Assembly of HL-LHC beam screens

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30/7-018 Kjell Johnsen Auditorium (CERN)

OUTLINE

1. Introduction
2. HL-LHC Beam Screens
3. Some numbers…
4. In-house production (@CERN)
5. Assembly Hall
6. Assembly and Integration
7. Beam Screen from En/MME
8. Step 1: Stud welding
9. Step 2: UHV cleaning
10. Step 3: Leak detection at room temperature
11. Step 4: W bloc assembly
12. Step 5: Thermal link brazing
13. Step 6: Cold testing (pressure & leak test)
14. Step 7: Assembly of pumping slot shields
15. Step 8: Ac Coating (VSC/SCC)
16. Step 9: Bending of cooling tubes (Fix side)
17. Step 10: Magnet insertion
18. Step 11: Bending of cooling tubes (Mobile side)
19. What remains to be done

Introduction

Why do we need beam screen?
What a beam screen looks like?

LHC Beam Screen

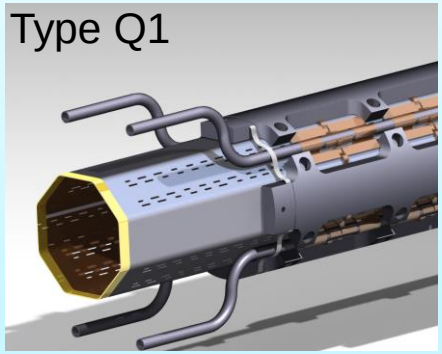
- Ensure vacuum performance
- Minimize and intercept beam induced heat loads
- Intercept collision debris

HL-LHC Beam Screens

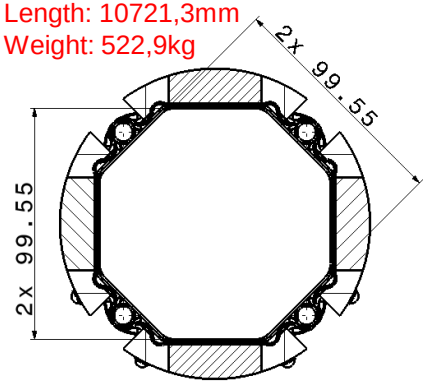
How many types are needed for HL-LHC project?
Where will we install them in the LHC machine?

TRIPLETS

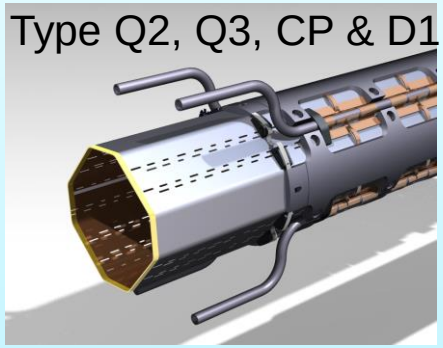
Type Q1



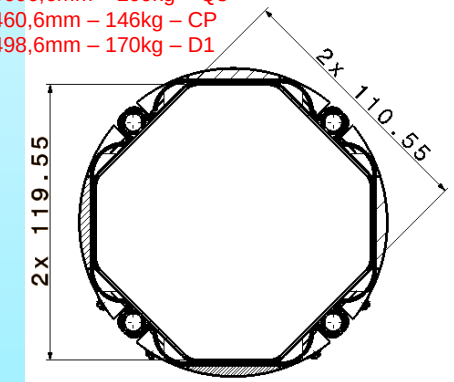
Length: 10721,3mm
Weight: 522,9kg



Type Q2, Q3, CP & D1

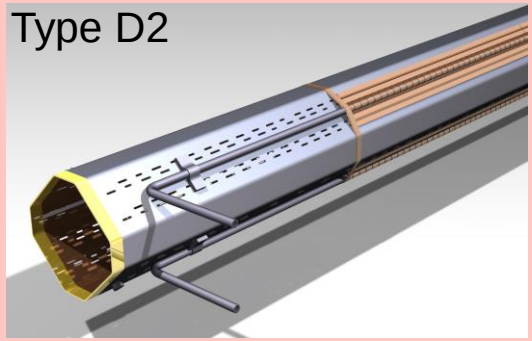


L:10291,6mm – 210,5kg – Q2
L:10606,6mm – 209kg – Q3
L:7460,6mm – 146kg – CP
L:8498,6mm – 170kg – D1

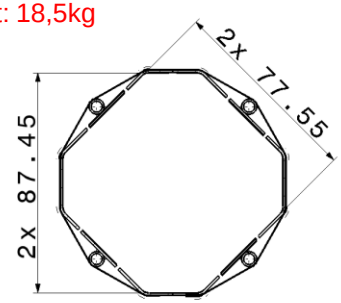


LSS

Type D2



Length: 14083mm
Weight: 18,5kg



Some numbers…

W bloc (Q1 type)

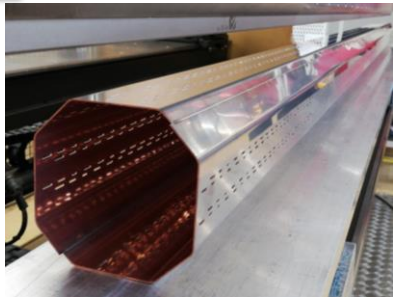
3 types but many variants are needed!

In total, **65x beam screens** (29+10+10+8+8) to be produced.

- **29x** (24 + 5) SHIELDED beam screens (W blocs)
  - 4 + 1 Q1 type
  - 20 + 4 Q2 type (including Q2, Q3, CP & D1)
- **10x** (8 + 2) D2 NON-SHIELDED beam screens
- **10x** (8 + 2) Q4 NON-SHIELDED beam screens (Existing LHC parts)
- **8x** Q10 beam screens identical to LHC ones
- **8x** Q5 beam screens identical to LHC but surface treatment to be decided by end 2024

Budget of 18,5 MCHF (WP12)!

IN-HOUSE PRODUCTION (@CERN)

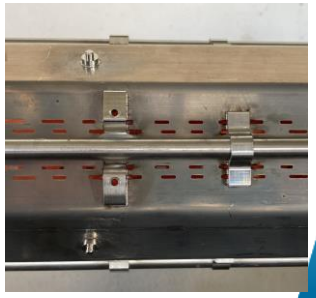


In-house production with the support of EN/MME.

Why?
- Complex design
- “Only” 65x beam screens

Industry did not want to take part in the project for this component, as it was too expensive to produce by lamination/pushback (only one offer, very expensive!).
EN/MME manufacturing of 3000mm hexagonal sections with longitudinal laser welding.

Collaboration with EN/MME:
- Colaminated sheet for machining to width
- Punching (sub-contracting)
- Bending and welding of 3000mm hexagonal sections
- Laser welding of beam screen
- Cooling tubes welding (x4)
- Thermal links and W blocs brazing
- Laser welding of thermal links, studs, cooling tube supports, end rings, etc…)
- Metrology controls (3D measurements)



ASSEMBLY HALL

Allocation of building 3173 (SMA18) to TE/VSC for the manufacture assembly and integration of LHC and HL-LHC beam screens in 2016 and 2021.
Allocation of building 6118 en 2023 (meeting room).

Building 3173 – Point 18

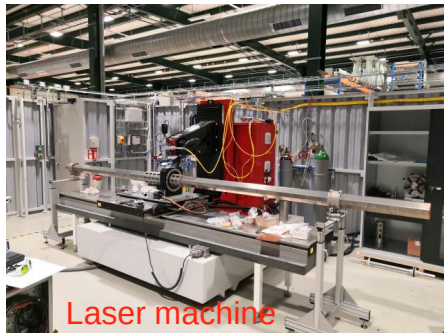
Civil engineering works (3173/R-V20 zone):

- 5T gantry crane
- Laser room– class 4

Electrical works: connection of different equipment (laser, washing machine, tool machines, etc…)

Installation of 5T gantry crane

Actual situation

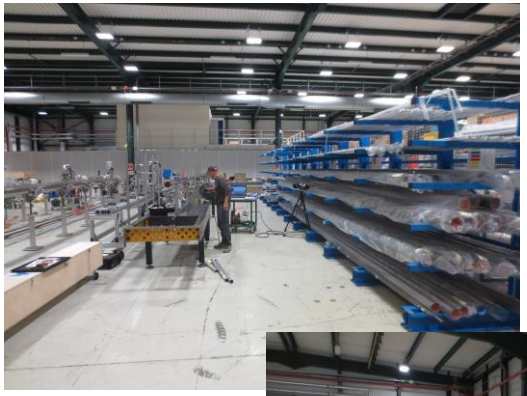


ASSEMBLY HALL

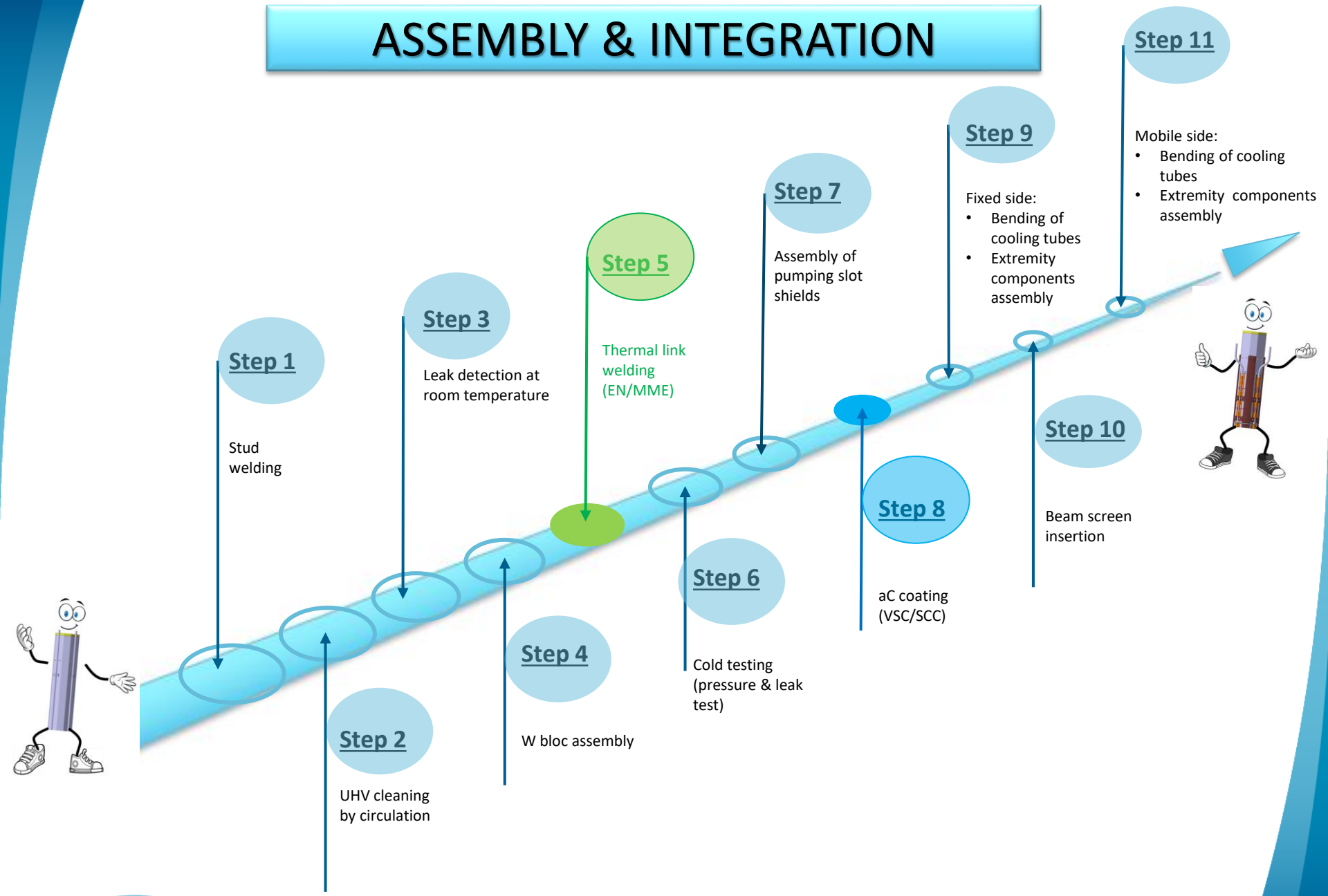
Layout of work zones:

- Installation of CB tube washing machine (12,5T) (removal from SMI2)
- Purchase and installation of demineralized water unit
- Common storage area (DLM/BVO) and 18m rack
- Fabrication of working benches:
  - Magnets (MB, SSS, HL)
  - Metrology,
  - Ac coatings,
  - W bloc assembly
  - Stud welding
  - Post-weld control test for studs
  - UHC cleaning (by circulation)
  - Insertions (Cold test bench & magnet)
  - Cold test
  - Mechanical cutting

More than 1,1 MCHF used for the Assembly Hall!

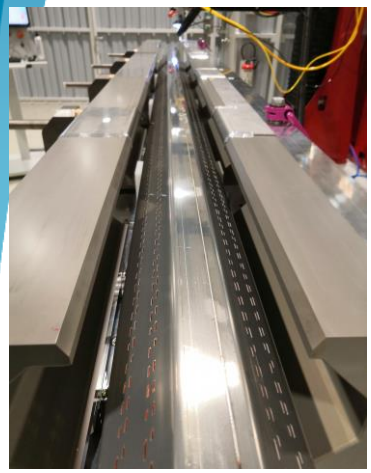
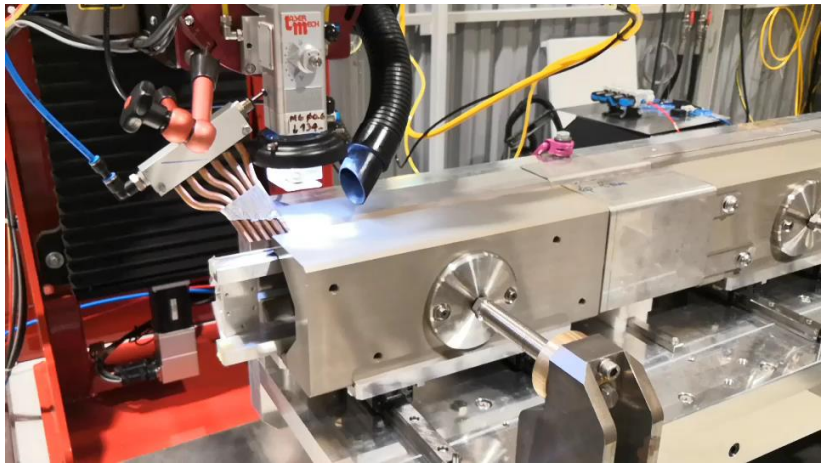
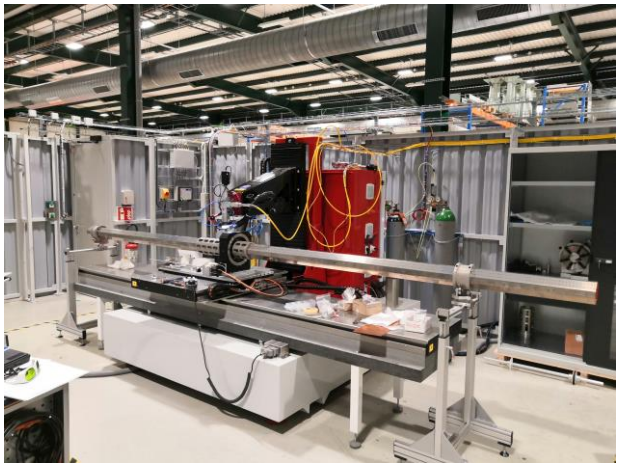
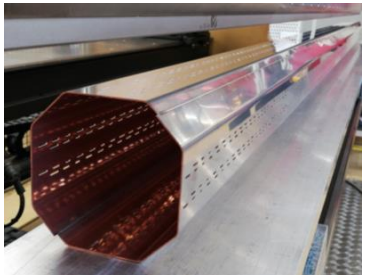


ASSEMBLY & INTEGRATION

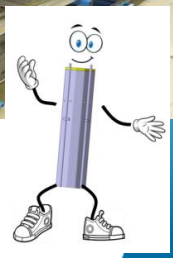


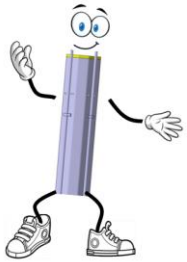
BEAM SCREEN FROM EN/MME

Beam screen reception from EN/MME on the 18m rack.

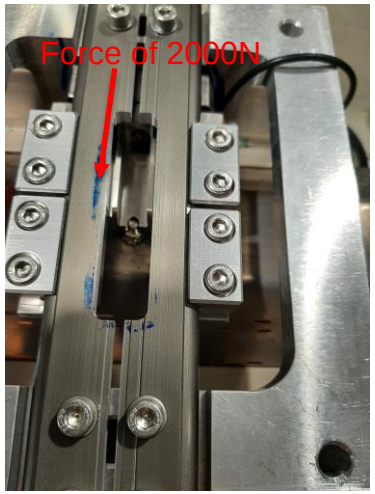


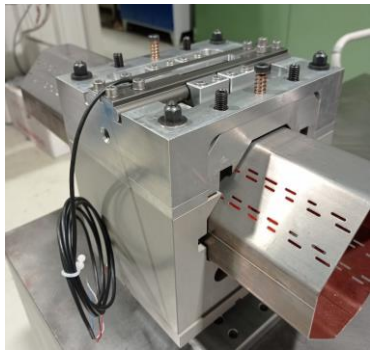


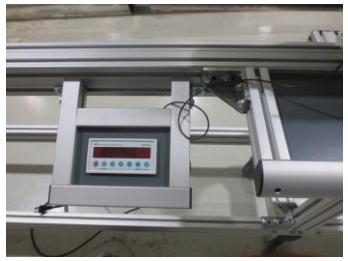


STEP 1

Stud welding by capacitive discharge.
100% weld control with a force of 2000N.
Final metrology measurements by EN/MME.

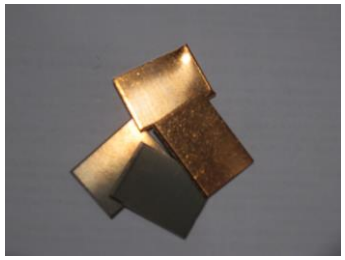


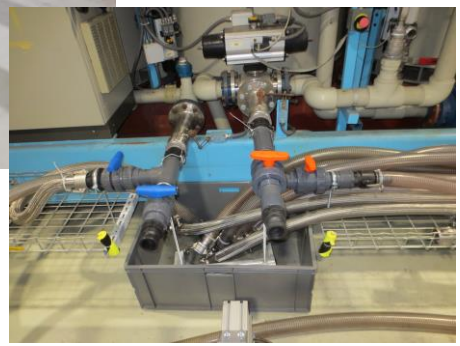




STEP 2

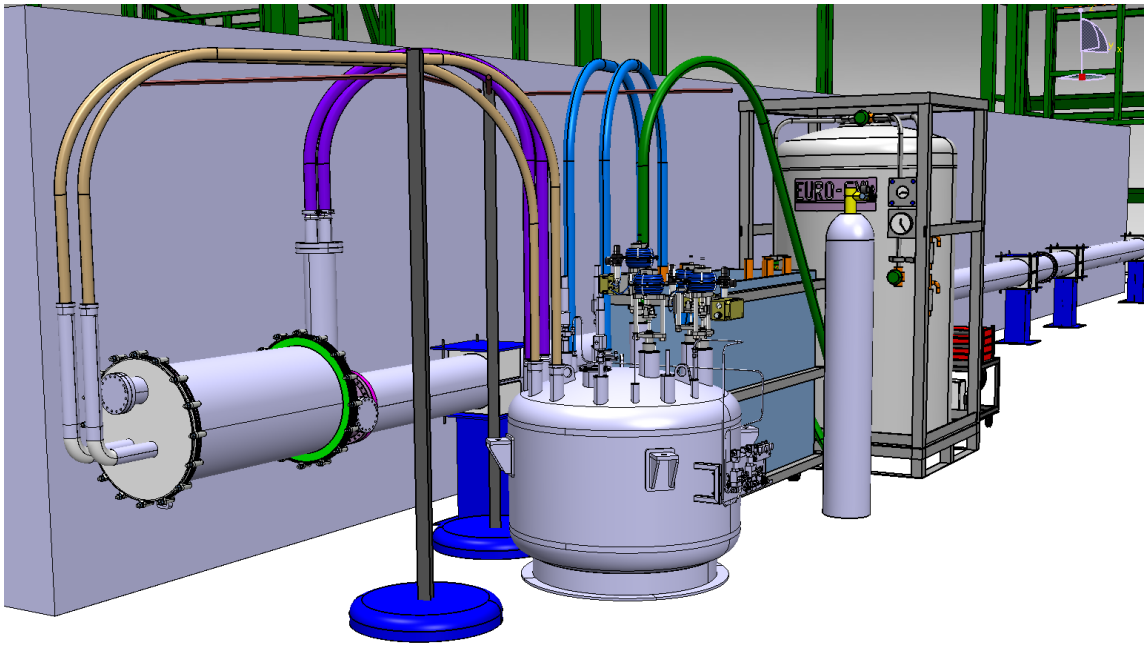
UHV cleaning by circulation (Deconex VP 1215).
Rinsing with demineralized water (in-situ production).
Drying with a ventilator.
2x reference samples for each beam screen (20x15mm).
No connection to waste water circuit!

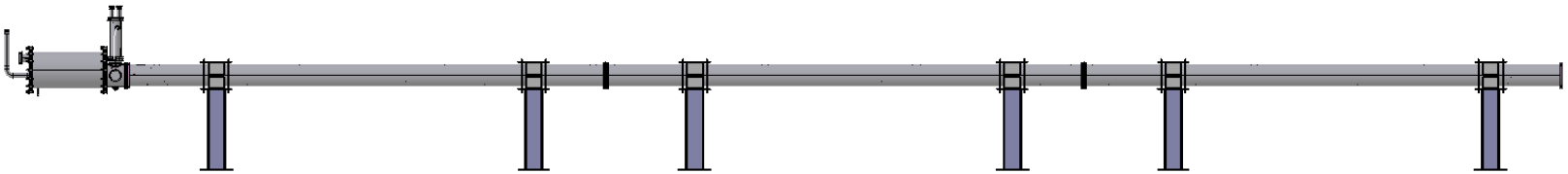




STEP 3

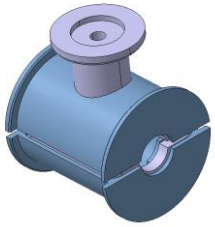
Leak detection of the cooling tube circuit at room temperature in the 20m long cold test bench.



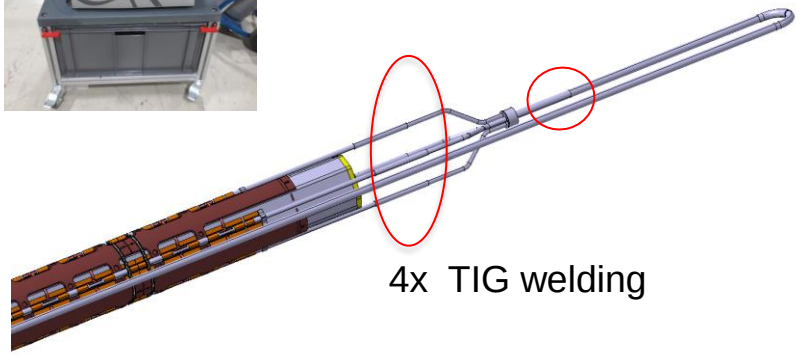


STEP 3

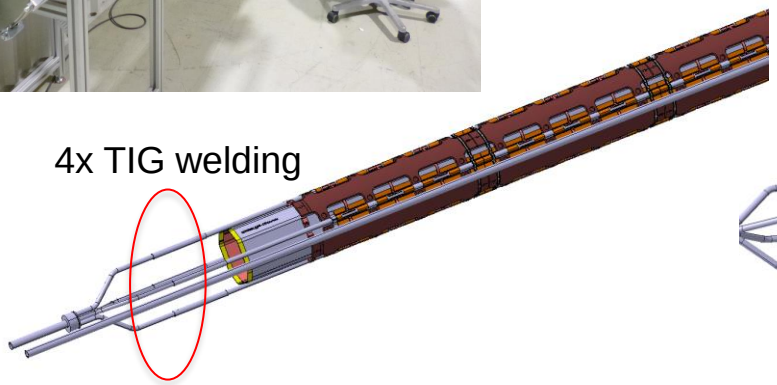
Intermediate leak detection with a clamshell of automatic TIG welding.
All welds will be done with an automatic TIG welding head.



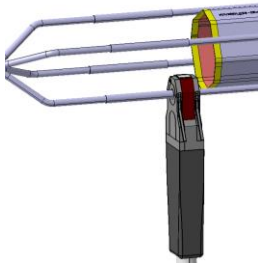
Clamshell

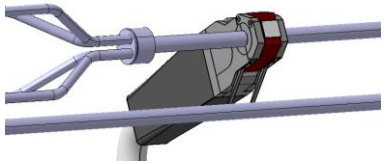


4x TIG welding



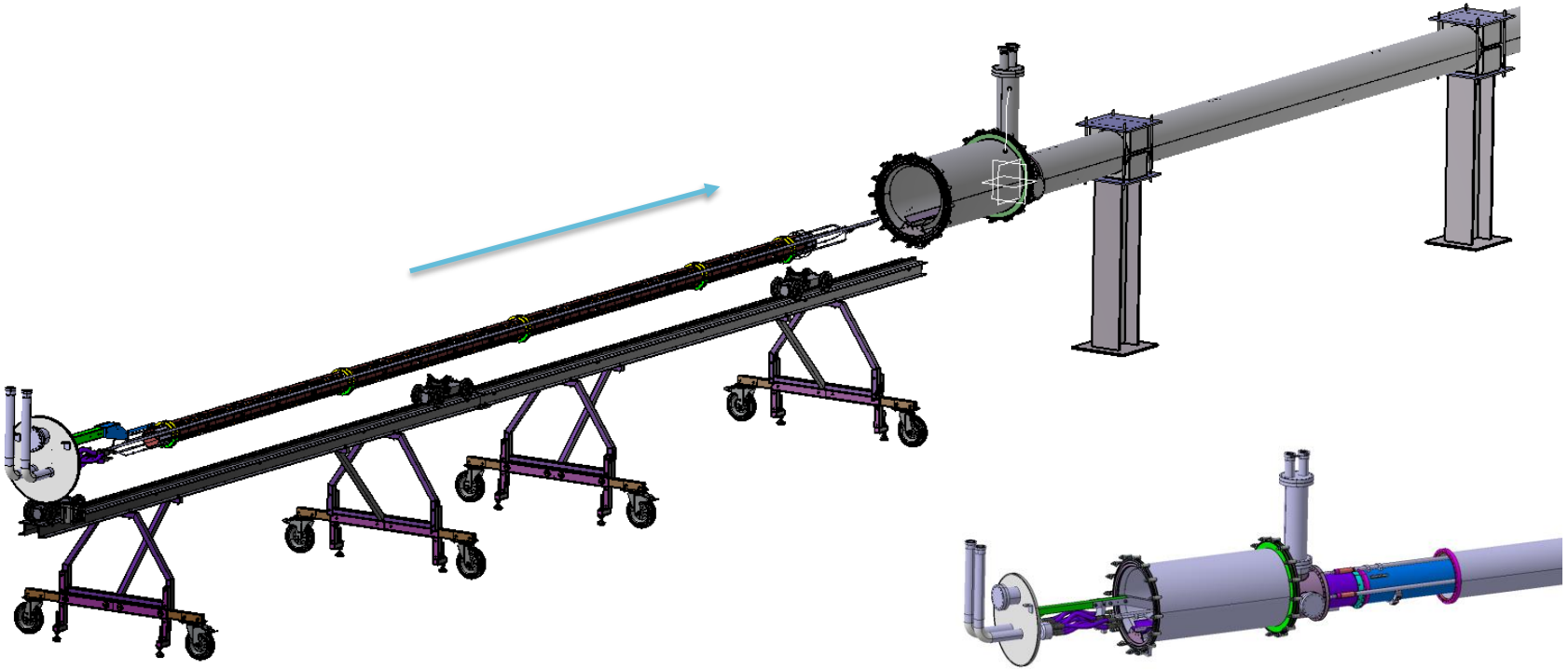
4x TIG welding





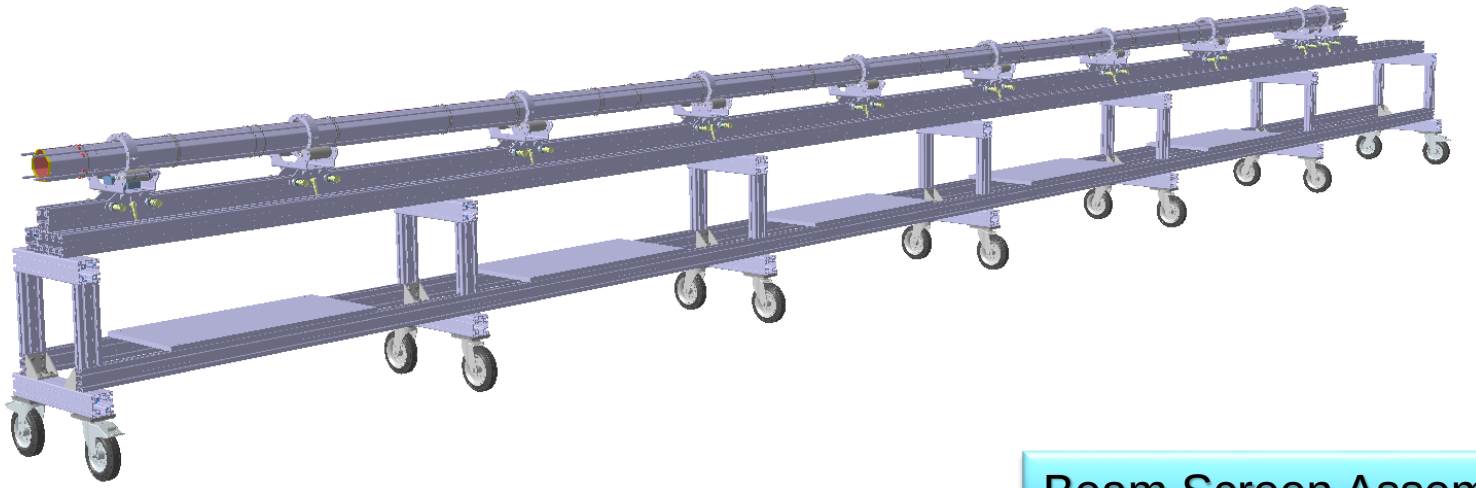
STEP 3

Beam screen insertion into the Cold Test Bench.



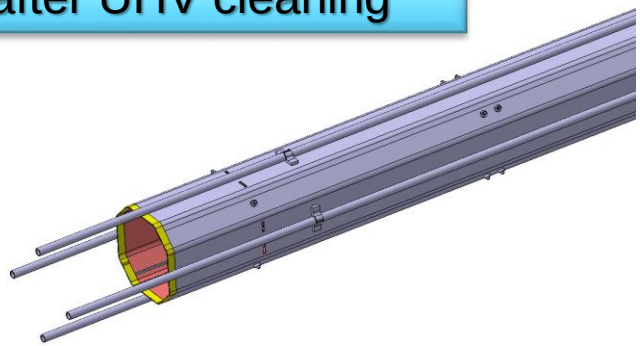
STEP 4

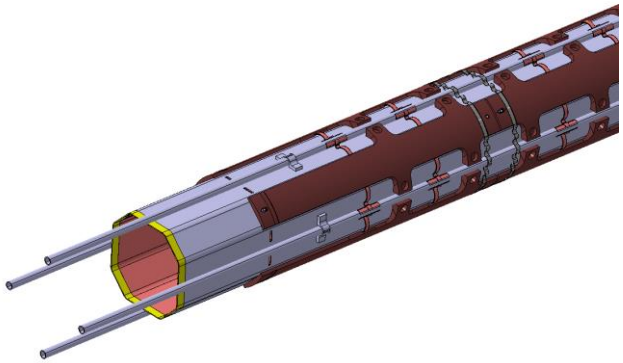
W bloc assembly with compression rings in Ti.



Beam Screen Assembled

Beam screen after UHV cleaning

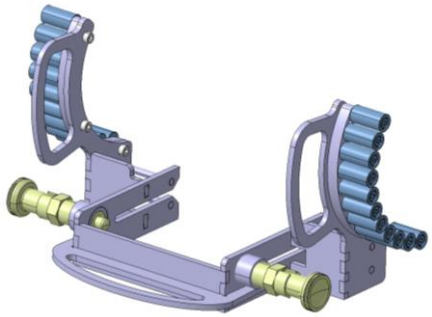


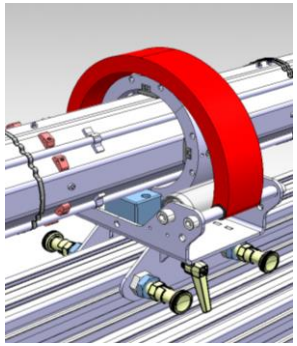


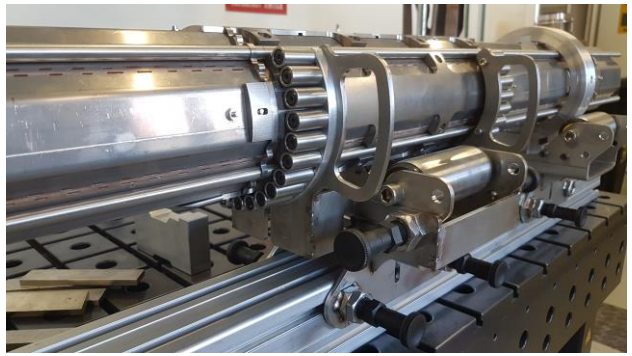
STEP 4

Precautions to be taken for working on beam screens:

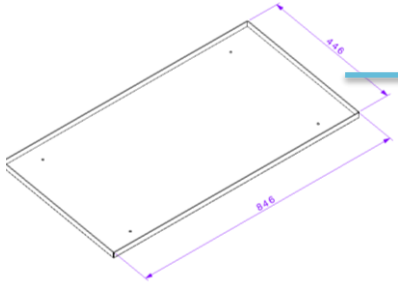
- Ethanol cleaning of assembly bench roller supports

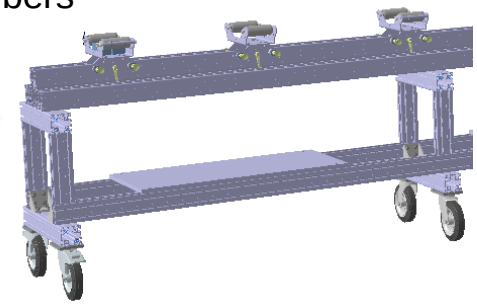






- Cleaning stainless steel trays for storing tungsten absorbers

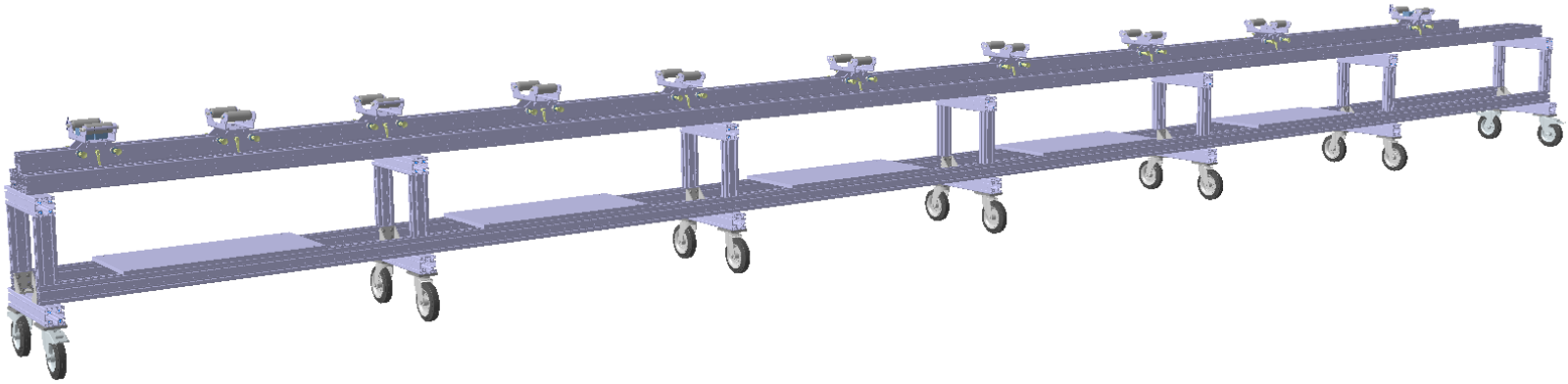




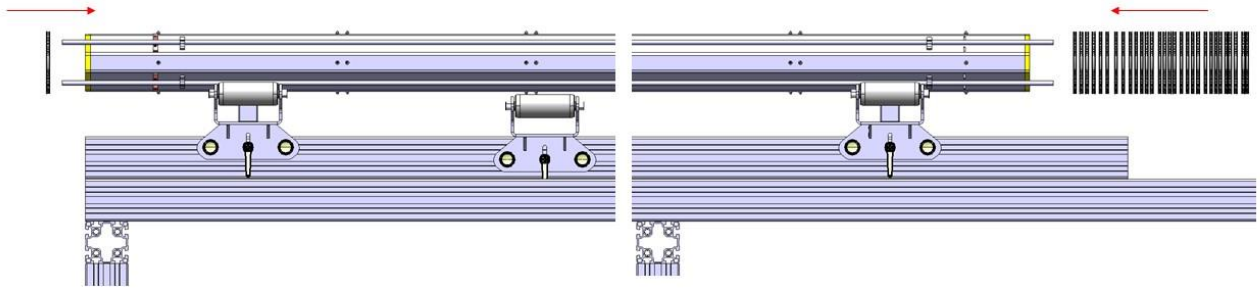
- All manipulation with gloves in latex
  SCEM code 50.43.20.832.7

STEP 4

Presentation of assembly bench:



- Aluminum frame - length 11400mm
- Roller support with longitudinal and height adjustment
- 2x safety system against tilt

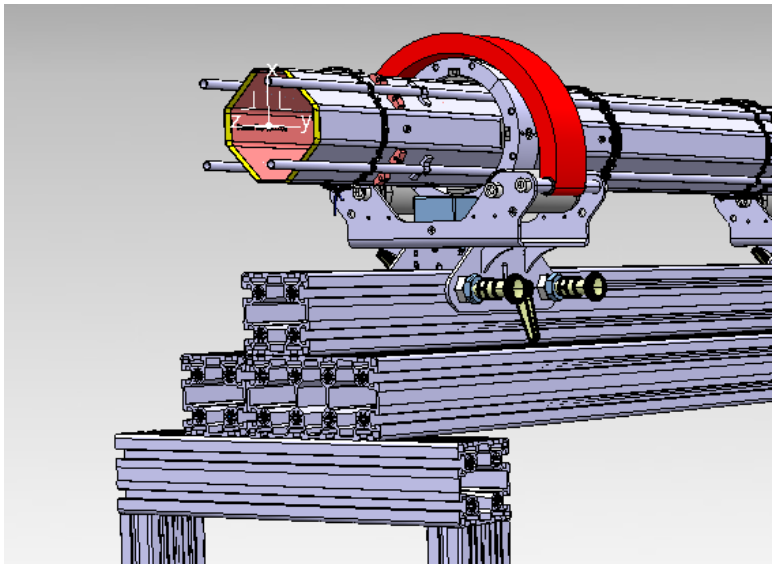


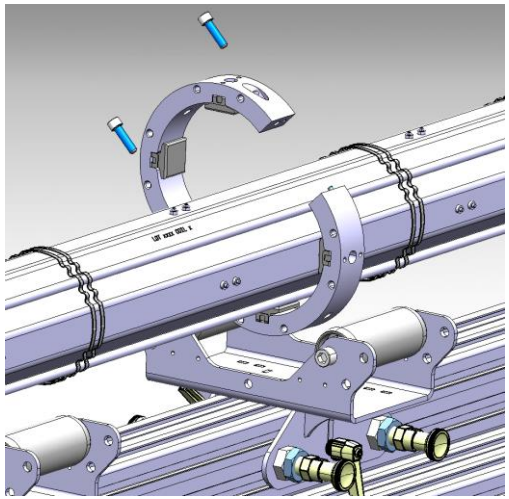
STEP 4

Assembly benches in SMA18:

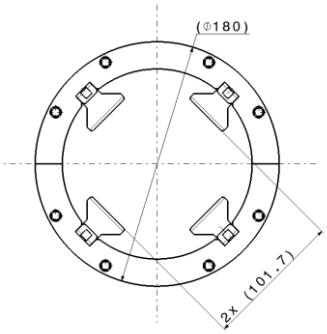
STEP 4

Mounting rings for assembly and welding benches:

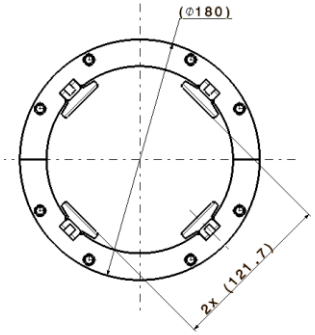




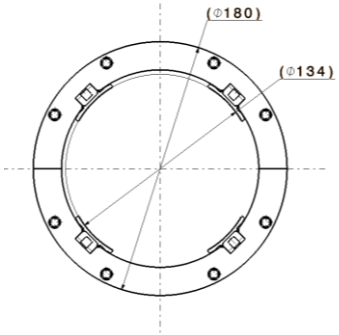
TYPE Q1



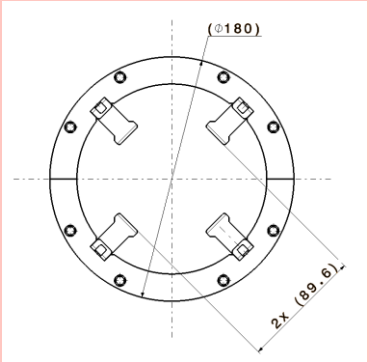
TYPE Q2



TUNGSTEN

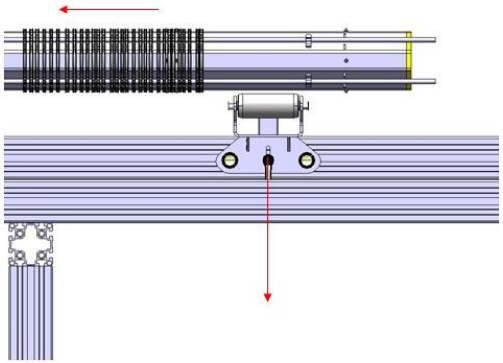


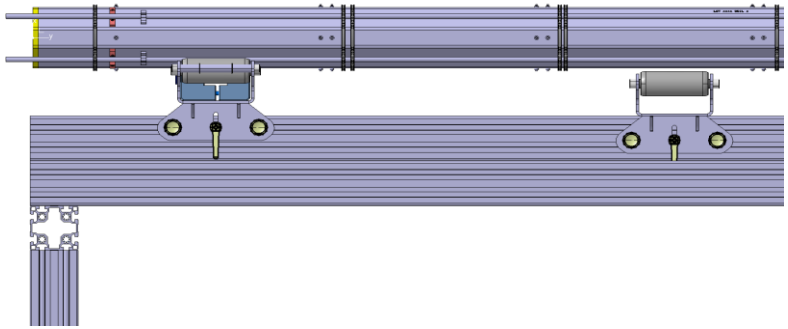
D2



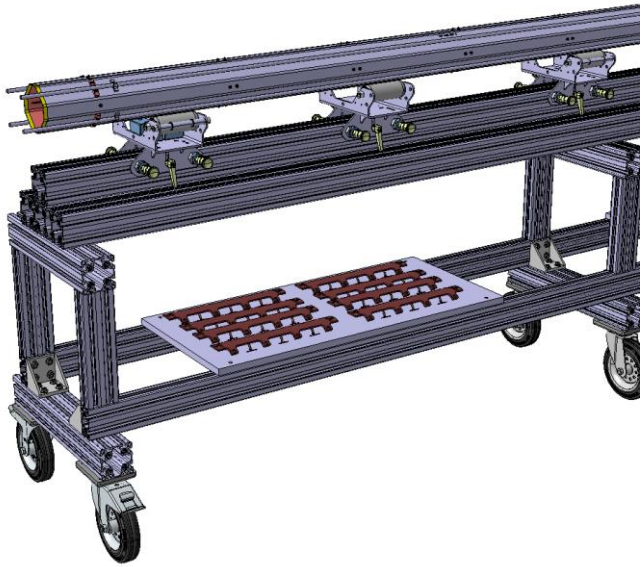
STEP 4

Installation of elastic ring (Ti) and preparation of W blocs:





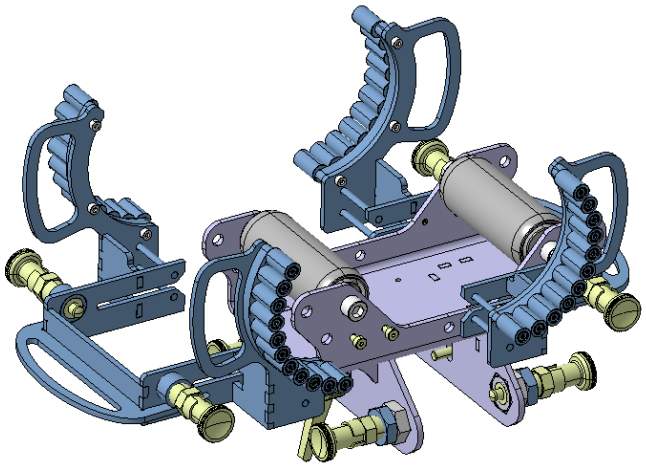
Assembly procedure EDMS: 2958304



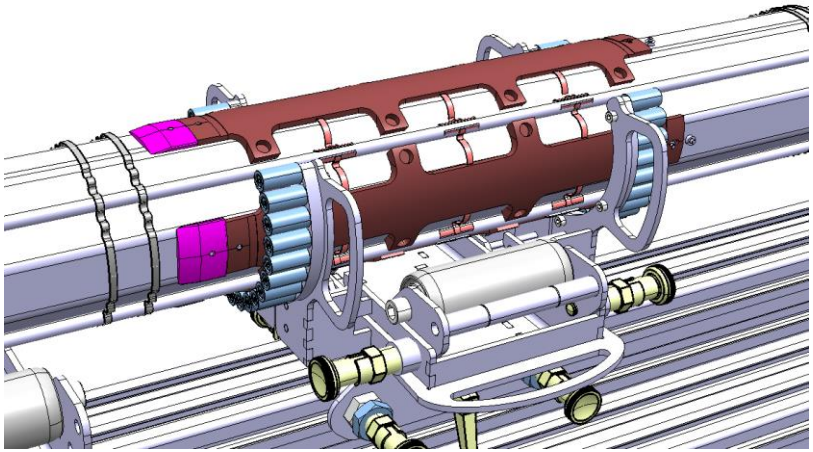
Place W blocs on the trays

STEP 4

Tooling for W blocs installation:



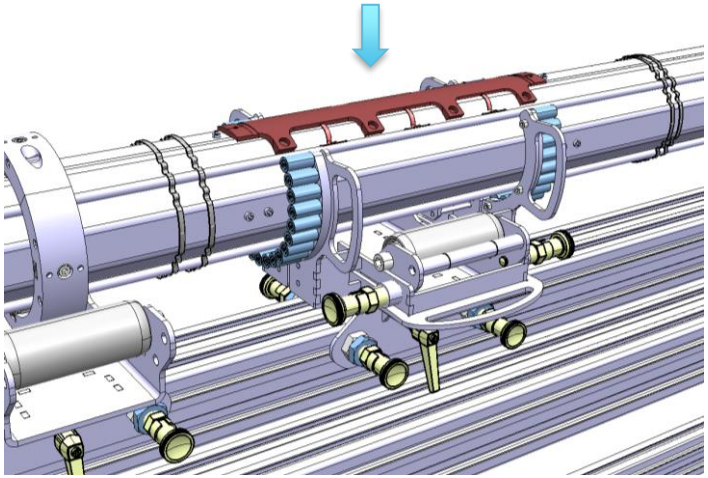
Special tooling for W blocs



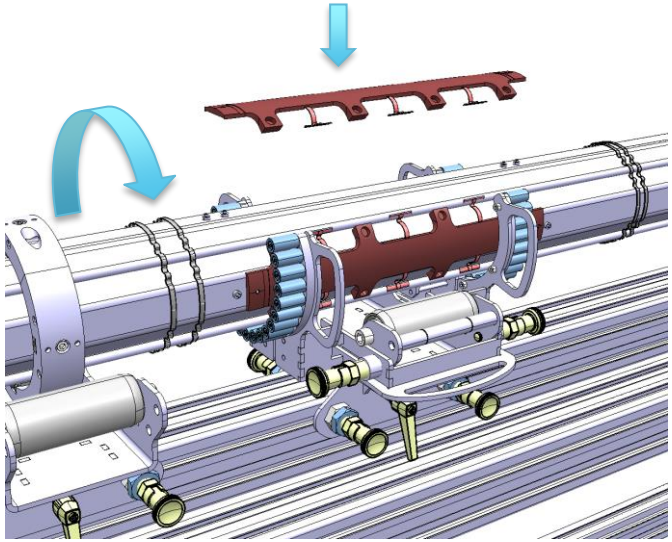
Insertion tooling of elastic rings (Ti)

STEP 4

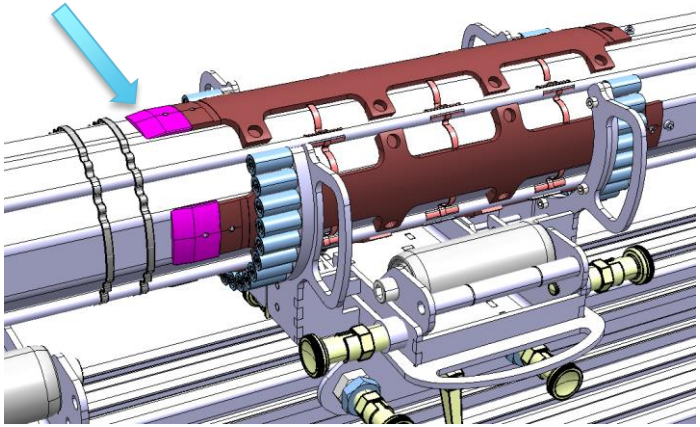
W blocs assembly and mounting ring with jaws in W:



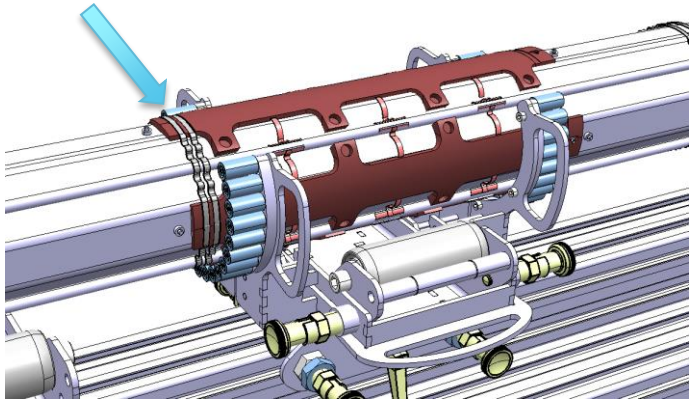
Installation of the 1st W bloc



BS rotation of ¼ turn three times

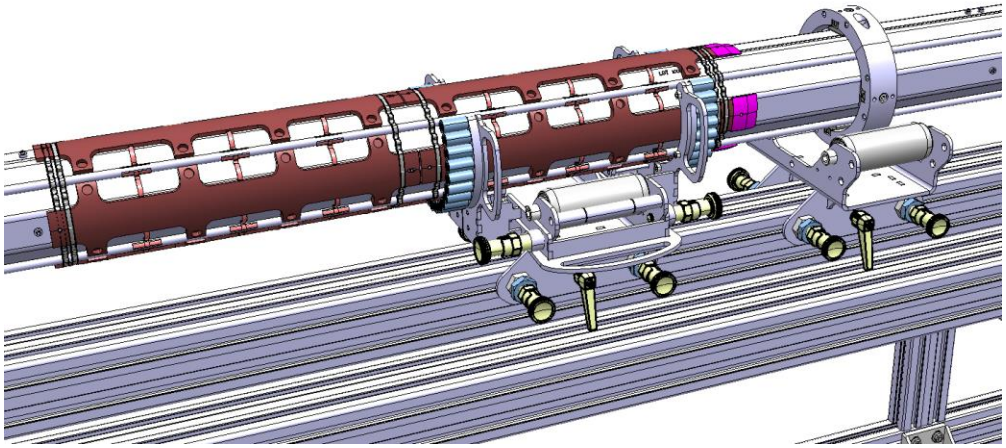


Installation of the 4x insertion tooling

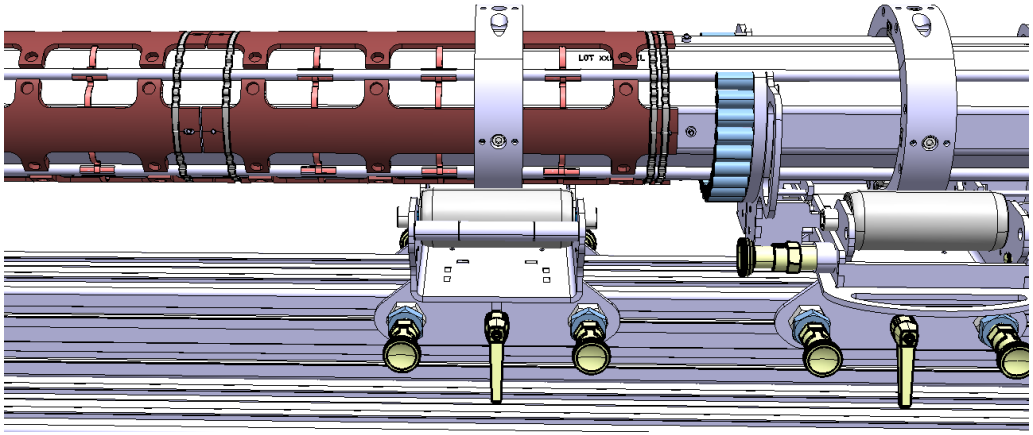


Installation of the two elastic rings

STEP 4



Repeat this operation

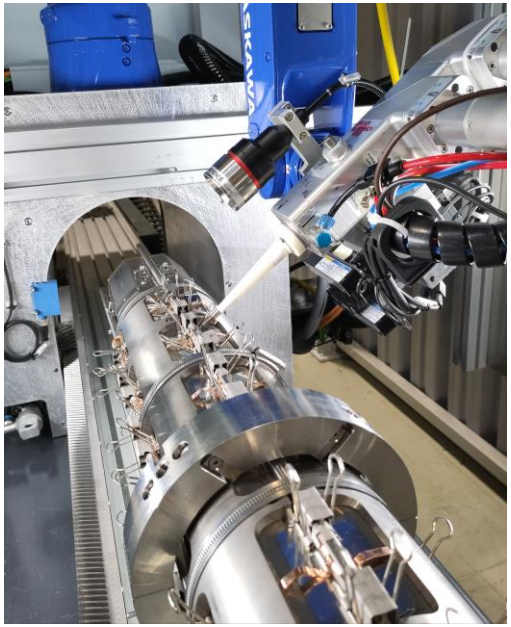


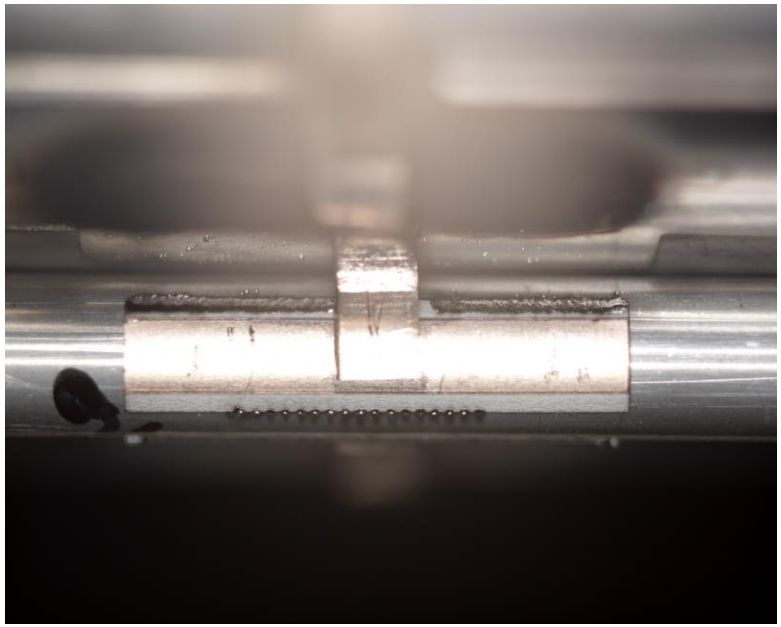
Installation of mounting ring after installation of the W jaws

STEP 4

STEP 5

Thermal links welding (EN/MME):





Q2 Beam Screen equipped for laser welding

Romain GERARD | Beam Welding and AM | https://indico.cern.ch/event/1216405/

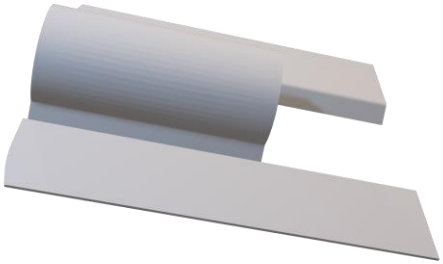
Before the laser welding, the beam screen have to be prepared with position clamps & protection parts in order to avoid any pollution.

STEP 6

Cold test of the beam screen at liquid Nitrogen temperature (pressure and leak test).
Preparation and insertion of beam screen as in STEP 3.

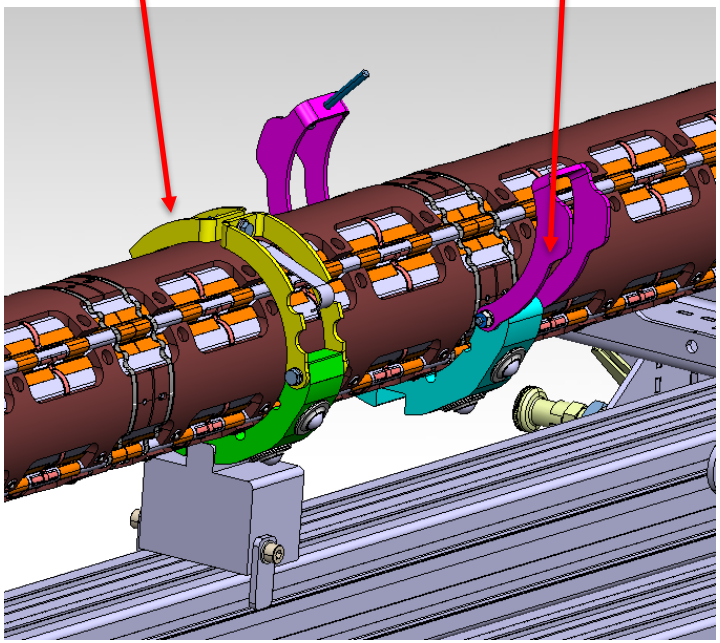
STEP 7

- The beam screen has to be reinstalled on assembly bench for the installation of the Pumping Slot Shields.
- Then, we have to do the assembly of the mounting rings because the diameter of aC coating chamber is different.
- Beam screen insertion into the aC coating chamber with the insertion bench.



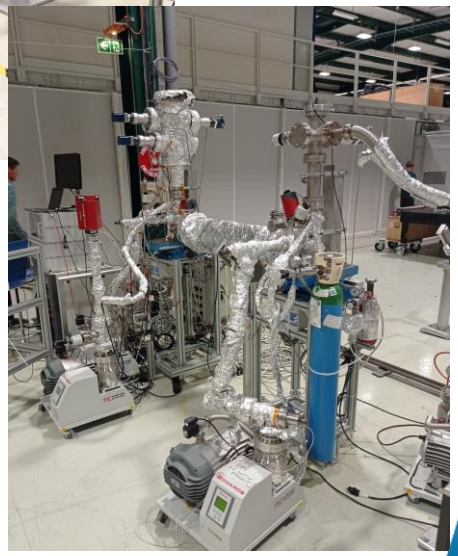
Mounting ring for Cold Test Bench
Ø190

Mounting ring for Ac Coating
Ø200



STEP 8

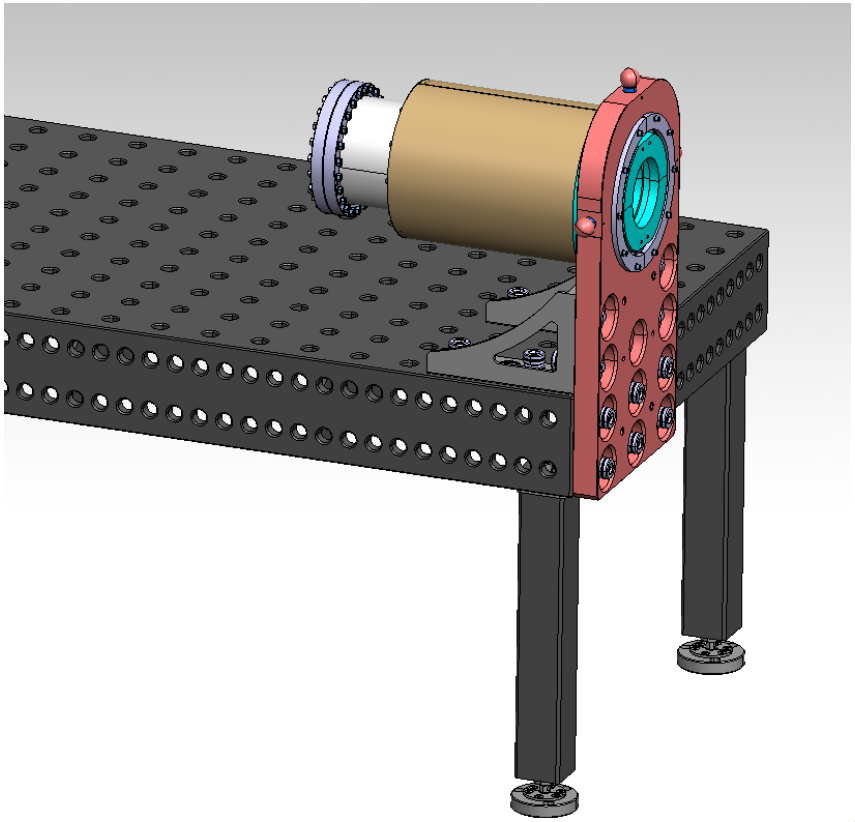
Ac coating done by VSC/SCC.
Facility under finalization but already operational.
Supports designed and produced by VSC/DLM.



STEP 9

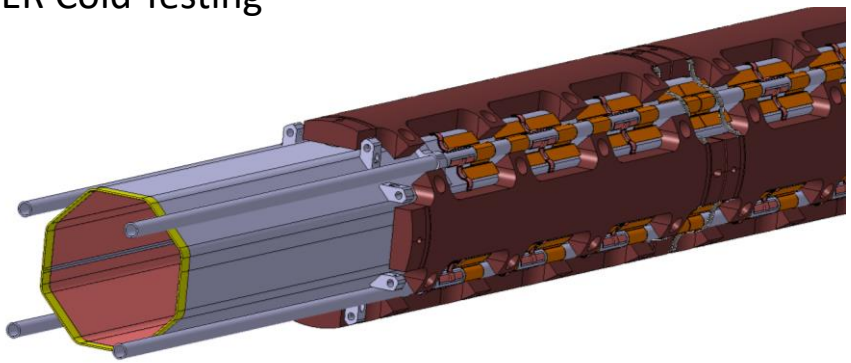
To limit the movement of beam screen and to facilitate the accessibility during the assembly and control phases, we developed a bench for:

- The bending of cooling tubes (fixed side)
- The assembly of fixed side and the metrological measurement
- The leak testing

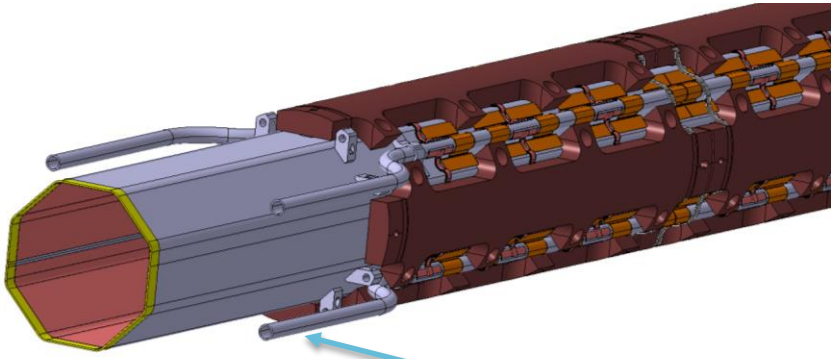


STEP 9

Beam Screen AFTER Cold Testing



Beam Screen AFTER bending of cooling tubes

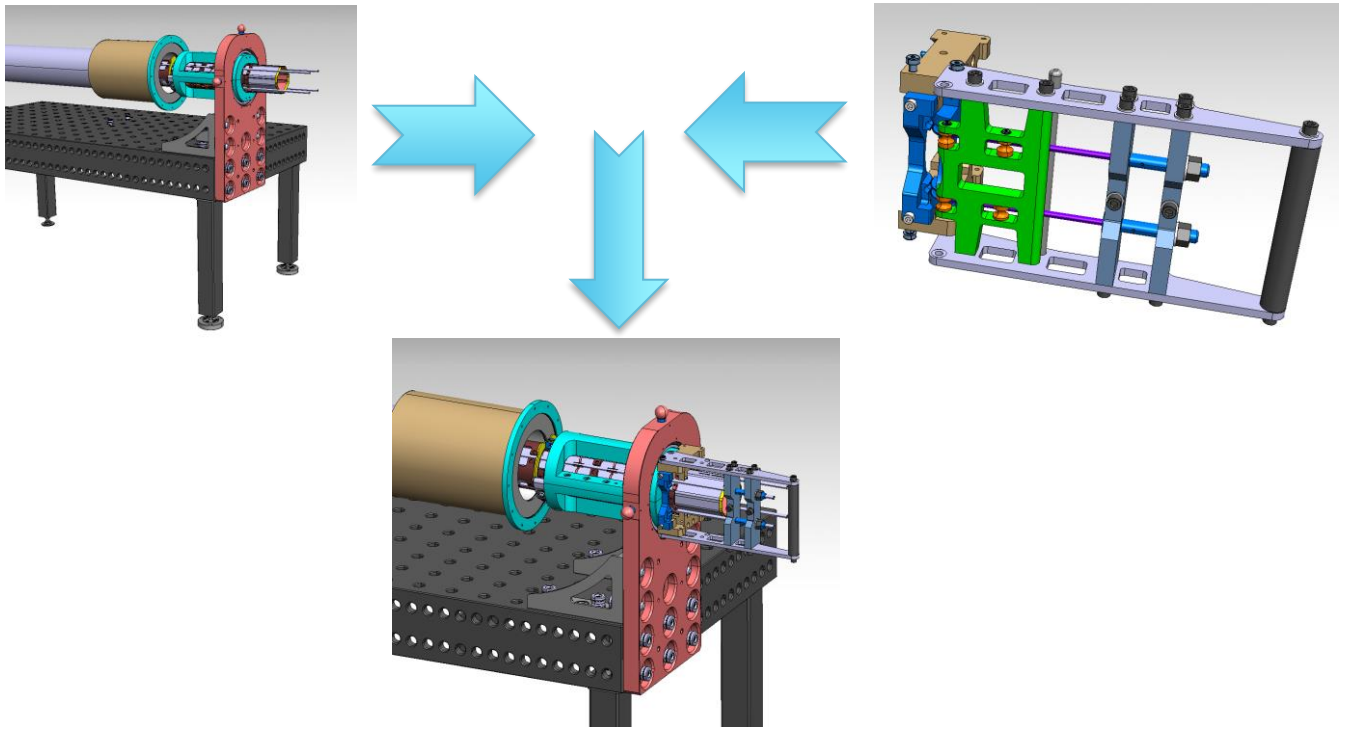


Cooling tubes Ø10mm

STEP 9

Installation of the beam screen on the bench:

- Use gloves for the manutention of the beam screen and all parts.
- Installation of the beam screen with its storage tube on the bench (length 14m). Fixation with a tooling designed as a cold bore flange.

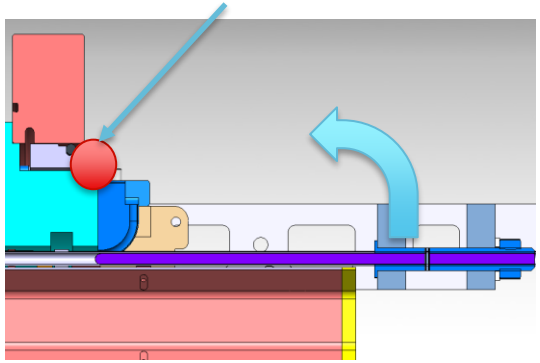


STEP 9

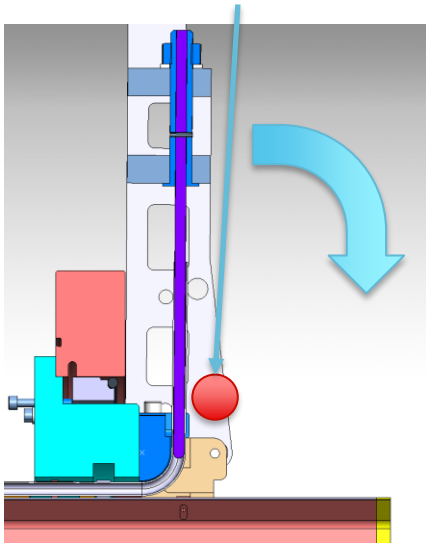
Description of bending process:

- No conventional tooling can be used for the bending of cooling tubes.
- Development of specific tooling (VSC/DLM).
- The principle is to insert a steel finger (90MnCrV8) into the cooling tube and rotate it in relation to the center of the radius of curvature.
- This principle ensures that the final position of the tube is very precise, and that the circularity is preserved.

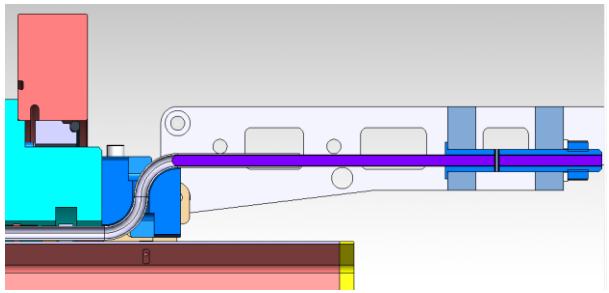
1st axis of arm rotation



2nd axis of arm rotation

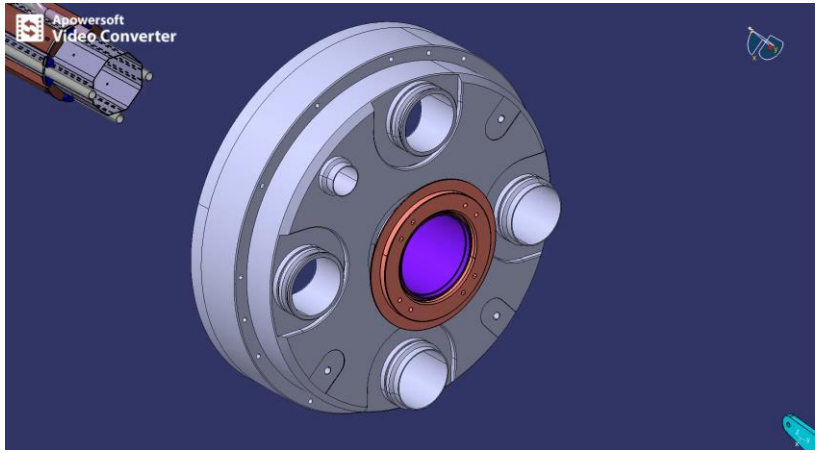


End of bending



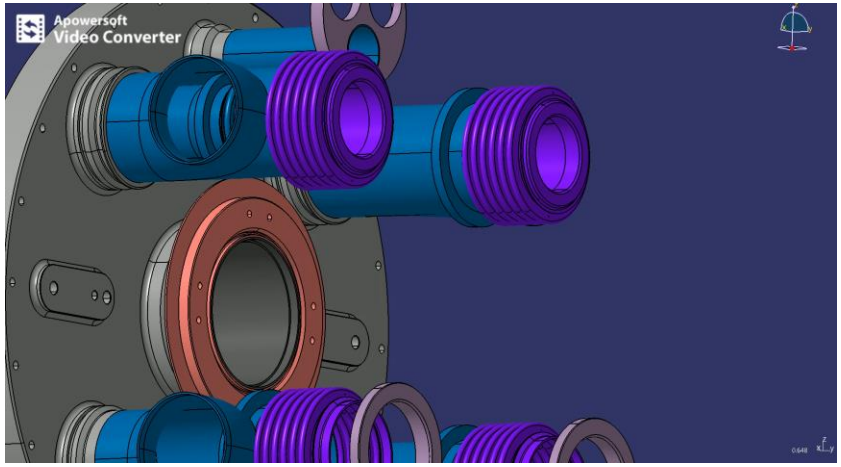
1st prototype to validate the principle

STEP 9



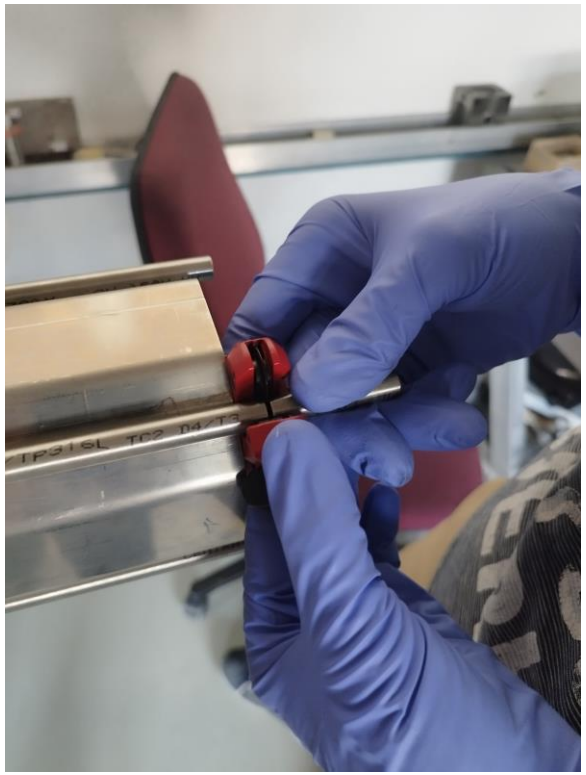
1st version of bending principle

2nd version of bending principle

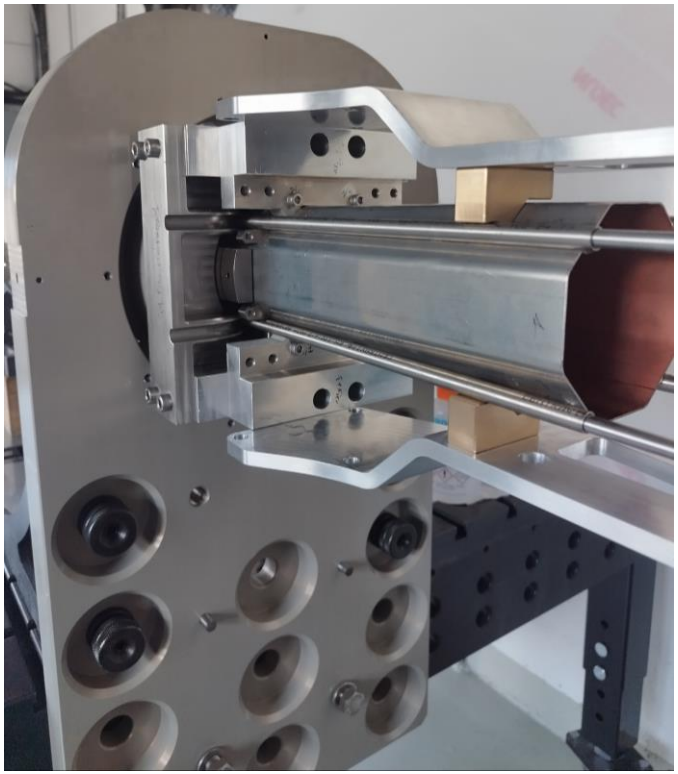


STEP 9

Cutting of the 4x cooling tubes



Installation of the parts for the 1st bending



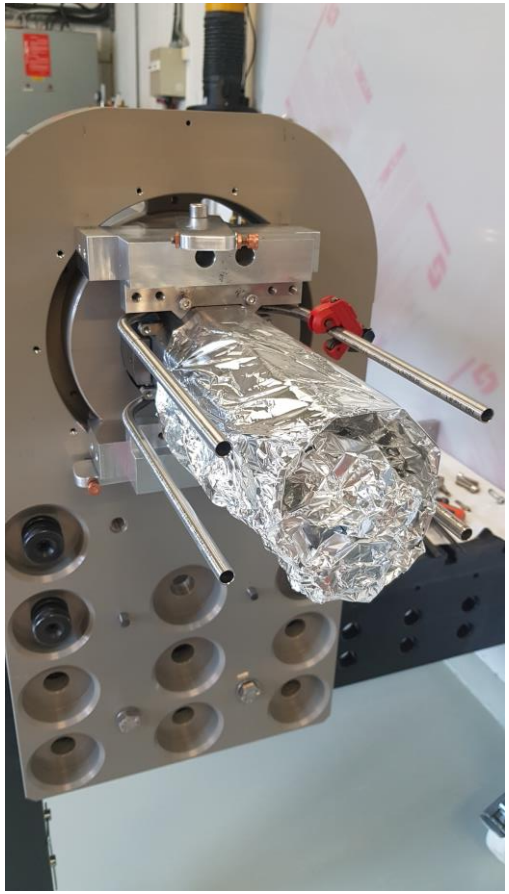
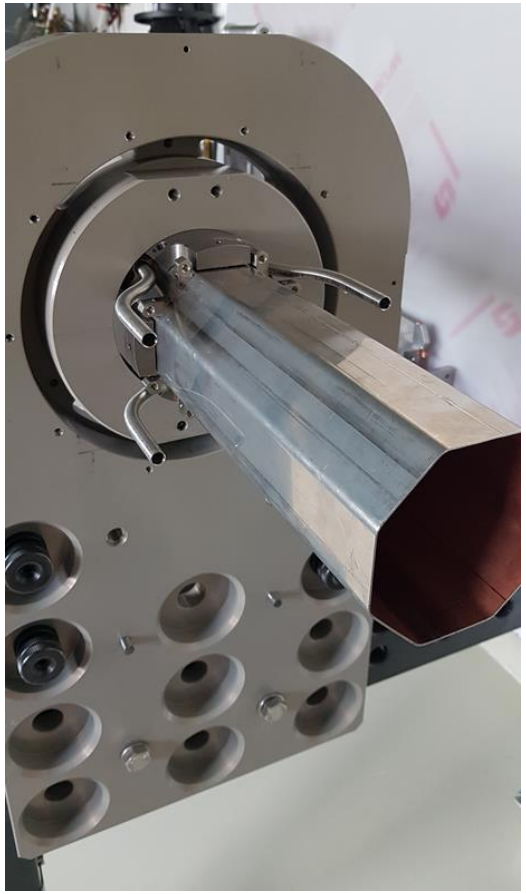
STEP 9

Installation of the parts for the 2nd bending

Video of the bending process

STEP 9

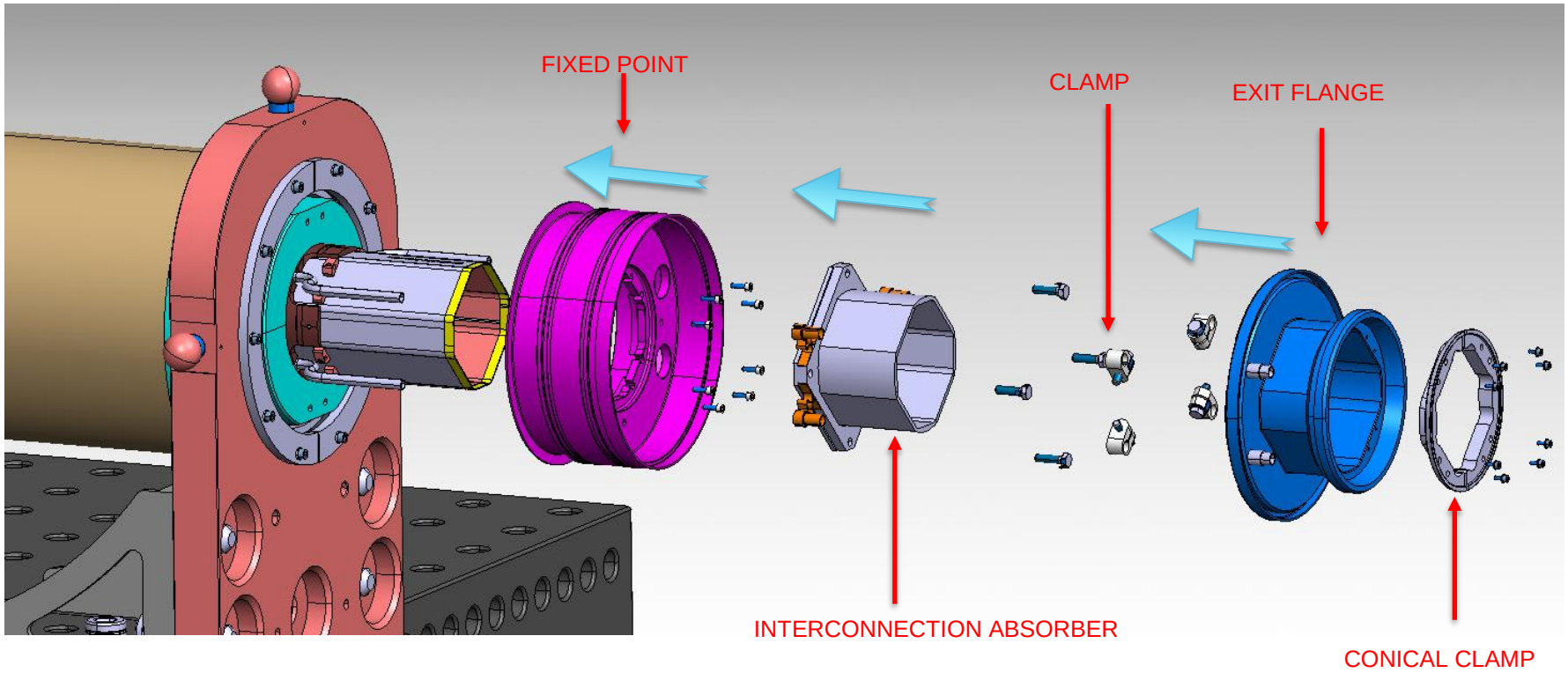
- Dimension control and marking of cooling tubes
- Final cutting of cooling tubes

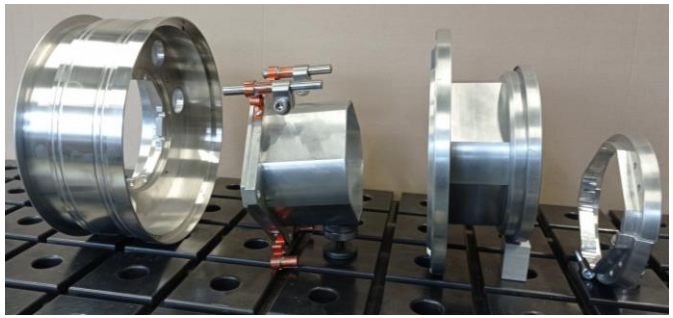




Procedure EDMS 2958267

STEP 9

Assembly of the fixed point (Q2 type)

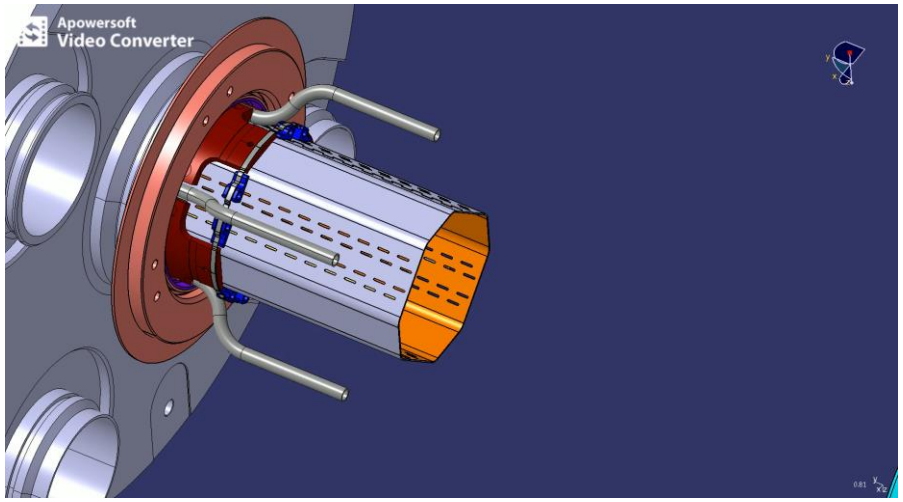




Fitting the fix point parts

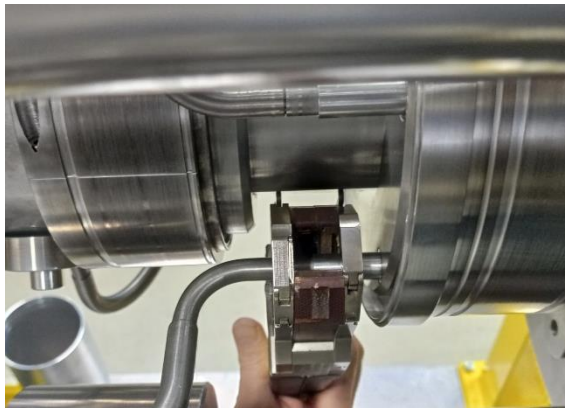
• - Q2 TYPE FIXED POINT	LHCVSMSI0006
• - INTERCONNECTION ABSORBER	LHCVSMSI0036
• - 4x CLAMP	LHCVSMSI0007
• - EXIT FLANGE	LHCVSMSI0095
• - 2x CONICAL CLAMP	LHCVSMSI0029

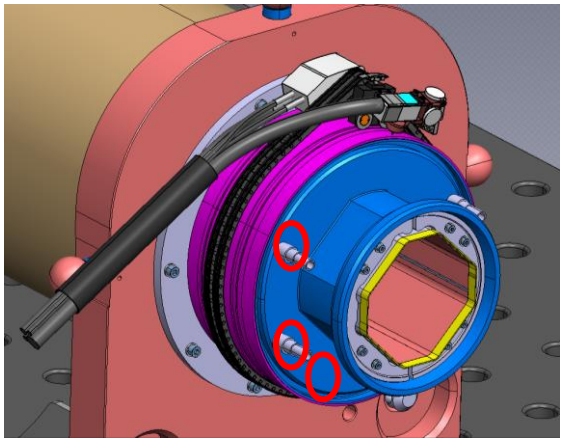
STEP 9

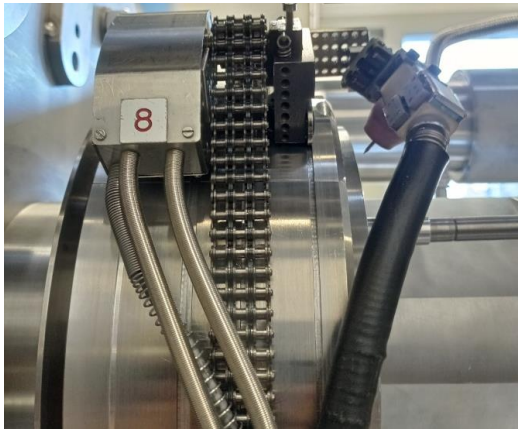


Overview of assembly kinematics

These two parts are welded together using an orbital welding machine, as well as cooling tube passages.



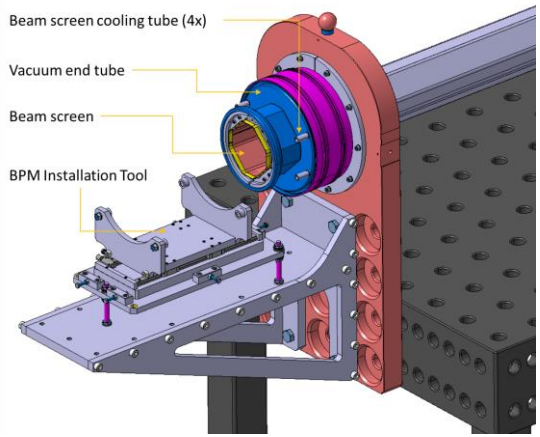


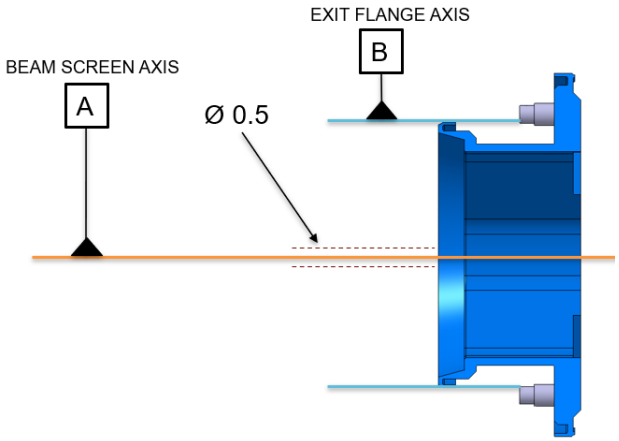


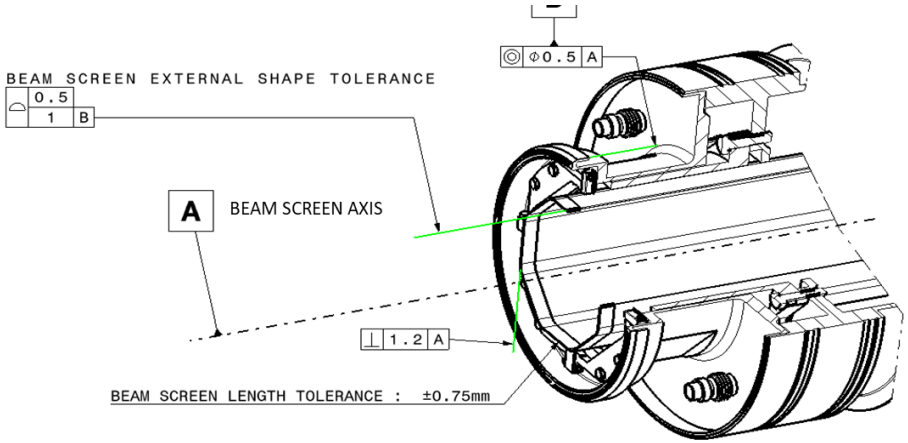
STEP 9

For precise positioning of the BPM, the **SY/BI** team has developed a tool that can be attached to our assembly. They require a positioning accuracy ±0.25 mm W.R.T the beam axis.

EDMS 2105453





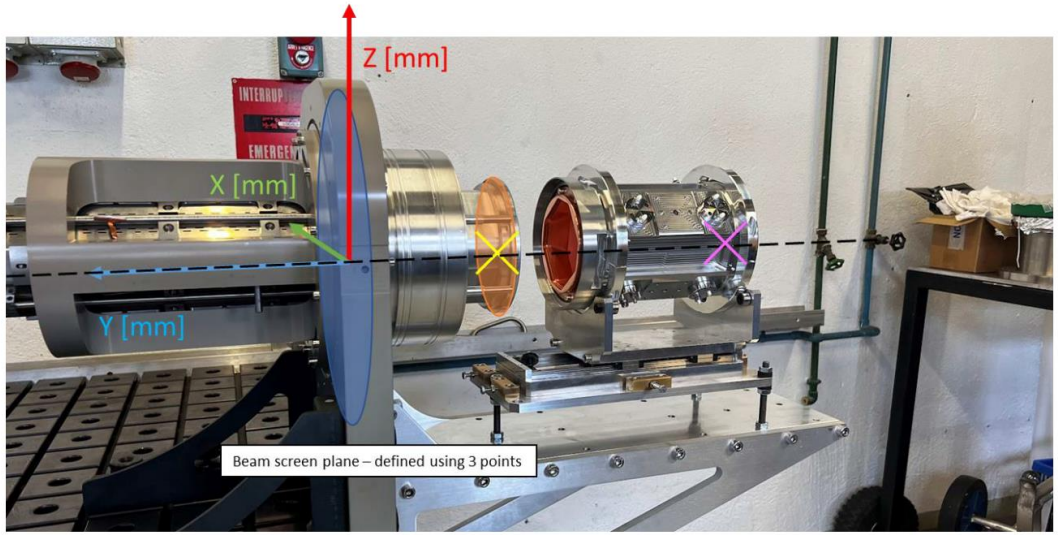


STEP 9

Measurement description

Reference frame was constructed as follows:

- Origin: centre of the beam screen circle
- Z-axis: normal to the gravity
- Y-axis: normal to the beam screen plane
- X-axis: perpendicular to the other axes



During our first installation, the survey team B. Descarques and K. Widuch found maximum alignment differences of 0.1 millimetre and 0.05mrad.

Welding tests and deformation measurements were carried out by M. Morrone and H. Kos to define a spot-welding range to compensate for possible misalignments.

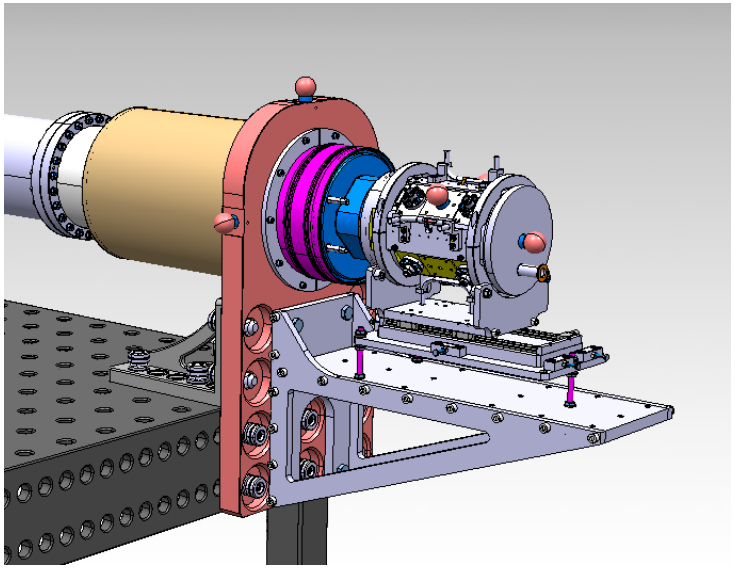
EDMS 2959040

Results:

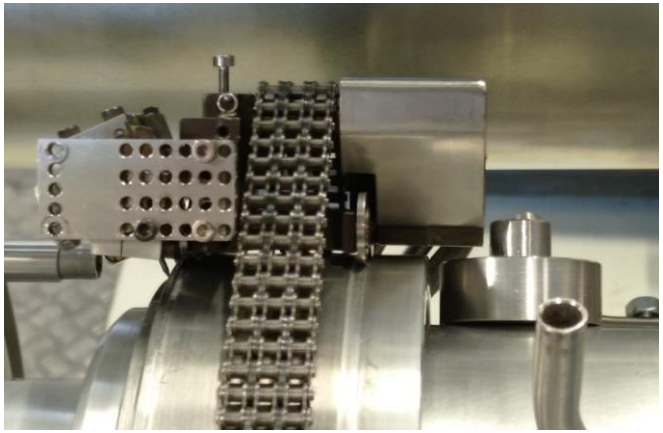
Alignment	X [mm]	Y [mm]	Z [mm]
Centre of BPM flange (yellow cross)	**0.06**	**-210.28**	**0.10**
Centre of BPM external flange (pink cross)	**<0.01**	**-**	**<0.01**

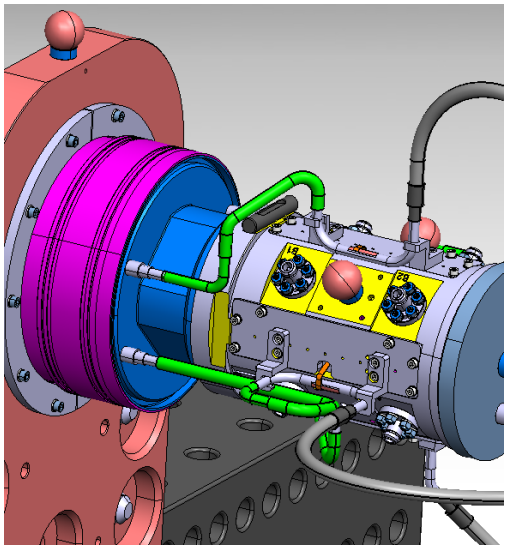
Roll difference between beam screen and the BPM on the alignment table: **0.05 mrad**

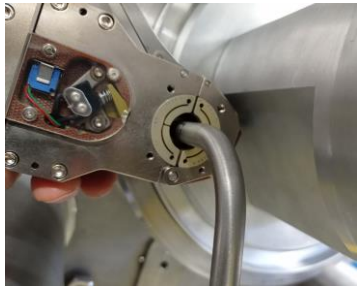
STEP 9



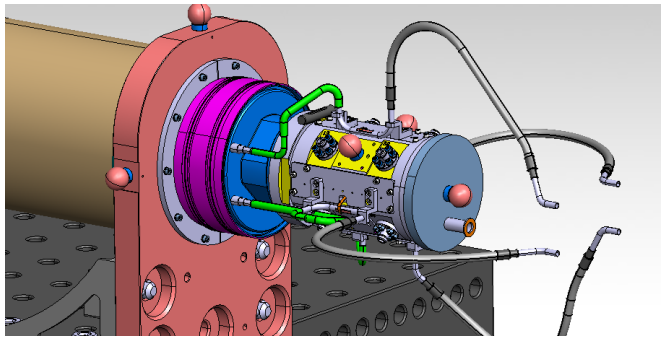
After installation, the BPM is welded to the assembly using an orbital machine.







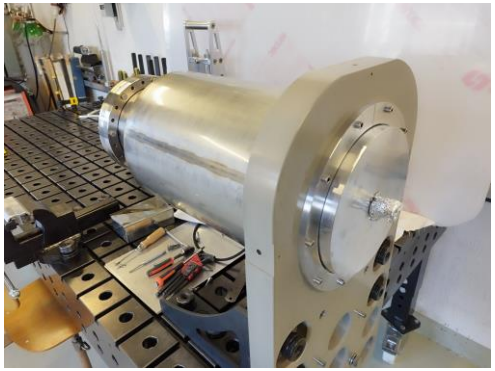
The cooling tubes are welded using a GTAW MODEL 9 675 orbital welding machine.



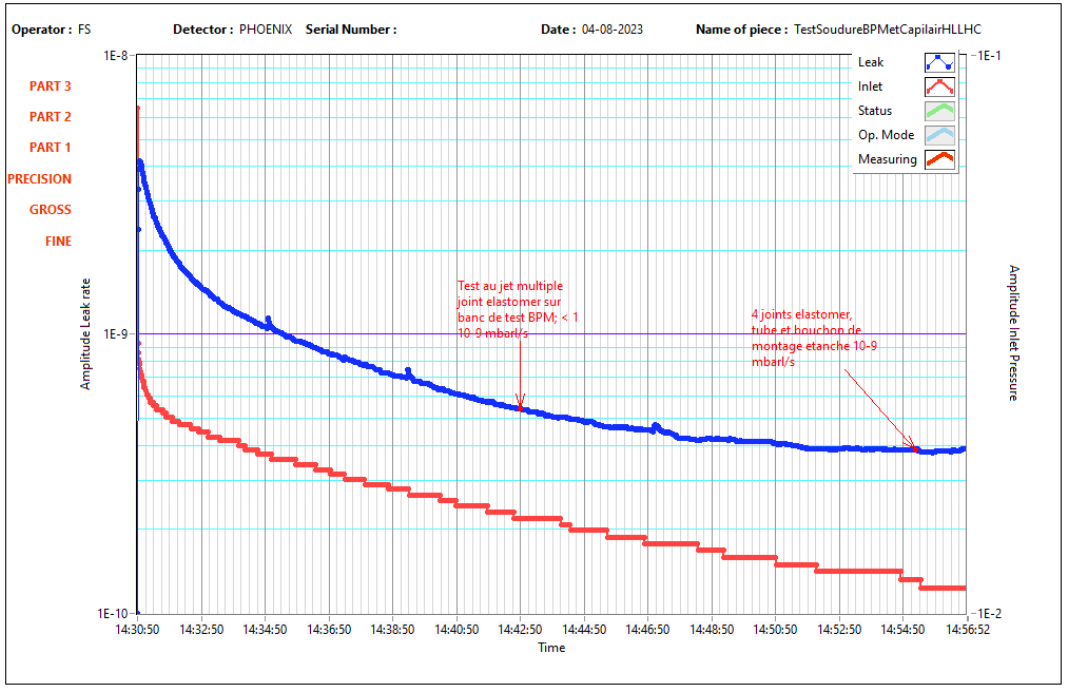
STEP 9

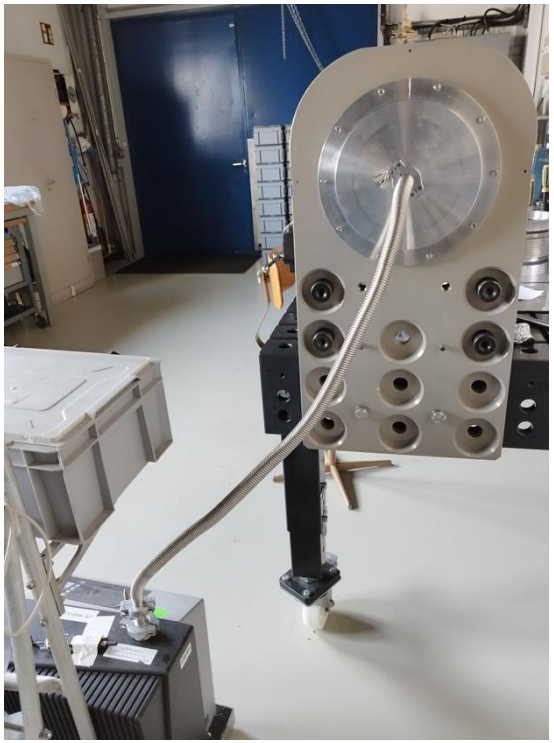
Leak tests have not yet been carried out.

Leak detection tools are available and tested with Willemjan Maan.



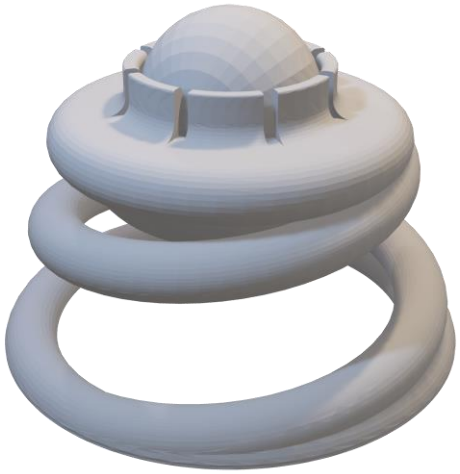
Tooling leak rate results





STEP 10

Conical spring and ball assembly.



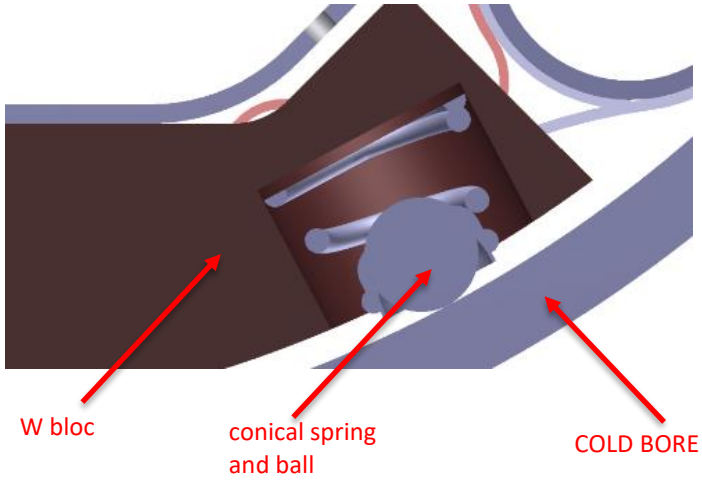
Inserting the beam screen into the magnet.

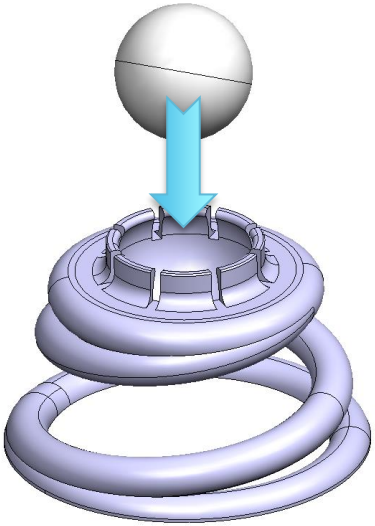
STEP 10

The conical spring and ball assembly for Q1 and Q2 types is designed to:

- Centre the screen in the cold bore.
- Limit heat transfer to the cold bore, as the ball is made of ceramic.
- Transfer forces evenly during a magnet quench.

Drawings LHCVSMSH0006 and LHCVSMSL0005 for Q1 and Q2 type





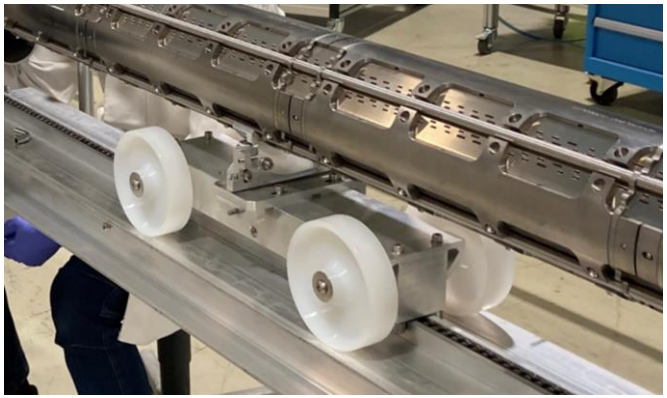
Conical springs and balls are supplied unassembled. We have created an assembly tool.

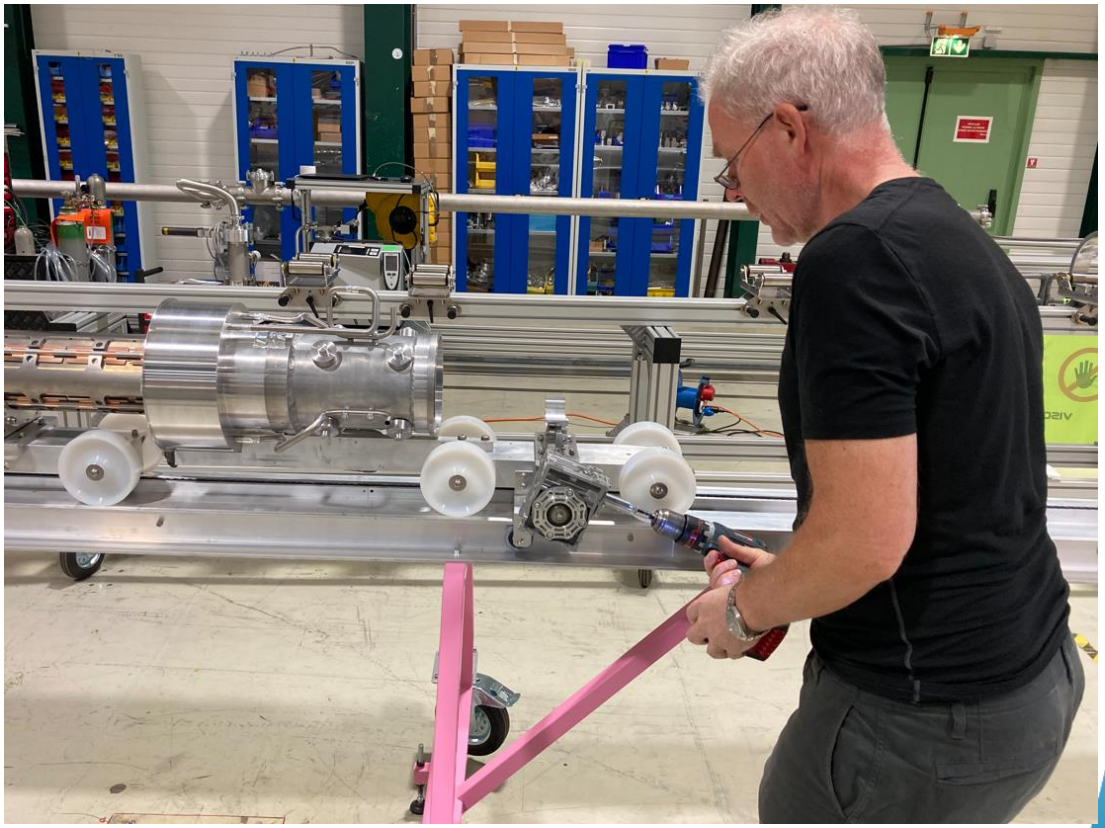
9000 sets for type Q2
2000 sets for Q1

STEP 10

Inserting the beam screen into the magnet:

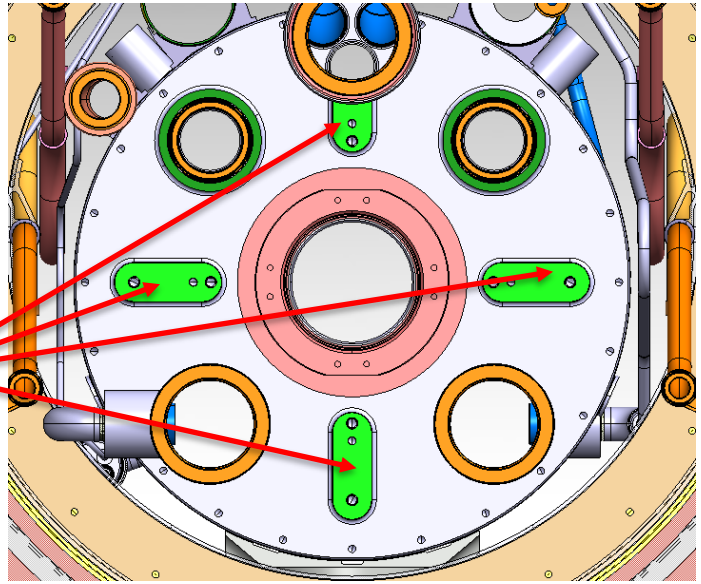
We use the same tooling as for the cold test bench to insert the beam screen with the addition of a drive carriage.

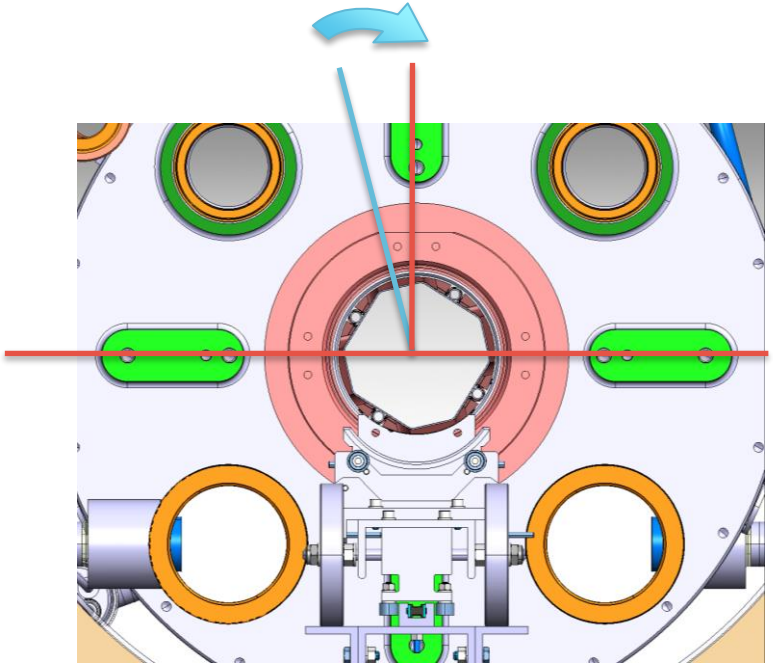




STEP 10

- The positioning of the bench w.r.t the magnet is very important, so it is indexed to the references of the cold mass and cover.

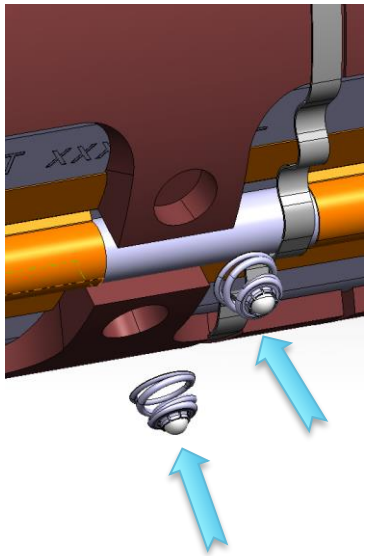


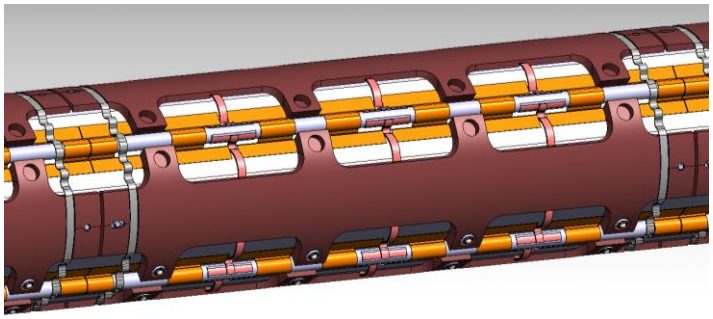


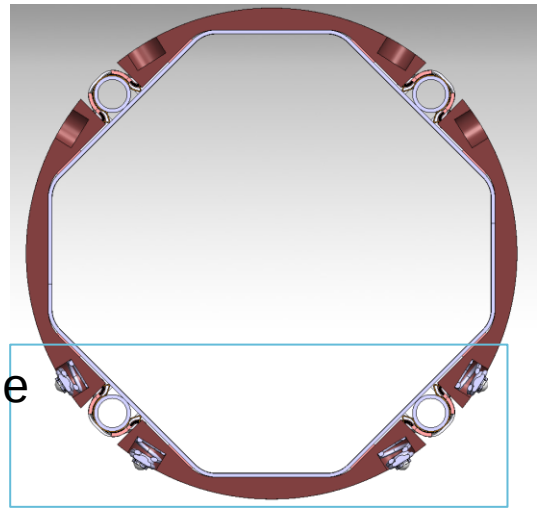
- The angular orientation of the beam screen on the bench is also very important.
- A tooling is required to perform this task.

STEP 10

Prior to insertion, the conical spring and ball assemblies must be fitted.

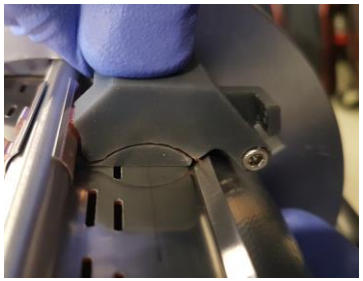


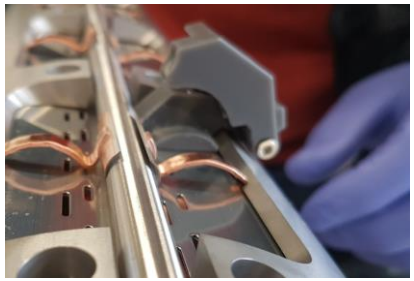


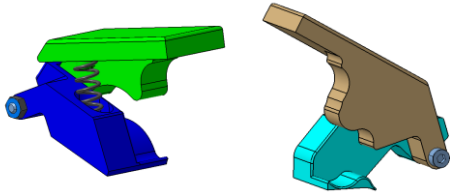


Only on the bottom half of the beam screen.

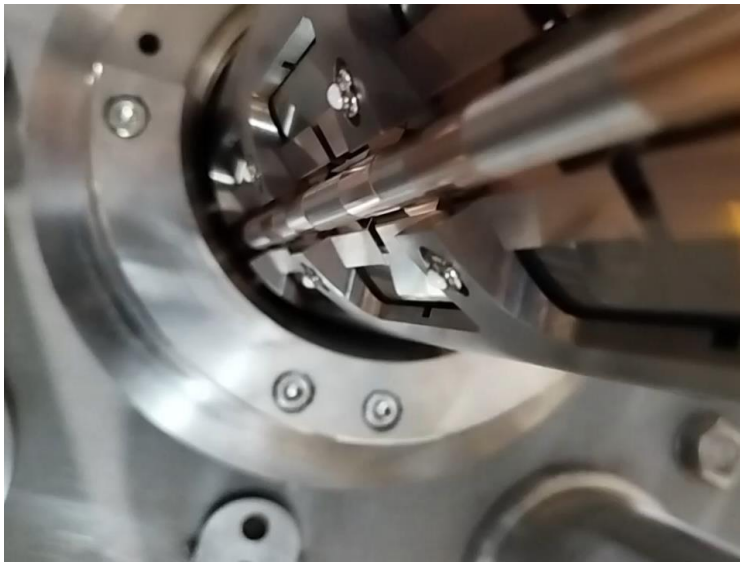
Re-check the shape of each thermal link on the W block and re-form them if need using the tools supplied. For your information, the first check of the thermal links should be done during the pumping slot shields assembly.





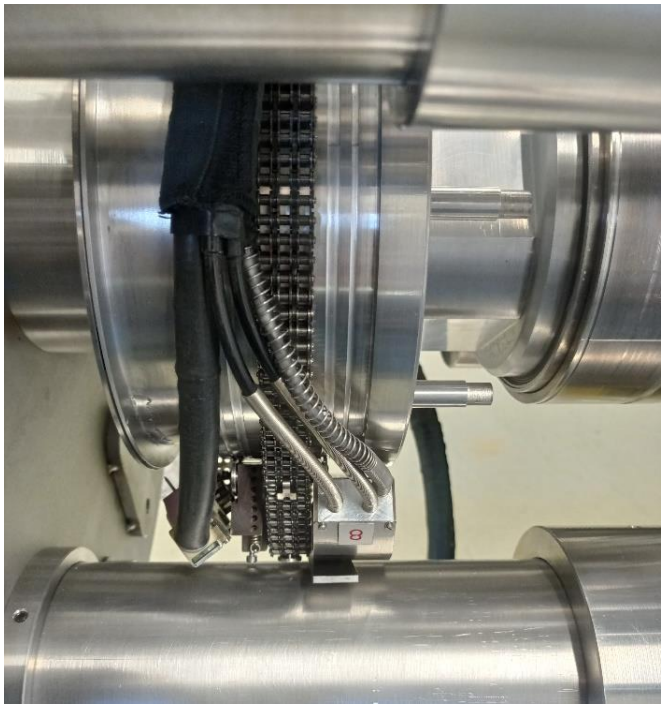


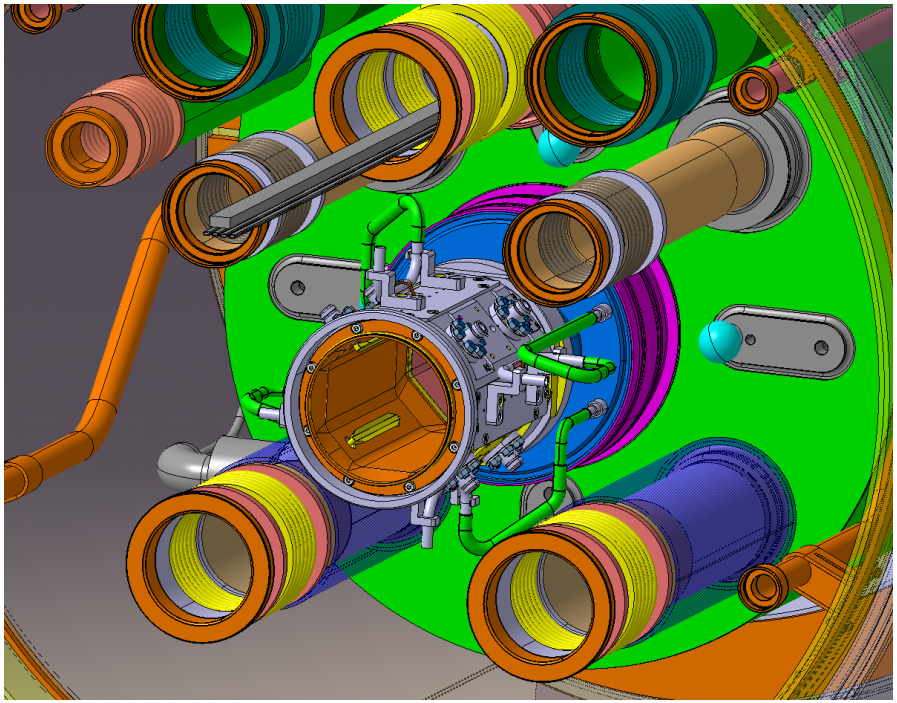
STEP 10



STEP 10

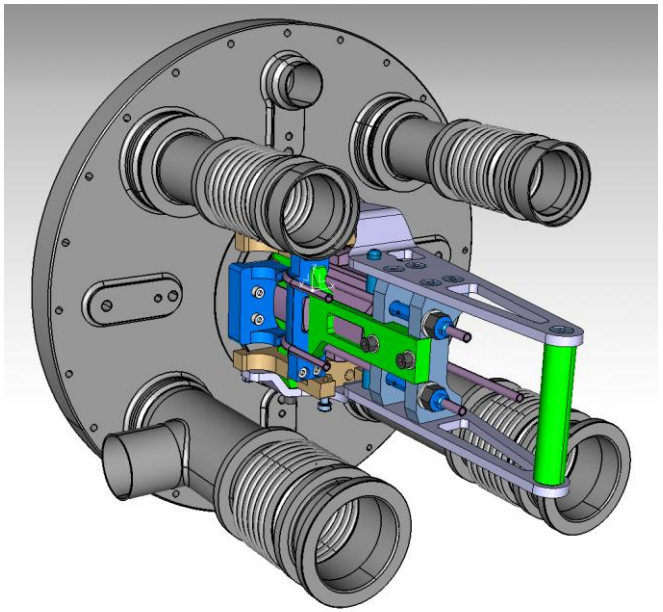
Once the BPM has been validated by the SY/BI, the assembly on the fix point is welded using an orbital machine.



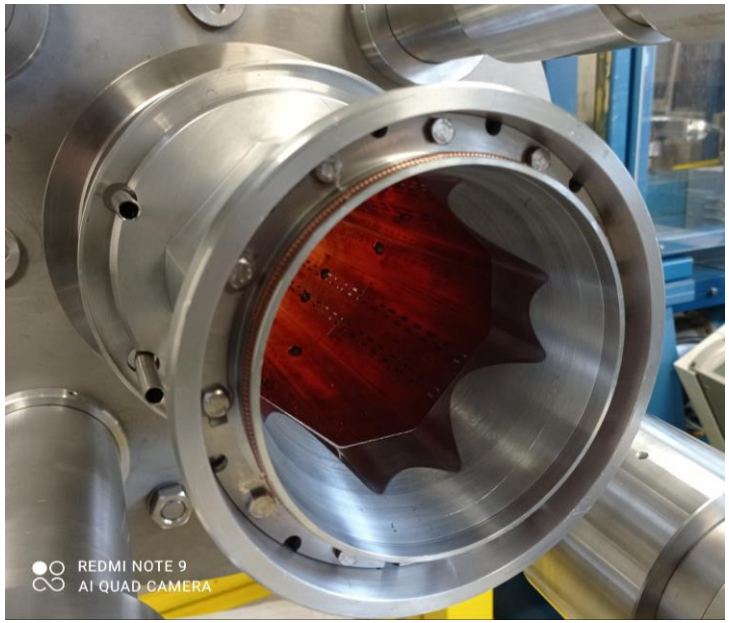


STEP 11

Bending the cooling tubes on the sliding side



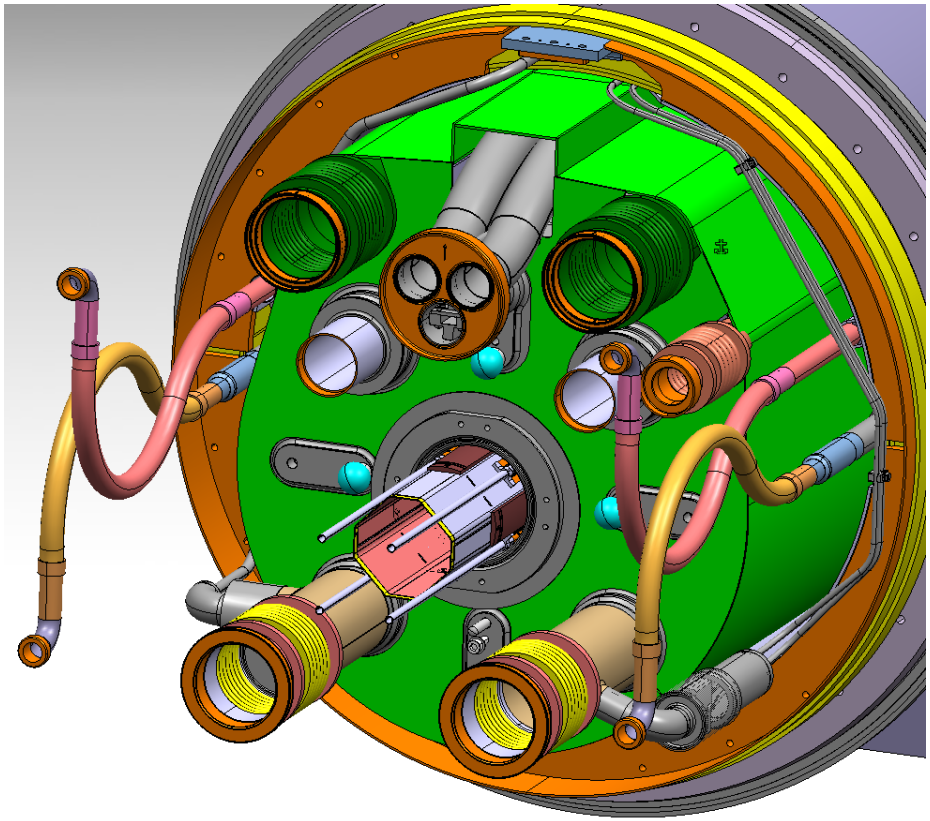
Assembly of the sliding point

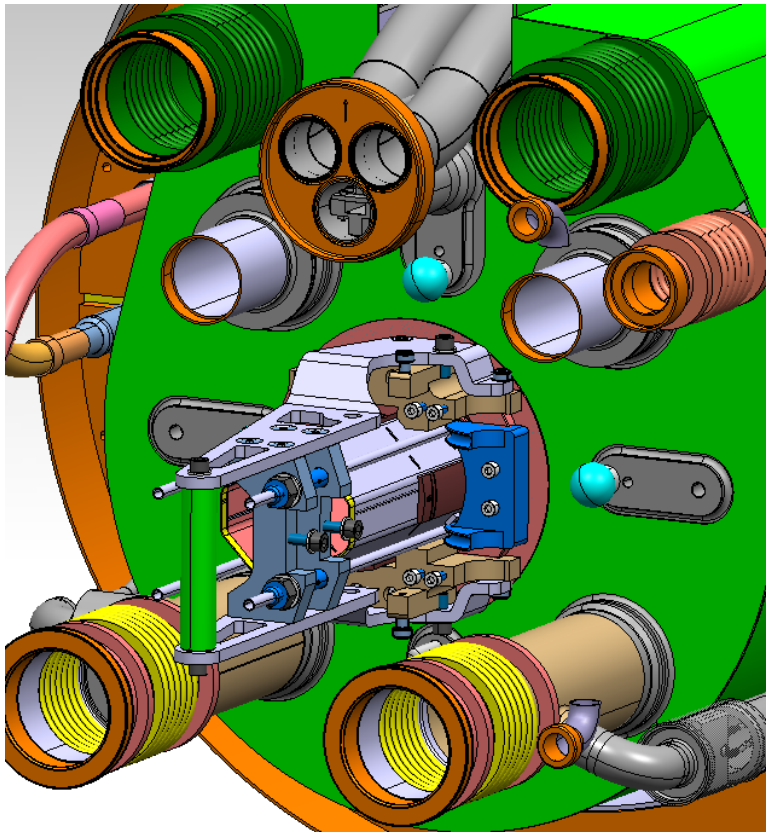


STEP 11

Bending the cooling tubes on the sliding side

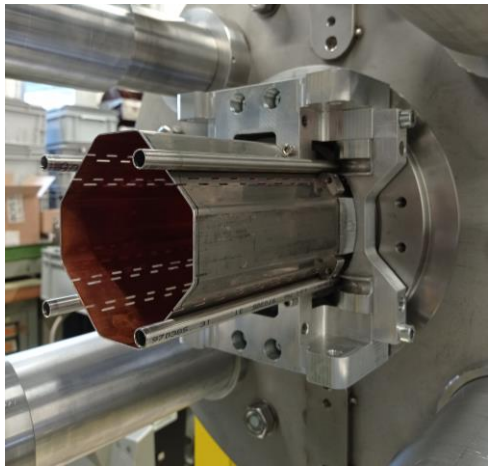
- Same principle as for the fixed point
- Much more constrained environment





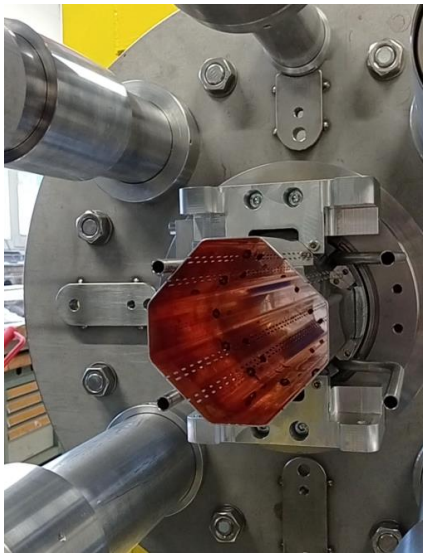
STEP 11

1. Cutting the 4x cooling tubes



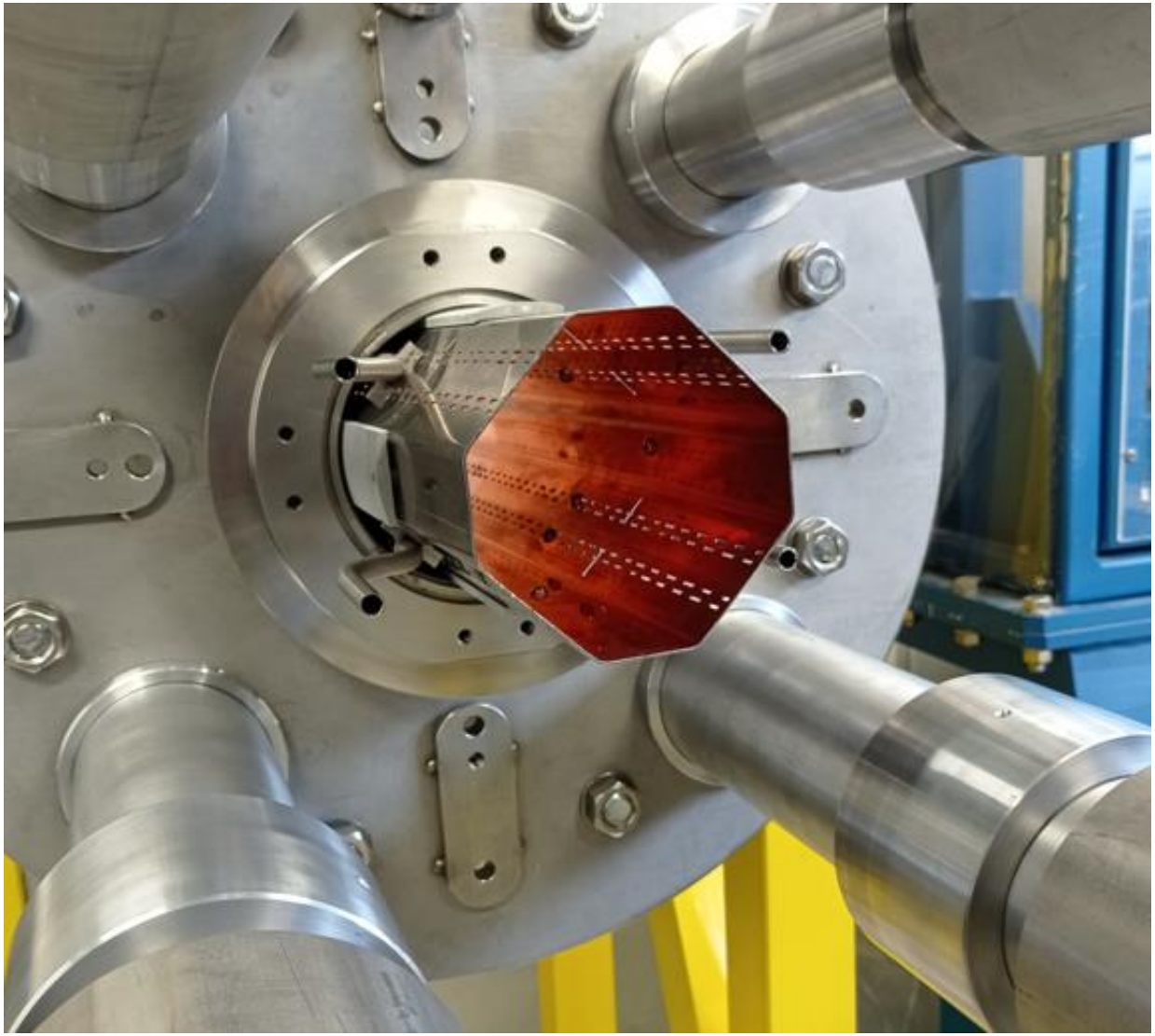
2. 1st bending

3. 2nd bending



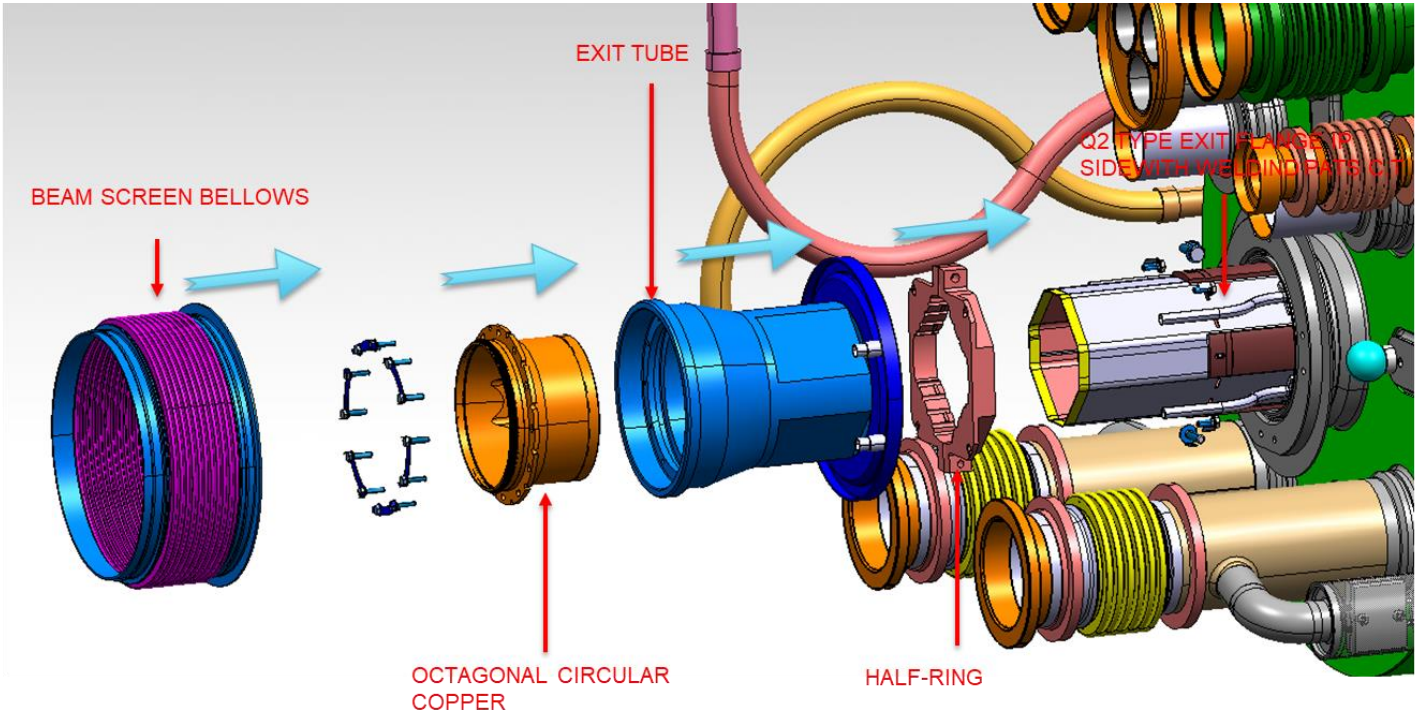
4. Dimensional control, tracing and cutting of cooling tubes

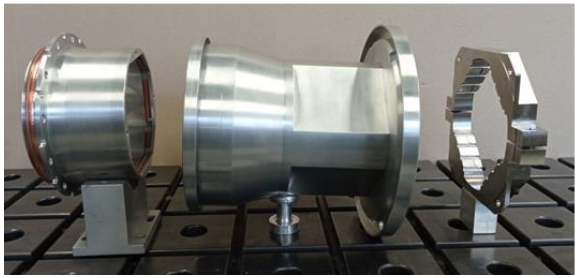
STEP 11



STEP 11

Assembly of the sliding point (Q2 type)



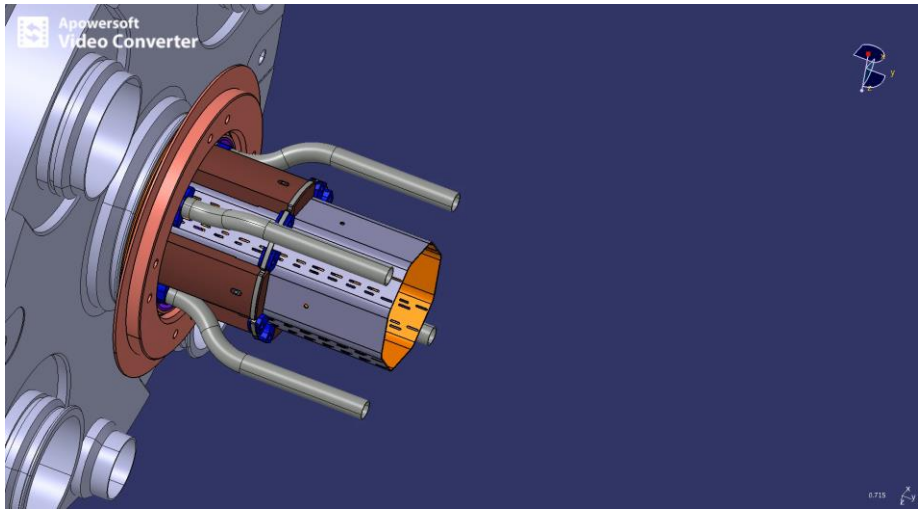


Fitting the moving point parts

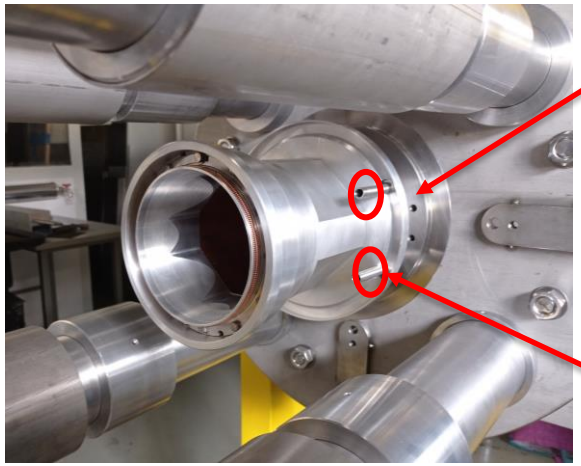
- BEAM SCREEN BELLOWS	LHCVBUTIA0001
- OCTAGONAL CIRCULAR COPPER	LHCVSMSI0015
- EXIT TUBE	LHCVSMSI0047
- 2x HALF-RING	LHCVSMSI0025

STEP 11

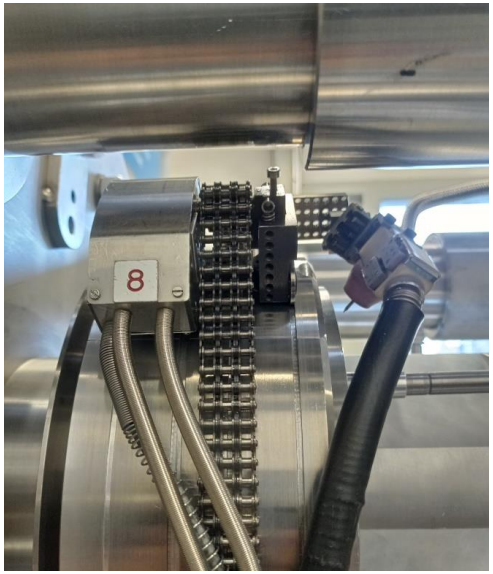
Assembly of the mobile point



Overview of assembly kinematics

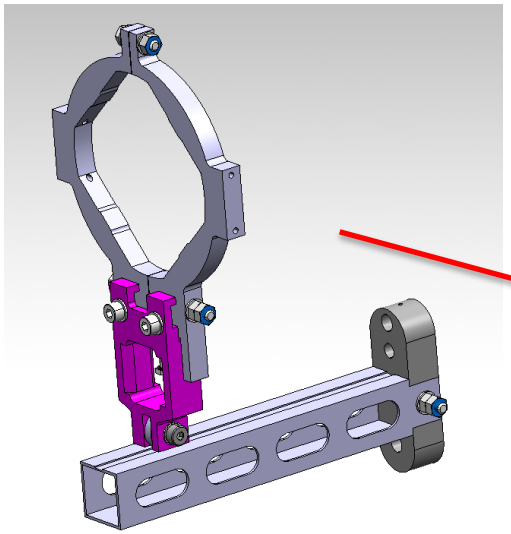


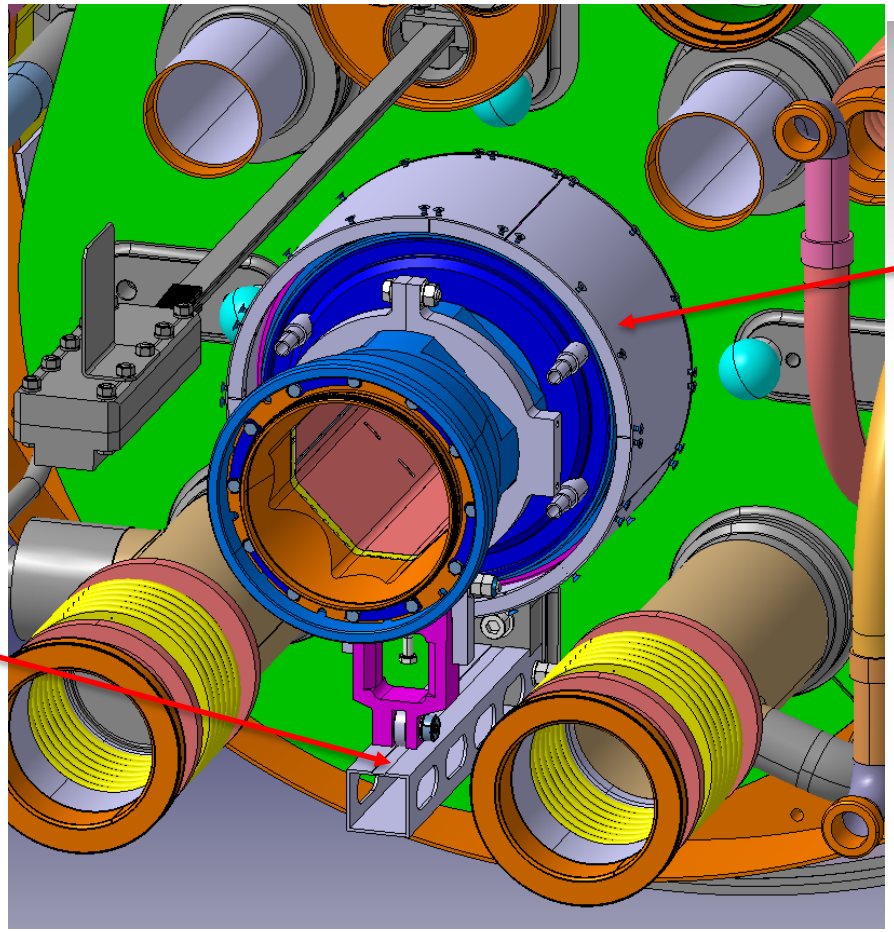
After integration of the bellows, the assembly is welded together using an orbital welding machine as well as cooling tube passages.

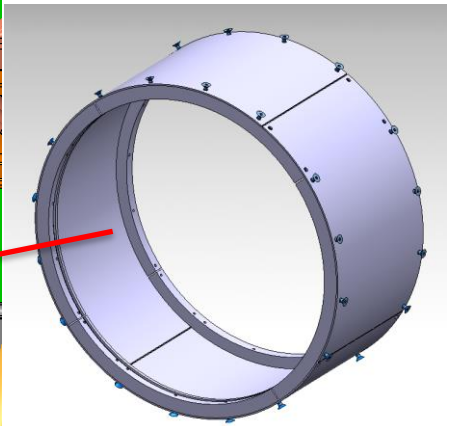


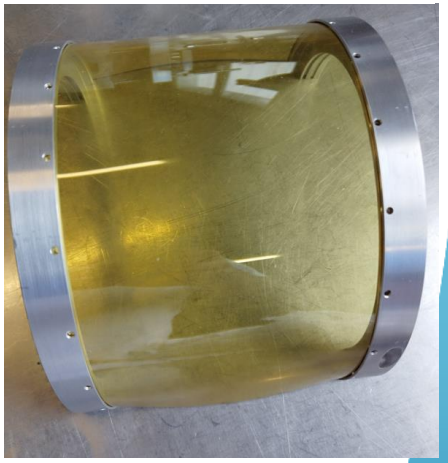
STEP 11

After leak tests, the moving point must be equipped with a sliding support and Ultem® protection.

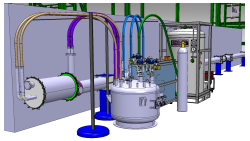






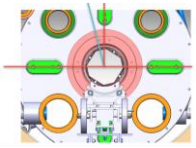


What remains to be done



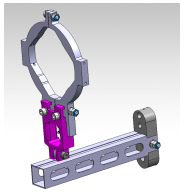
Finish cold test bench (control system)

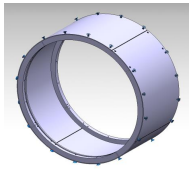
Tools for indexing the beam screen on the insertion bench



Redesign insertion tooling with new cold bore weld sections

Send mobile point support parts to production





Finalize thermoforming tests for Ultem® bellows protection

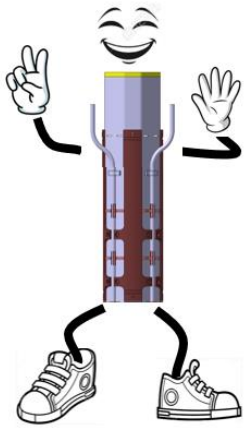
Develop tooling to limit the load transfer on conical spring at the fix point of the beam screen during insertion

Finalize procedures

Finalize magnets assembly drawings

Create interconnection drawings

Thank you for your attention



Thanks to the whole DLM section for support