an self-trapped modes and a they prove beauty, ACC-IV Pastwaing. 2012. [1] CS F Statio, Daniel & Sectional Principles of CS P.

IPAC23

Estimated heat load and proposed cooling system in the FCC-ee Interaction Region Beam pipe

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We discuss the beam power loss related to the heating of the beam pipe walls of the PCC-ee interaction region. We analyse the excitation of trapped modes, which can accumulate electromagnetic energy and determine the locations of these modes. We study the unavoidable resistive-wall wake field, which is responsible for the direct beam pipe walls heating. We show the distribution of the heat load along the central part of the interaction region. We also present the cooling system design and results for temperature distribution in interaction region in the operational mode.

The FCC Interaction Region (IR) consists of the intersection of four beam pipes and presents a very complicated inhomogeneity geometry. Both beams generate electromagnetic fields in IR. Depending upon the bunch spacing frequency, this may lead to a resonant excitation of a trapped mode located in some special

Another heating effect is an excitation and diffusion of the image currents inside the metal beam nine walls. This leads to a direct heating of the beam pipe. Naturally, the beam also loses energy as it is decelerated by the longitudinal electric component of the field generated by the image currents.

Previously, we optimized the geometry of the PCC IR beam pipe for a minimum geometrical impedance [2-4]. We use a numerical code CST [5] for 3D electromagnetic calculations. In these calculations we assume that the beam pipe materials have infinite electrical conductivity Now the engineering design of the IR suggests what kind of materials will be used. Using the correspondent conductivity of the materials we calculate the heat load distribution along IR

WAKE POTENTIALS AND TRAPPEL

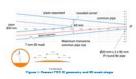
Using this CAD model, we performed wake field calculations giving to all wall materials an infinite conductivity. The result for the wake potential highlight two beating oscillations with a smaller amplitude. therefore we have two trapped modes with close frequencies

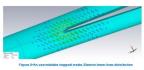
We also did a special eigen mode calculation for this geometry. The electric force line distribution of the mode is shown

HEAT LOAD DISTRIBUTION

We use specially designed CAD model as an input for the wake filed calculations using the CST code. At first, perform wake field calculations assuming that all materials have an infinite conductivity. Then perform wake filed calculations, still assuming that all materials have infinite conductivity, except the interested part, which is given the correspondent material. And finally, we take the difference, which shows how much power is lost in this part. In Fig. 3 we present the distribution of the heat load along the central part of IR (+- 4.5 m).







electron and positron beams collide. The last geometry of the PCC IR beam pipe [3, 7] is shown in Fig. 1. Two symmetric beam pipes with radius of 15 mm are merged at 1.2 m from the IP. The central part has a 10 mm

LOW IMPEDANCE IR BEAM PIPE

The main idea to decrease the wake field

radiation or minimize the impedance of the

chamber is naturally to use a very smooth

transition from one pipe to a conjunction of

two pipes. Starting with a round pipe we make

a smooth transition to a pipe with a cross

section of a half of ellipse. Then we combine

two half-ellipses in one full ellipse making

one pipe from two pipes. An important point is

that the inner part at the conjunction location

must be rounded. Finally, we make a smooth

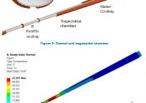
transition from a pipe with an elliptical cross

section to a round pipe, which is the main

central part of the interaction region, where

radius for ± 9 cm from the IP. There are two synchrotron radiation (SR) 7 mm masks [7] in incoming beam pipes at the distance of ±2.1

The cooling system consists of paraffin cooling of the central chamber (Fig.4) and of asymmetric water-cooling channels in the trapezoidal chamber , just before the luminosity monitor (Fig.5). The trapezoidal chamber is created using the 50 mrad cone as the cutting profile, to assure the respect of the spatial constraint. We performed a thermo-structural analyses using a detailed model for PEA (Ansys) to calculate temperature distribution along the pipe. In the central part we can notice a linear increase of the temperature without any asymmetry, instead along the trapezoidal chamber there is an asymmetric temperature distribution due to the configuration of the cooling channels (Fig.6). In both parts of the chamber the cooling is efficient and keeps the temperature low as wanted.





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

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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

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23/05/2023, Frascati





THANK YOU FOR YOUR ATTENTION

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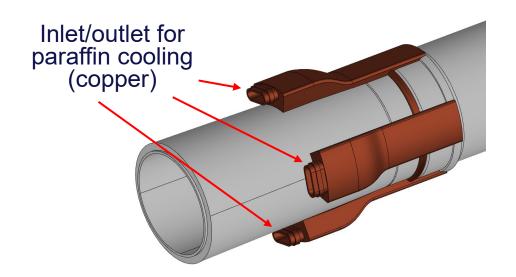
BACK UP SLIDES

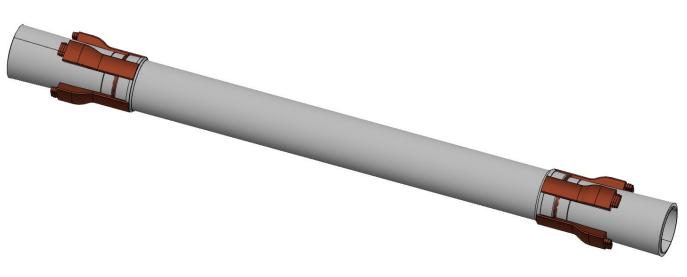


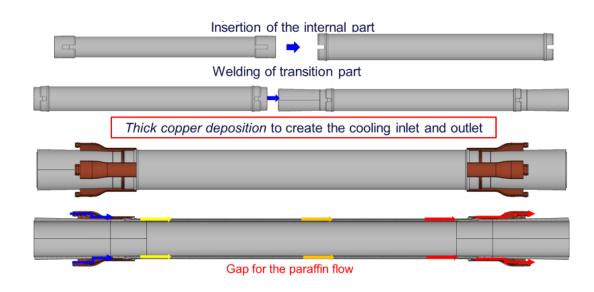
Chamber design – central chamber

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







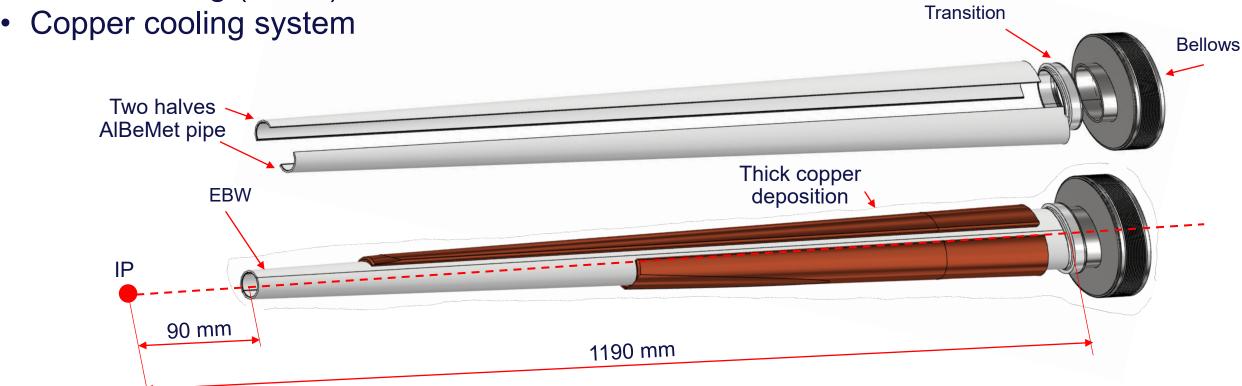




Chamber design – trapezoidal chamber

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)







From CST calculations (Alexander

Novokhatski (SLAC))

Structural analysis – central chamber

Loads, constraints, characteristic parameters, design



Temperature distribution, stress and displacement along the pipe

- Paraffin flow (central chamber)
- ➤ Flow rate: 0,015 kg/s
- > Section:68,17 mm²
- Velocity: 0,3 m/s
- Inlet temperature: 18°C
- ➤ Convective coefficient: 900 W/m²K
- Water flow (trapezoidal chamber)
- Flow rate: 0,0019 kg/s
- Section: 9,62 mm² (20 different channel)
- Velocity: 0,2 m/s
- ➤ Inlet temperature: 18°C
- Convective coefficient: 1200 W/m²K



Chamber design



- 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



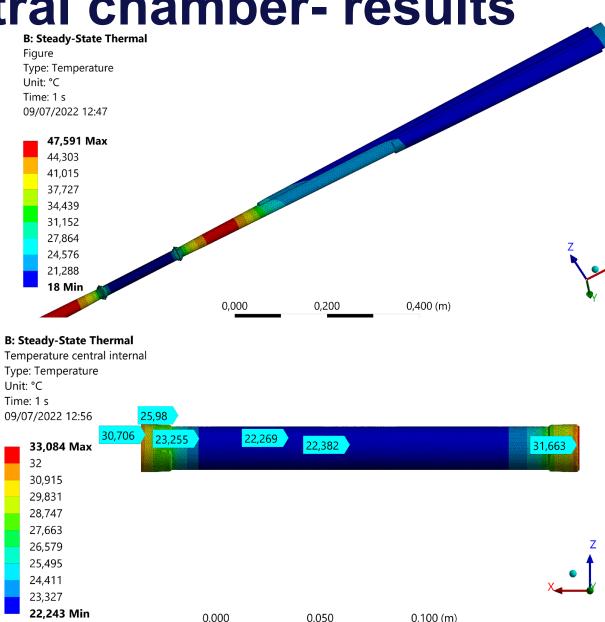


Structural analysis – central chamber- results

	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
DEAM	Fixed ends	22,07	21,86	46,8	38,9
BEAM	Fixed+displ	14,65	10,63	9,69	17

Maximum displacement [mm]			
		Х	Υ
DEAM	Fixed ends	0,031	0,07
BEAM	Fixed+displ	0,1	0,29







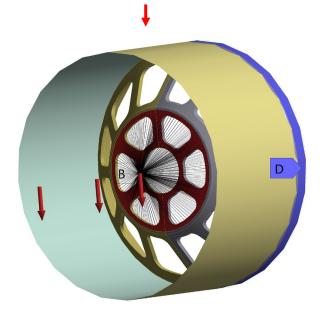
Support tube – Structural analysis

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



Loads applied to remote point to distribute

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

Face Sheet (Al 5754 or CFRP)

Adhesive (3M 2216)

Honeycomb Core (Al 3003)

Carbon fiber/ honeycomb creation → layered section





B: Static Structural

Support tube - Structural analysis - results

B: Static Structural

Equivalent Stress FLANGE 2

Type: Equivalent (von-Mises) Stress - Top/Bottom - Layer 0

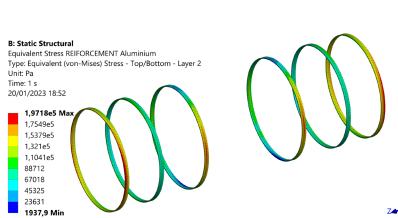
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20/01/2023 18:55

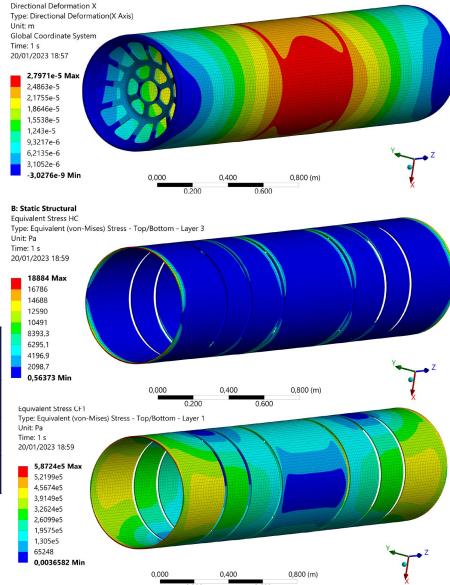
2,3079e5 100,03 Min



	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

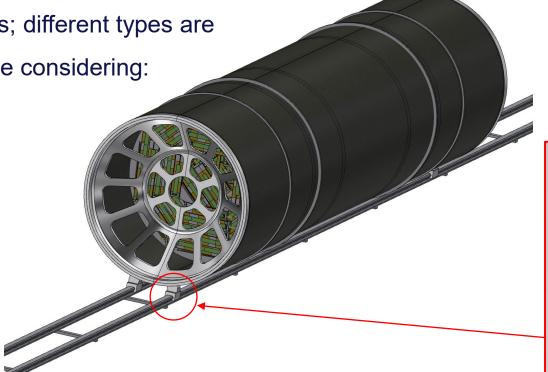
The support tube needs to be inserted into the main detector; the idea is to use a rail, starting from the outside of the detector to allow the sliding of the cylinder.

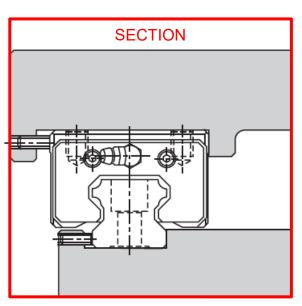
To assure a good precision and appropriate support it is necessary to use the linear bearings; different types are available, the choice has to be made considering:

Required positioning precision

FCC

- Weight of the whole structure
- Necessary degrees of freedom

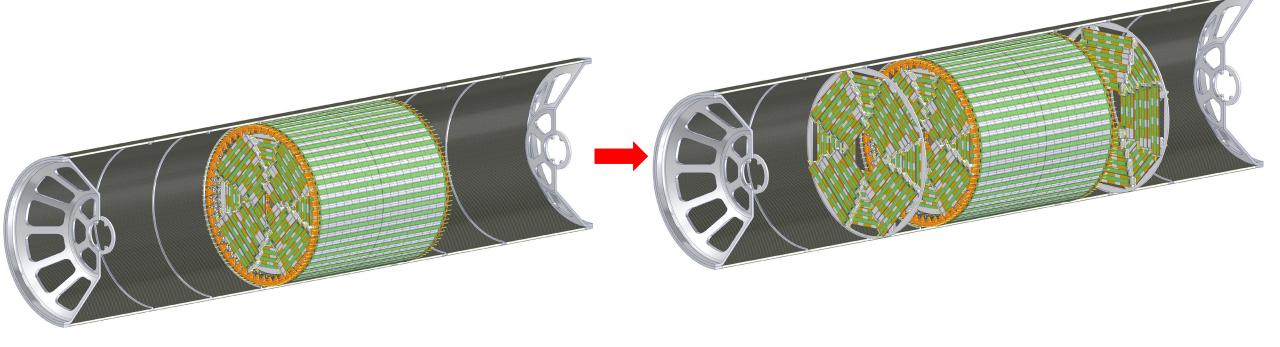








Assembly procedure



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

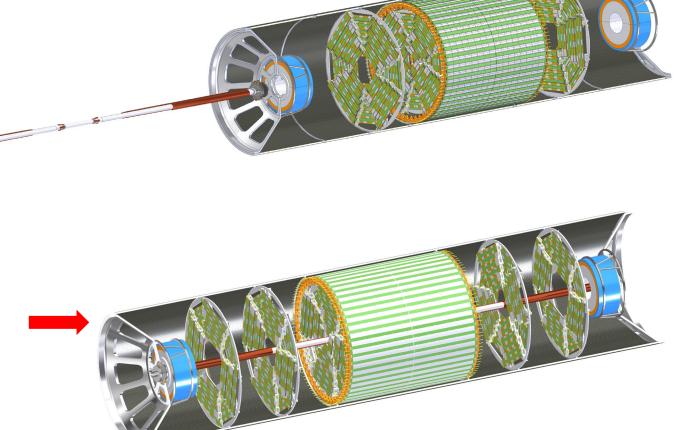
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Assembly procedure

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



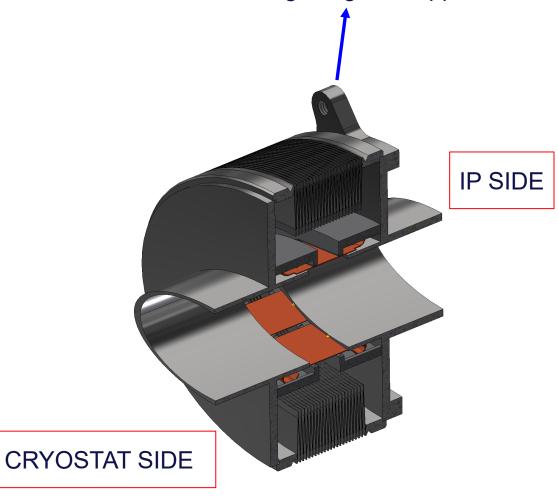


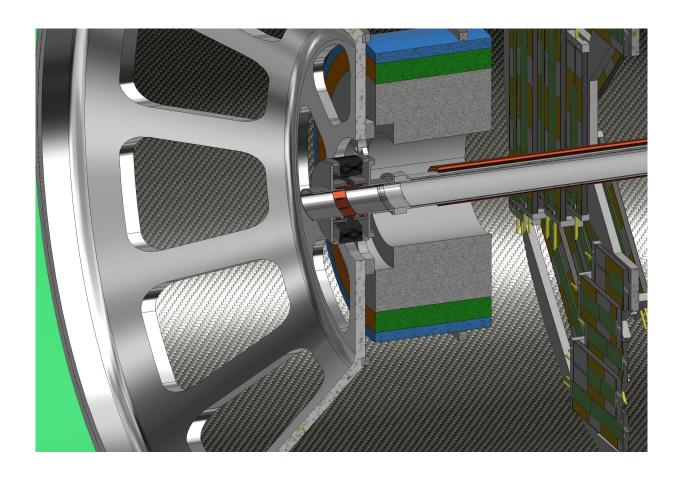
5) Support tube can be closed



1st Bellows (Single bellows)

Anchoring flange to support tube

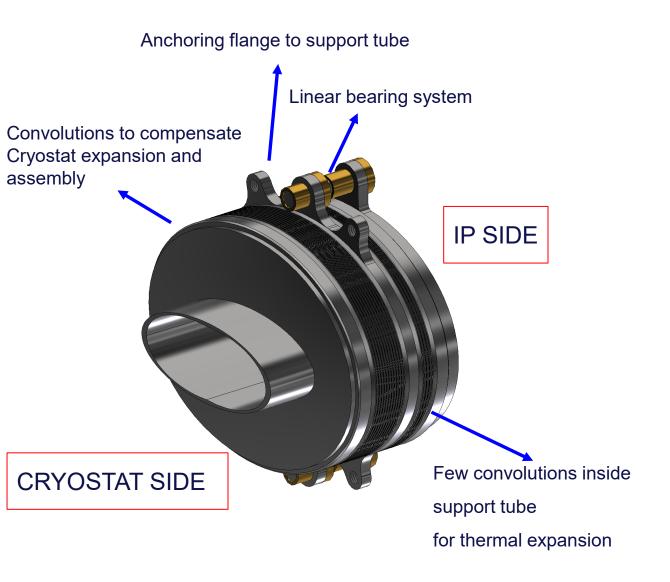


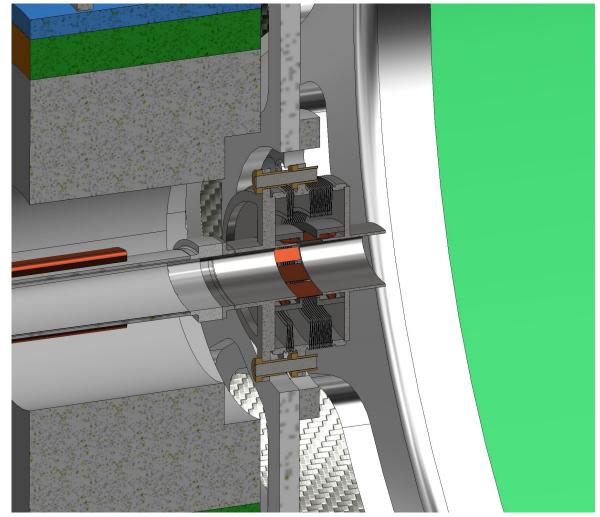






2nd Bellows (Double bellows)









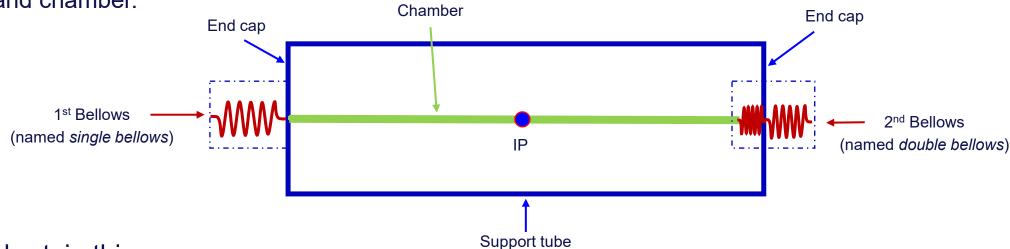


Bellows – constraint configuration

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