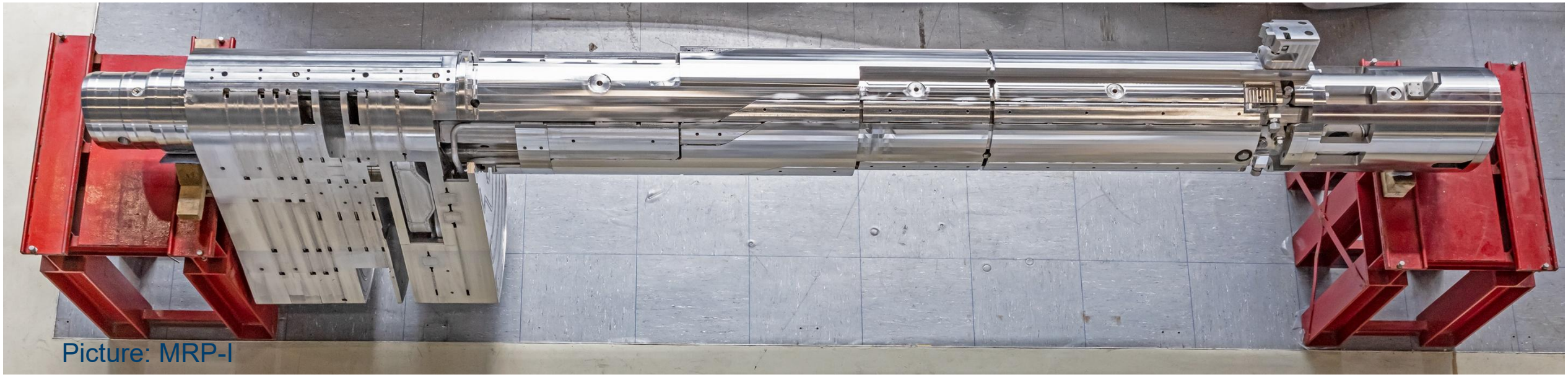


Picture: MRP-I

Status of development and production of second ESS Moderator & Reflector Plug (MRP-II)

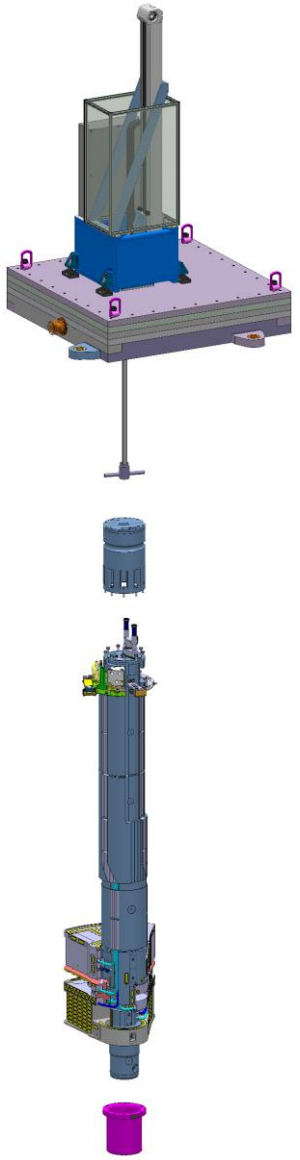
ICANS XXV, Malmö, Sweden

2025-04-15 I Y. BEßLER, C. HAPPE, P. SCHUMACHER, U. PABST, S. SCHÖNEN, J. WOLTERS, G. NATOUR

Mitglied der Helmholtz-Gemeinschaft

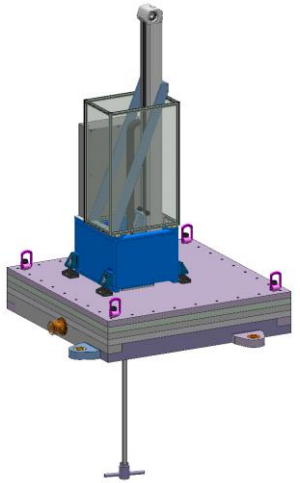
JÜLICH Forschungszentrum

CONTENT



CONTENT

Handling Tool
“Rotation Unit”



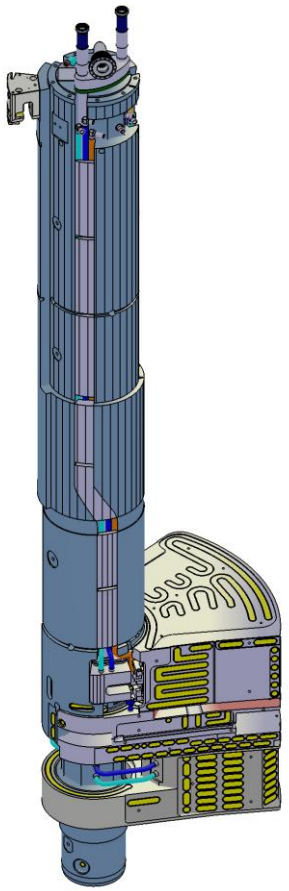
Lifting & rotation
Adapter “Crown”

MRP-II

MRP
“Bucket”

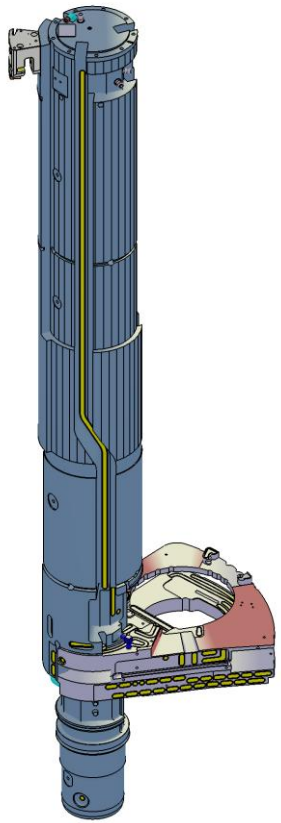
DESIGN SOLUTION MRP-II

Overview



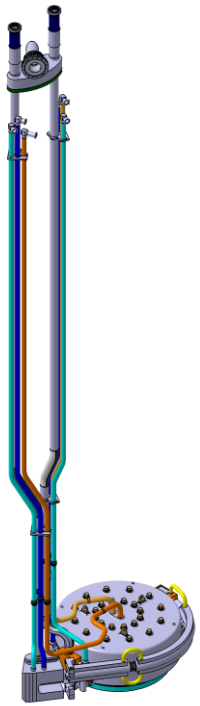
MRP 2

=



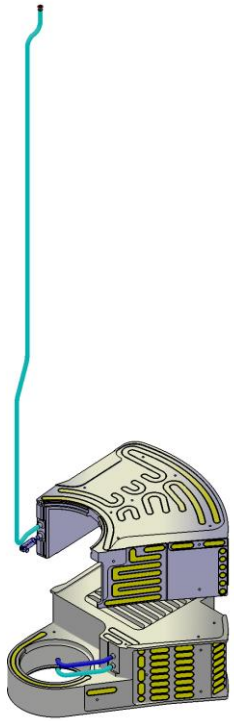
MRP Support Structure

+



Moderator & Reflector Unit

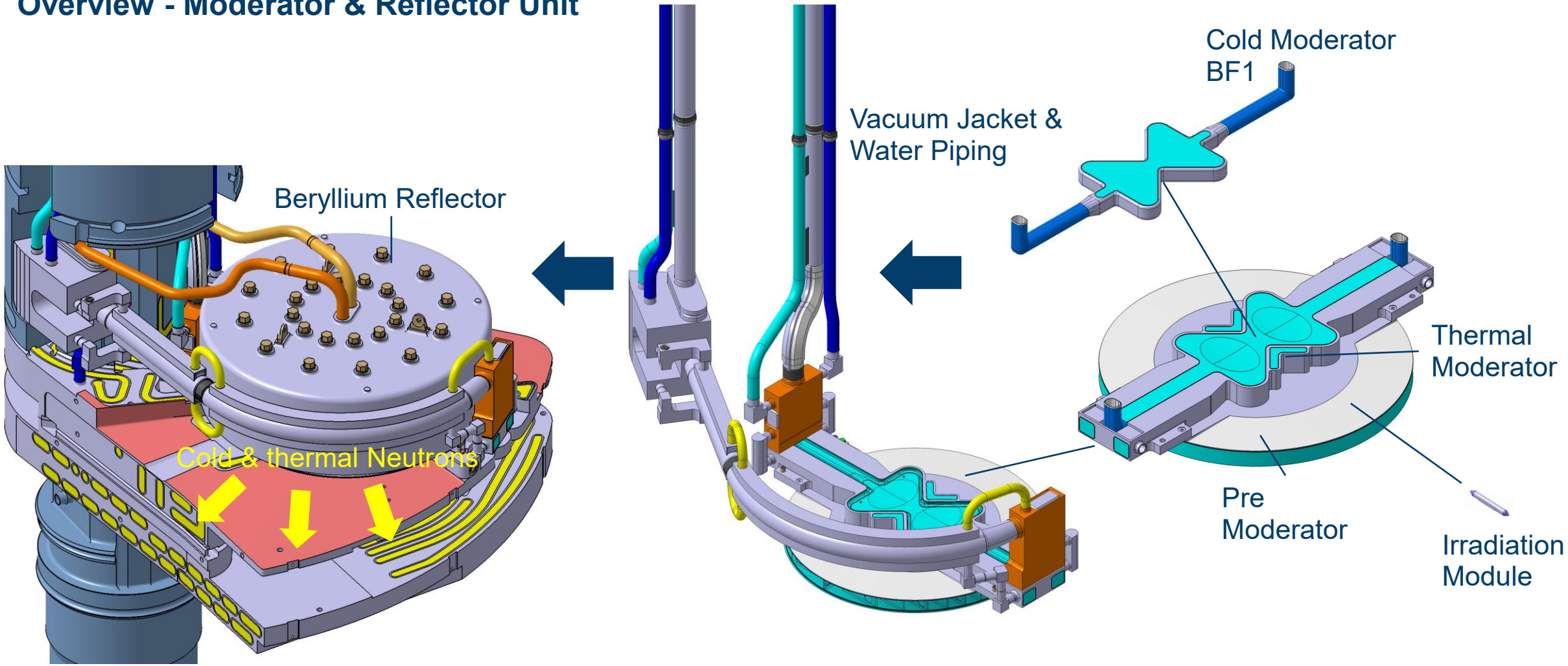
+



Outer Frame / Reflector

DESIGN SOLUTION MRP-II

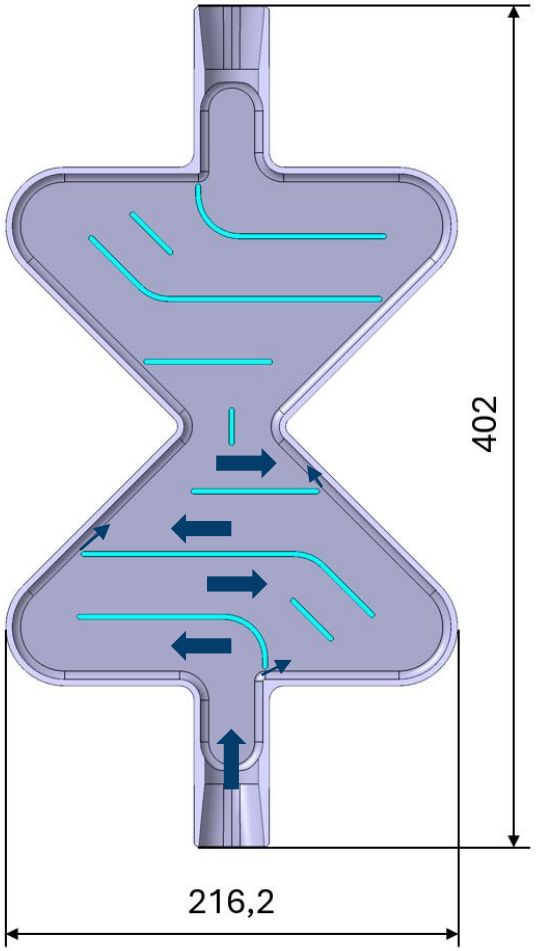
Overview - Moderator & Reflector Unit

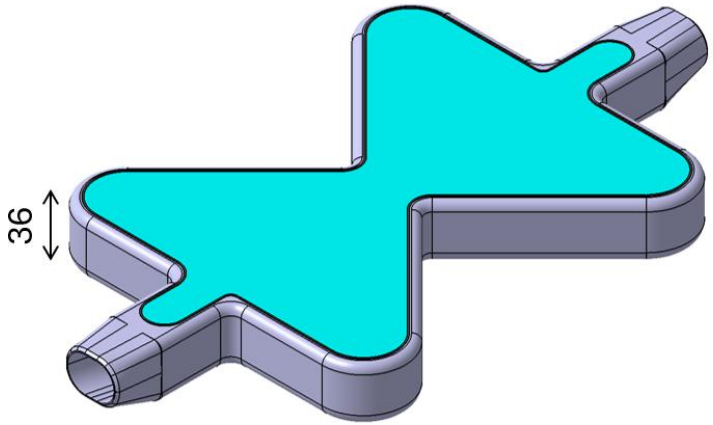


CONTENT

DESIGN SOLUTION MRP-II

Cold Moderator BF1 – Overview





- Pressure vessel made of Al6061 T651
- Electron-Beam (EB) welded with filler material Al4047
- Liquid Hydrogen at an inlet temp. of T_{in} =17.5 K with a temp. increase of dT ≤3 K
- Design pressure 17 bar
- Operating pressure 10 bar
- Heat deposition of ca. 7.1 kW
- m_{Al} = 1.15 kg (without LH_2 inventory)
- V_{LH_2} ~ 1 l
- 3 mm wall thickness

DESIGN SOLUTION MRP-II

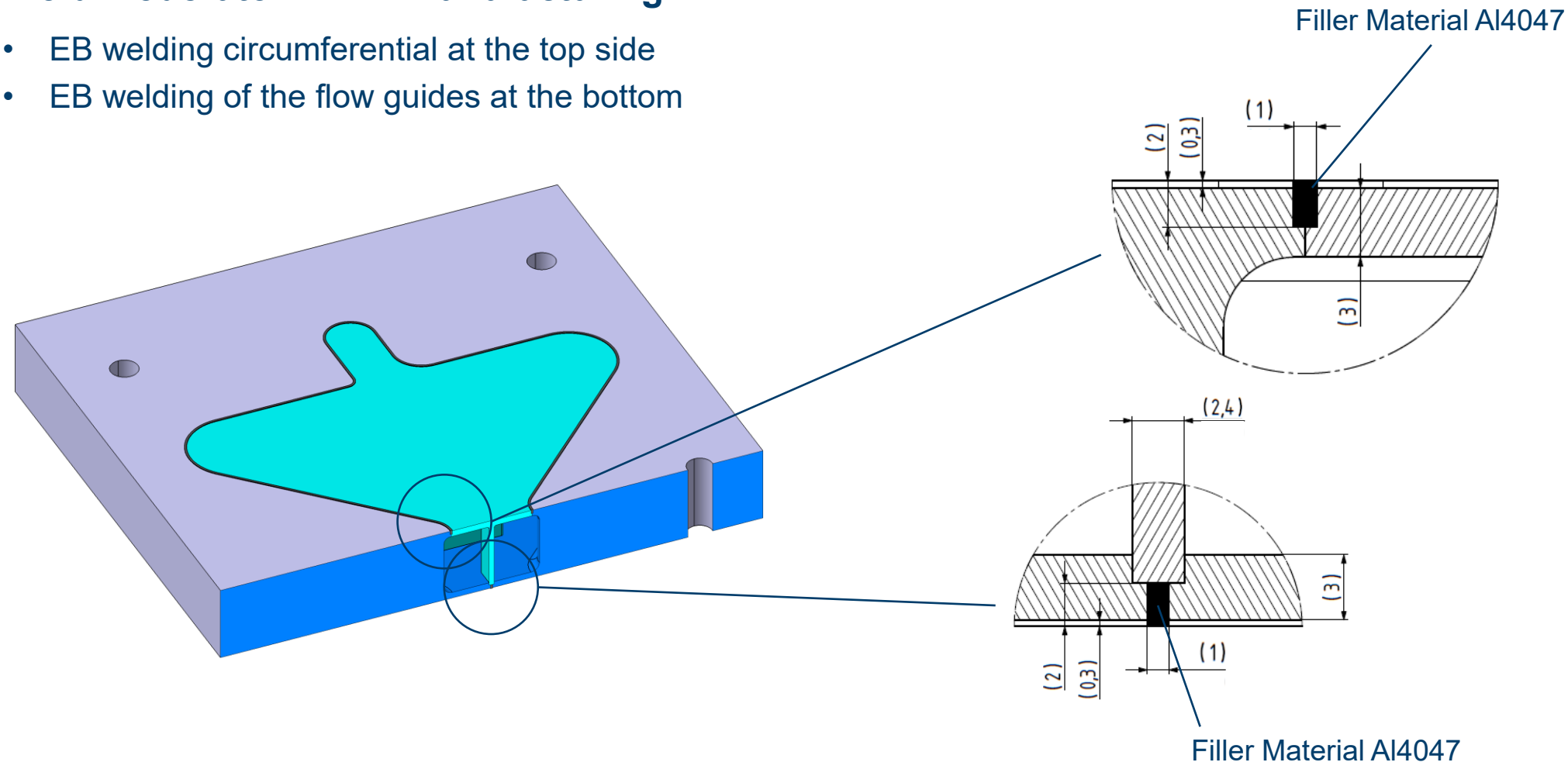
Cold Moderator BF1 – Manufacturing

- Milled from solid block of Al6061 T651

DESIGN SOLUTION MRP-II

Cold Moderator BF1 – Manufacturing

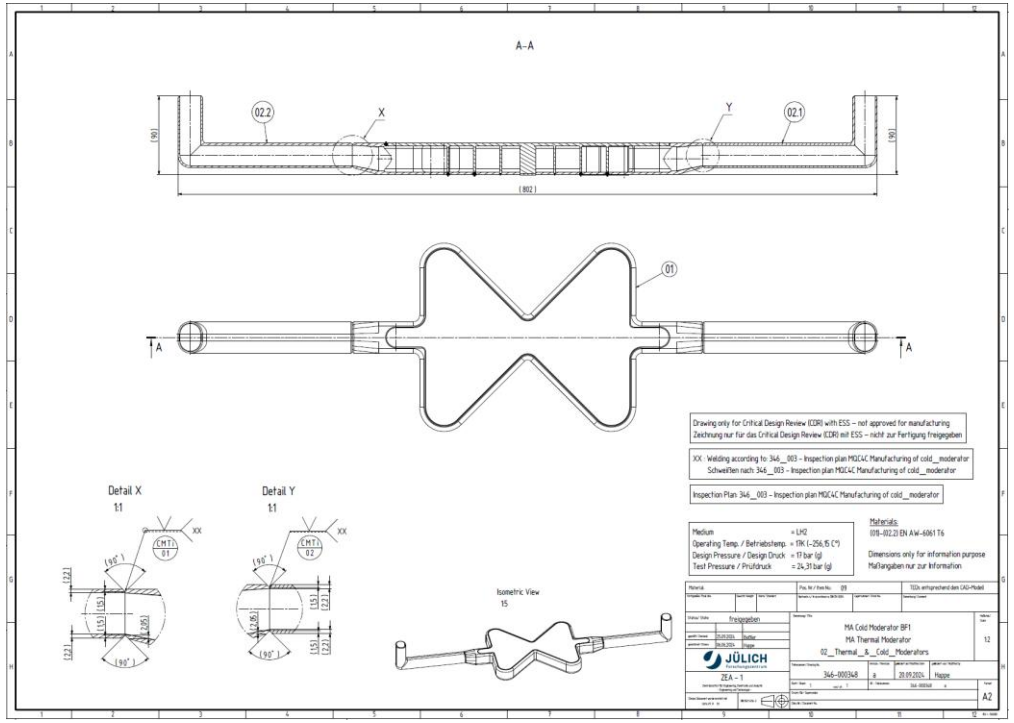
- EB welding circumferential at the top side
- EB welding of the flow guides at the bottom

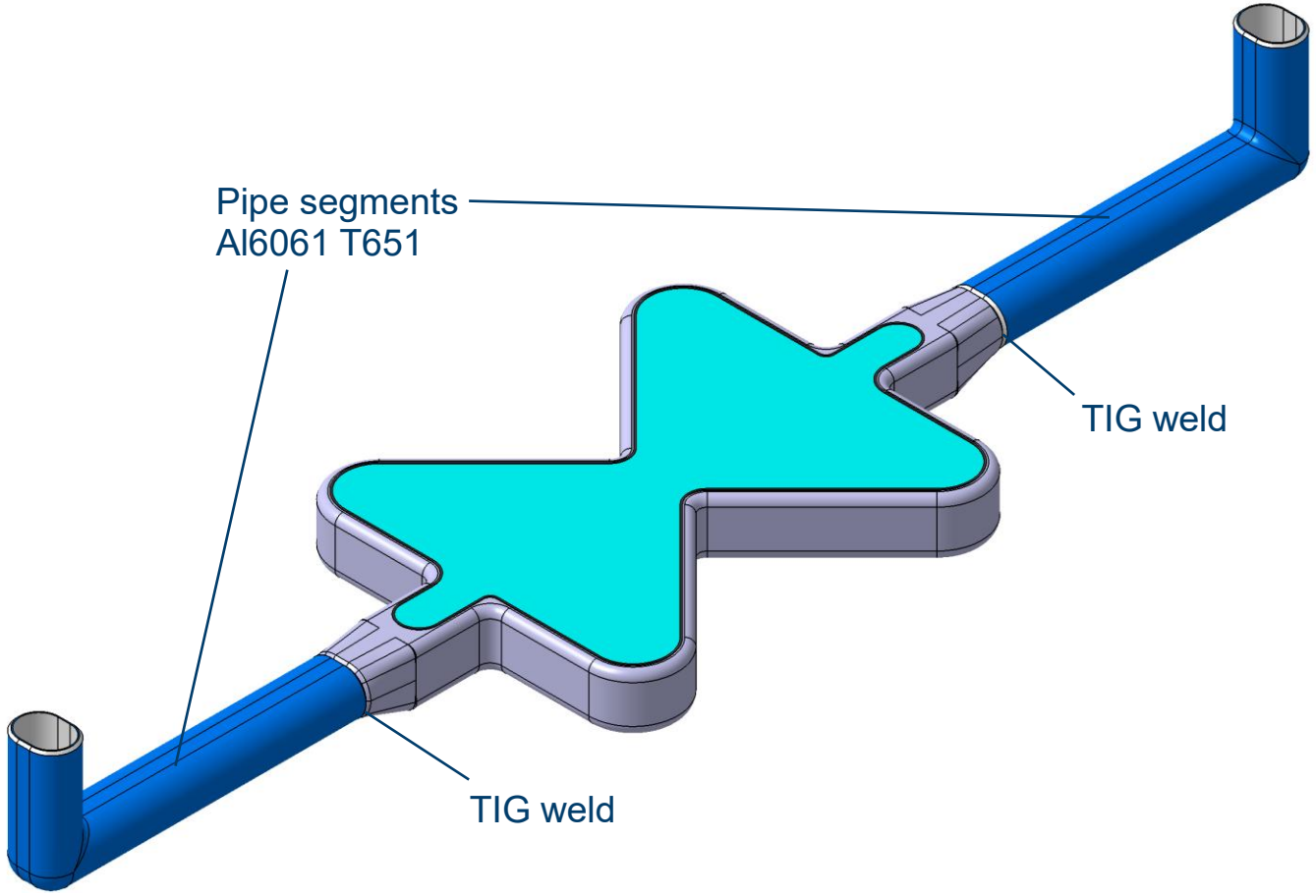


DESIGN SOLUTION MRP-II

Cold Moderator BF1 – Manufacturing

- TIG welding of pipe connections





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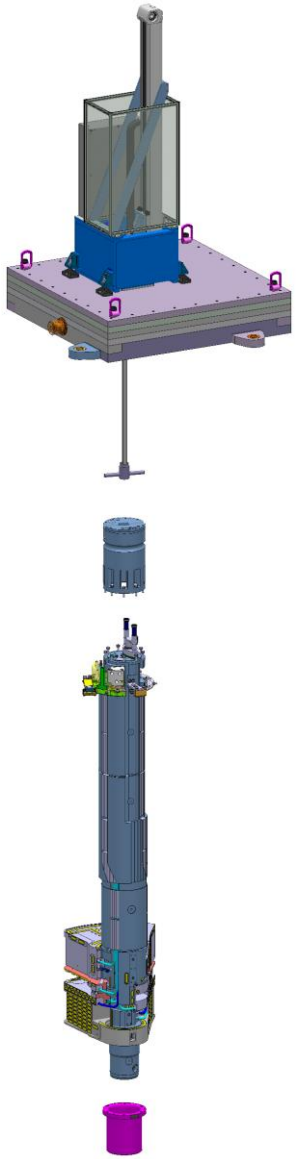
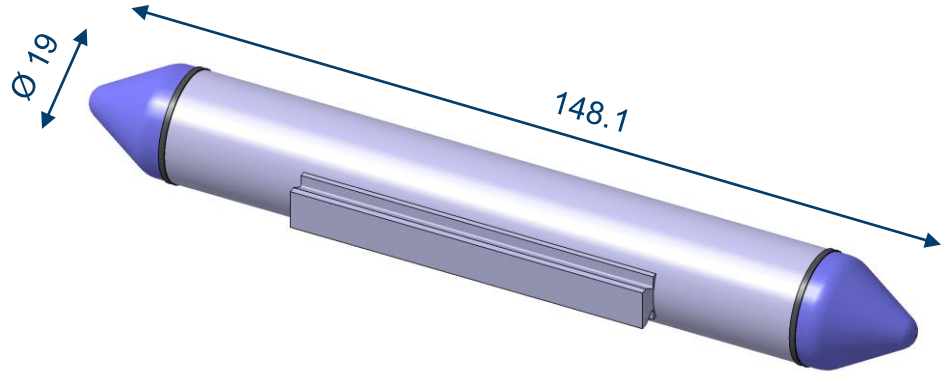


DESIGN SOLUTION MRP-II

Irradiation Module – Overview

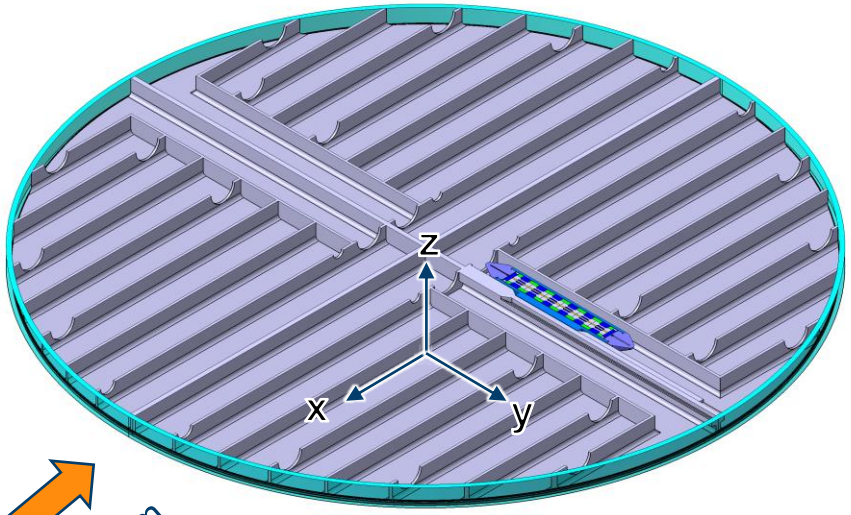


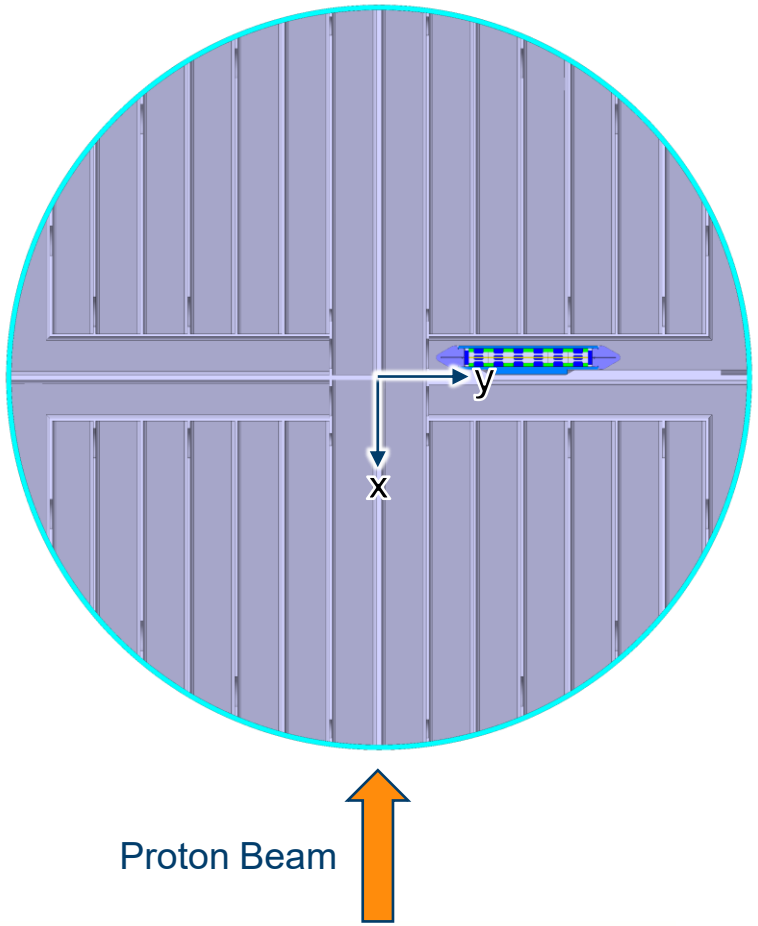
- Small vessel installed inside the Thermal Moderator
- Passively cooled by the Thermal Moderator water flow
- Exposed to fast & thermal neutrons and dedicated to the study of radiation damage of the enclosed materials
- Filled with helium (He) at a pressure of 1 bar to increase the thermal conductivity
- m = 120 g

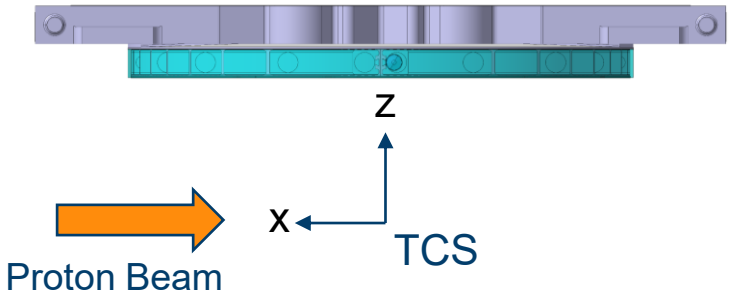
DESIGN SOLUTION MRP-II

Irradiation Module – Overview

- Location inside the Thermal Moderator Water Disc in relation to the TCS of X=-16 mm; Y=120 mm; Z=96 mm



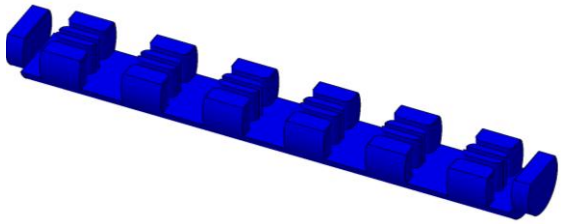




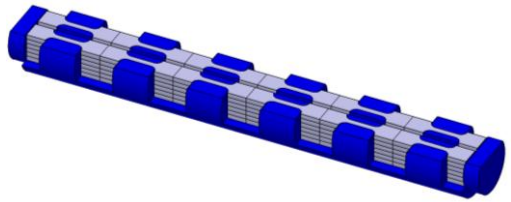
DESIGN SOLUTION MRP-II

Irradiation Module – Assembly

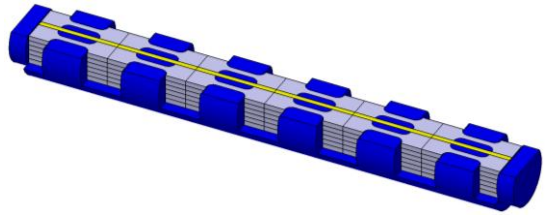
Specimen Holder Al5083



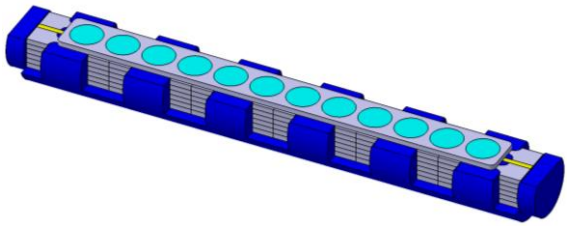
12 x 6 Tensile Specimen



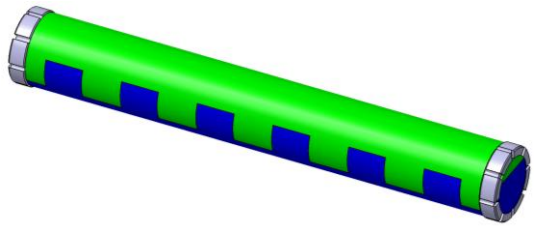
6 x 6 EC Samples



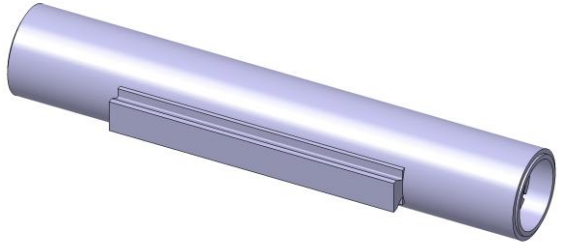
3 x 4 LFA Samples



Closing of Sample Holder Al5083



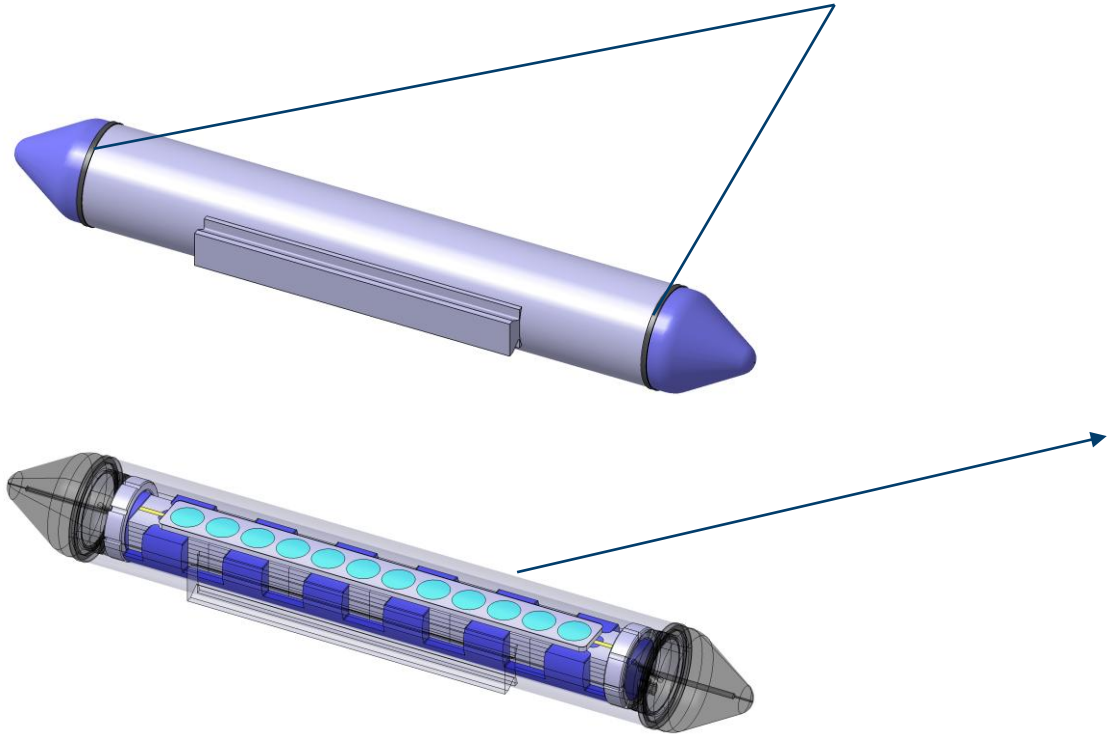
Insertion in Outer Vessel Al6061 T651



DESIGN SOLUTION MRP-II

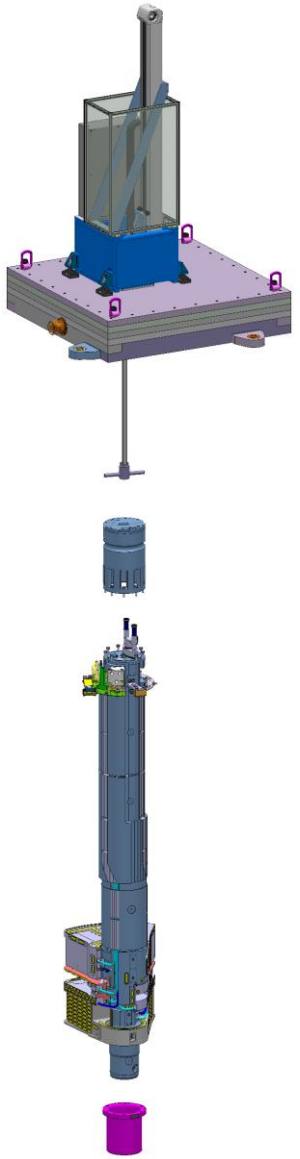
Irradiation Module – Assembly

- EB welding of Vessel Tips Al6061 T651 and Al4047 Filler



Material	Number of samples	ID	Laser Marking
Tensile samples			
Al6061 T651	6	Mat-01	20.1 – 20.6
Al5754 O	6	Mat-02	21.1 - 21.6
Al6061 T651 with filler material Al4047	6	Mat-03	28.1 – 28.6
Inconel 718	6	Mat-04	32.1 – 32.6
Ti6Al4V	6	Mat-05	29.1 – 29.6
3D printed Al6061 T6	6	Mat-06	25.1 – 25.6
Stainless Steel 304L	6	Mat-07	22.1 – 22.6
Stainless Steel 316L	6	Mat-08	23.1 – 23.6
1.3912+Al6061 (friction welded)	6	Mat-09	33.1 – 33.6
Invar 36 (1.3912)	6	Mat-10	34.1 – 34.6
3D printed AL	6	Mat-11	24.1 – 24.6
Al6061 T651	6	Mat-12	20.7 – 20.12
EC samples			
EC samples Al6061 T651	6	Mat-01	40.1 – 40.6
EC samples Al5754 O	6	Mat-02	41.1 – 41.6
EC samples SS316L	6	Mat-08	42.1 – 42.6
Silicon Carbide Temperature Monitors	18	Mat-13	43.1 – 43.18
LFA samples			
LFA Al6061 T651	4	Mat-01	50.1 – 50.4
LFA Al5754 O	4	Mat-02	51.1 – 51.4
LFA SS316L	4	Mat-08	52.1 – 52.4

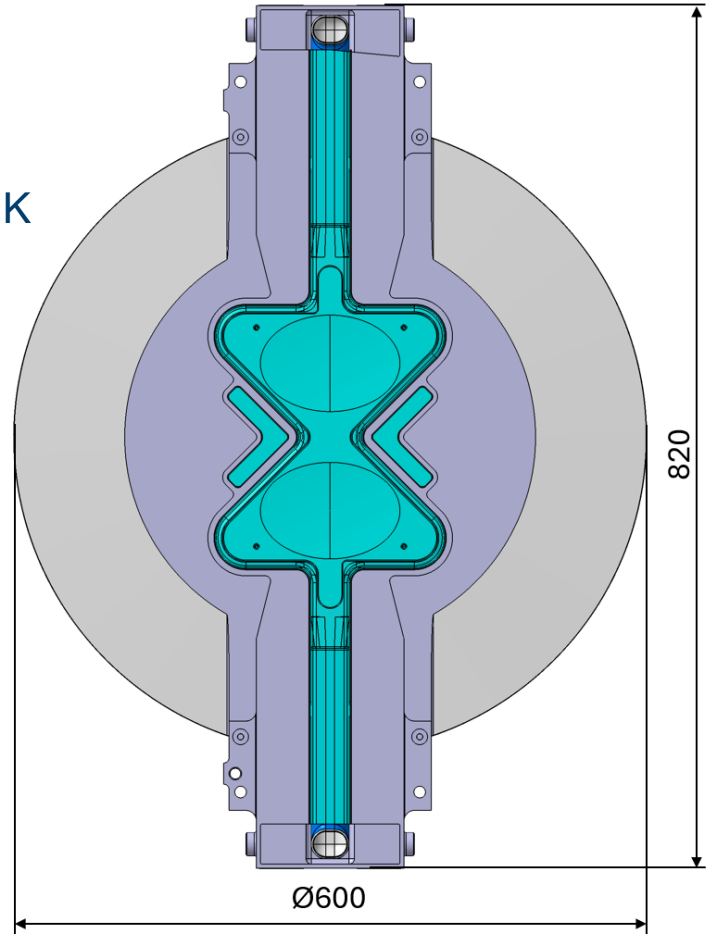
CONTENT

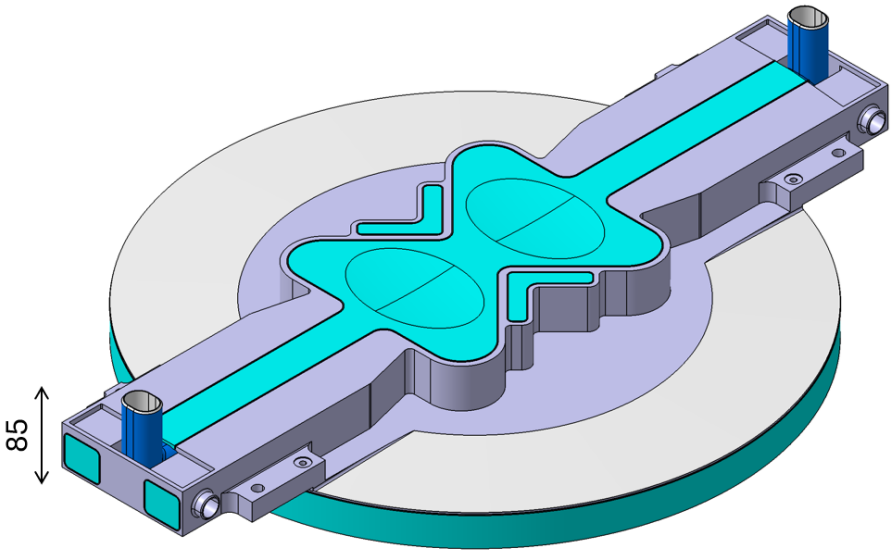


DESIGN SOLUTION MRP-II

Thermal Moderator – Overview

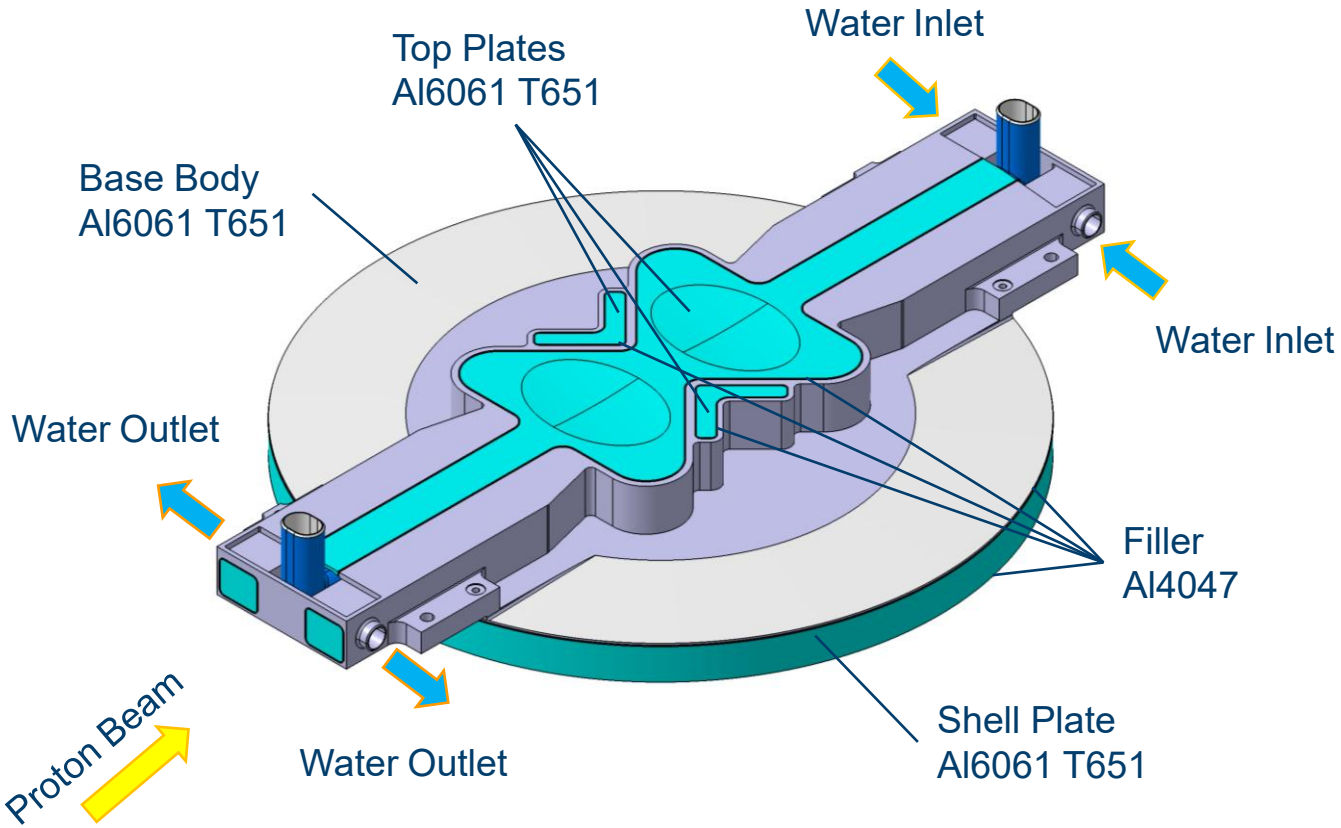
- Pressure vessel made of Al6061 T651
- EB welded with filler material Al4047
- Light water at an inlet temp. of T_{in} = 293.15 K with a temp. increase of dT ≤ 16 K
- Design pressure 5 bar
- Operating pressure 4 bar
- Heat deposition of ca. 79 kW
- m_{Al} = 12.5 kg (without CM & water)
- Mostly 3 & 4 mm wall thickness

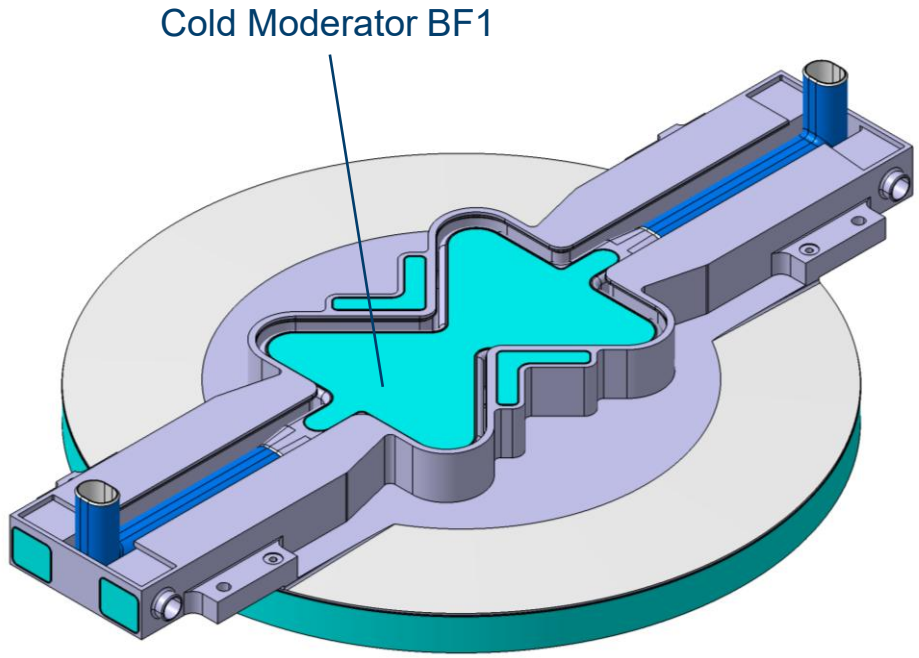




DESIGN SOLUTION MRP-II

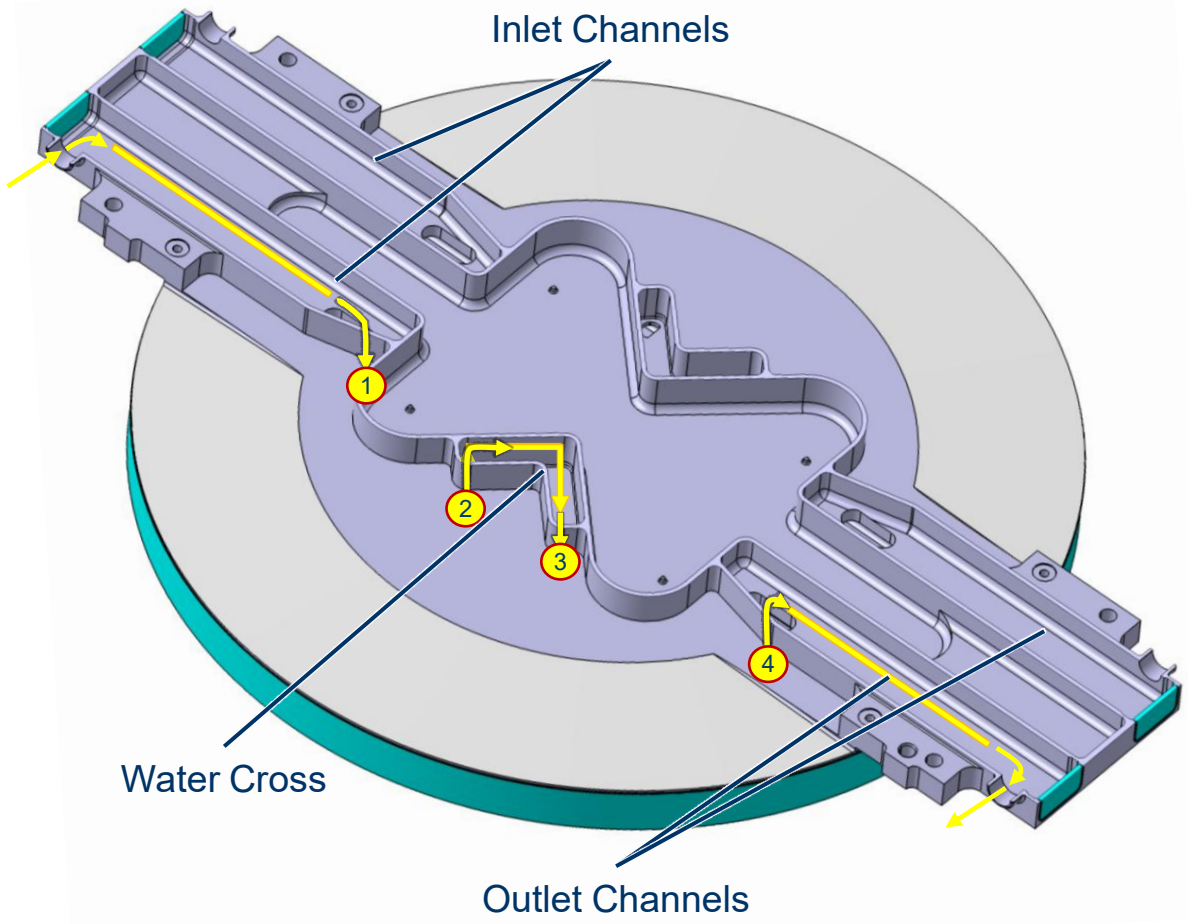
Thermal Moderator – Overview



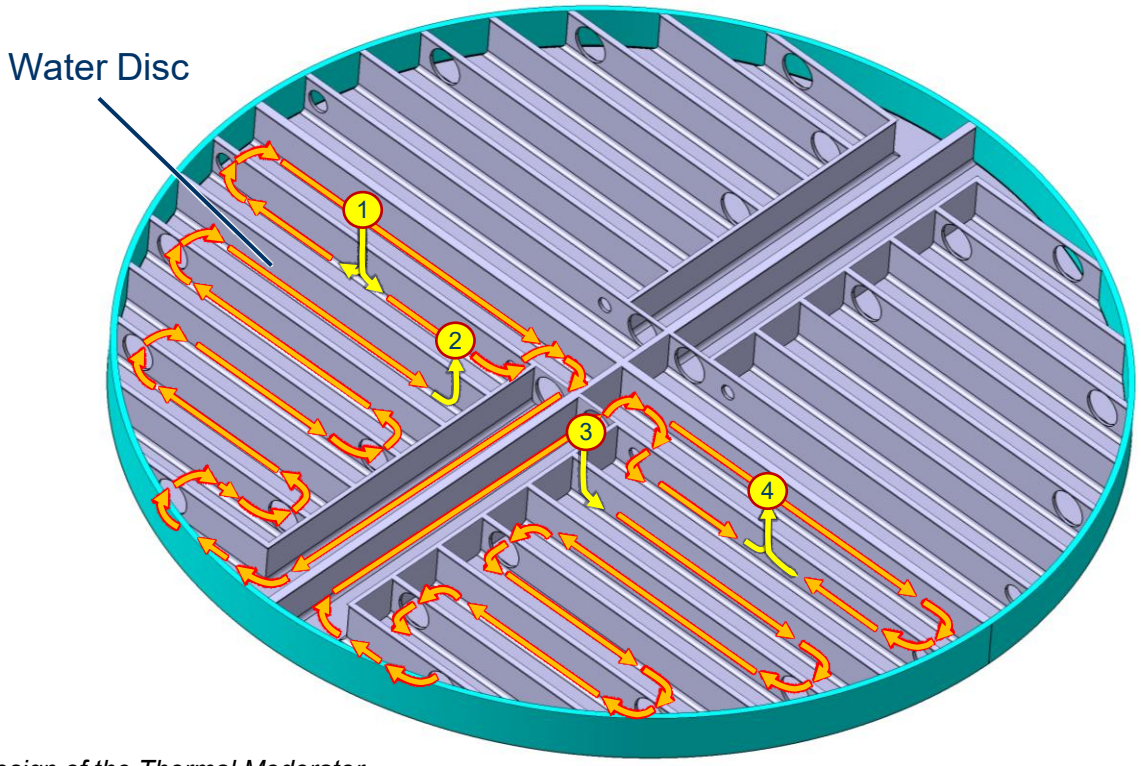


DESIGN SOLUTION MRP-II

Thermal Moderator – Waterflow



1. From Inlet Channels down to Water Disc
2. From Water Disc up to Water Cross
3. From Water Cross down to Water Disc
4. From Water Disc up to Outlet Channels



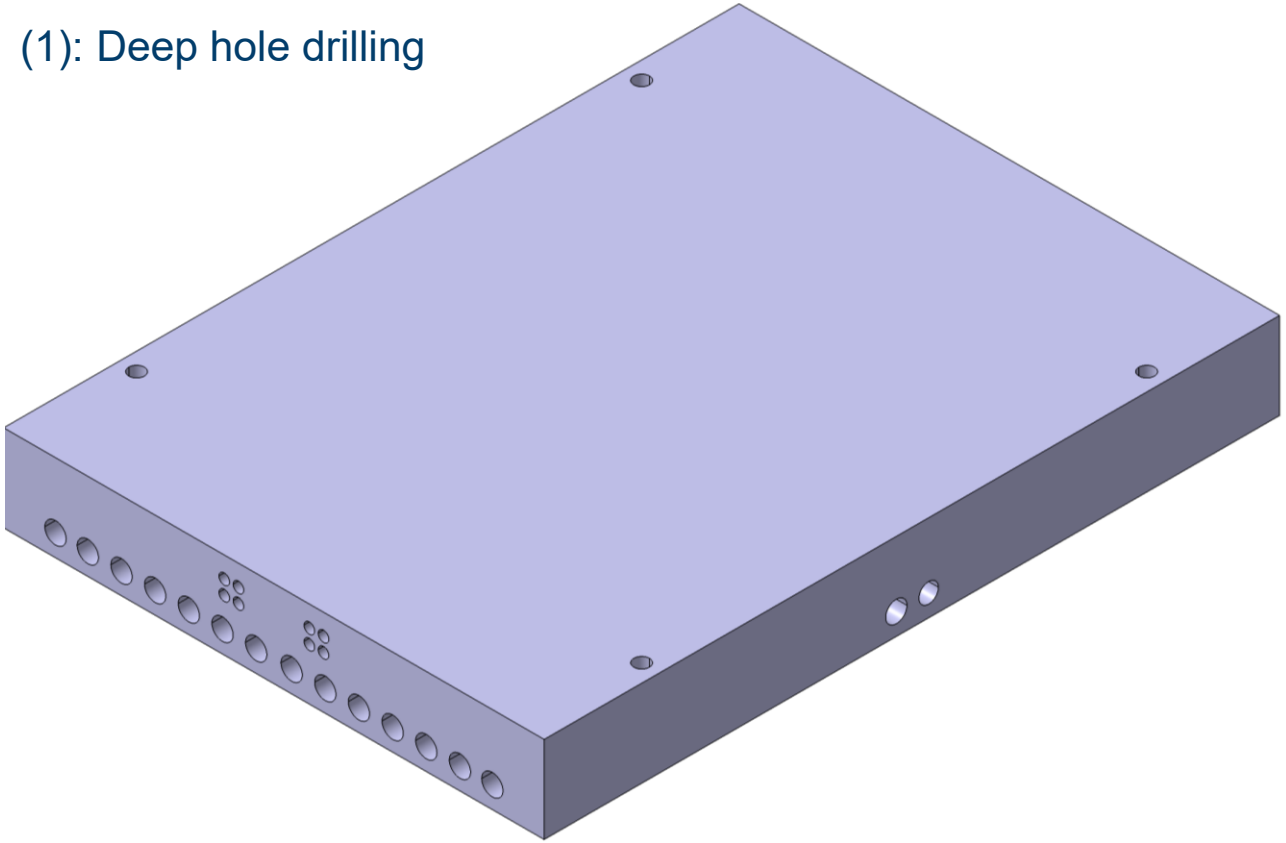
Original schematics: 6-346-PPT-20241015-YBessler-JWolters-Thermal-Hydraulic and Thermo-Mechanical Design of the Thermal Moderator

DESIGN SOLUTION MRP-II

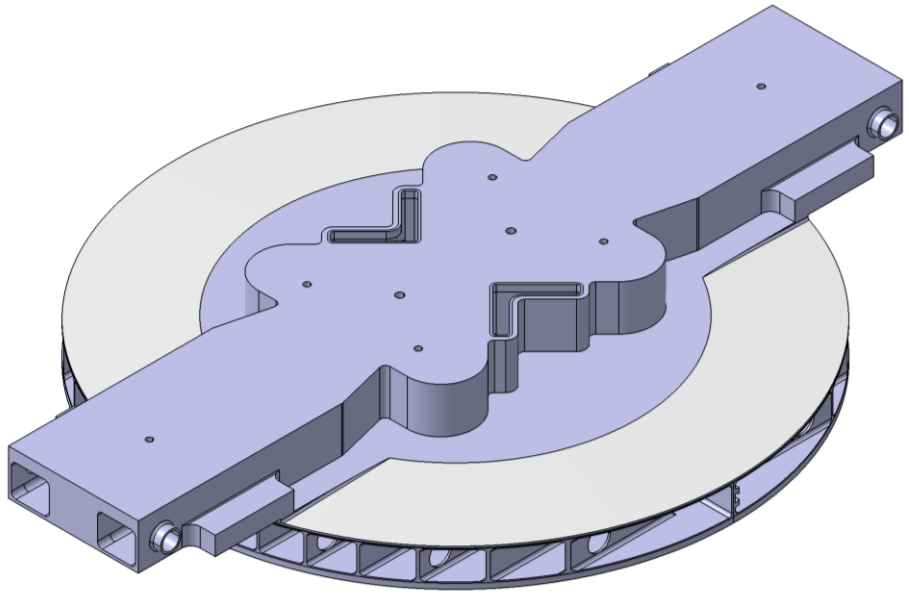
Thermal Moderator – Manufacturing

- Solid block Al6061 T651
- 7 main manufacturing steps for final product

(1): Deep hole drilling



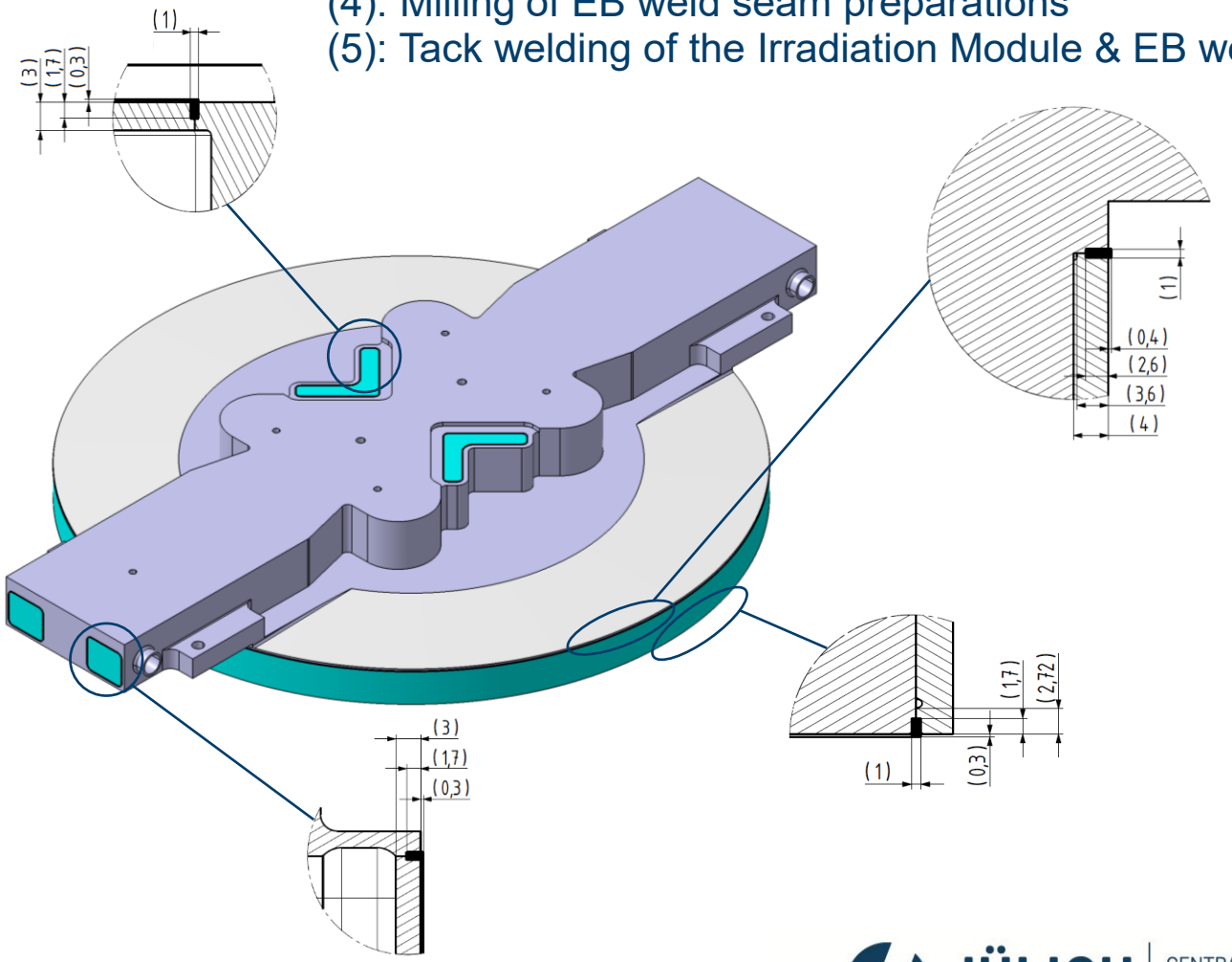
(2): Milling of the outer contour
(3): EDM of water channels

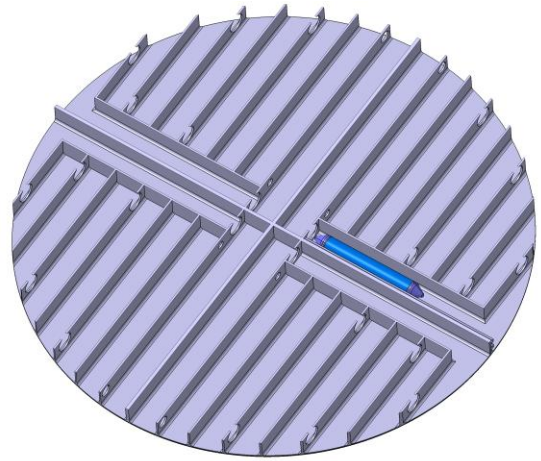


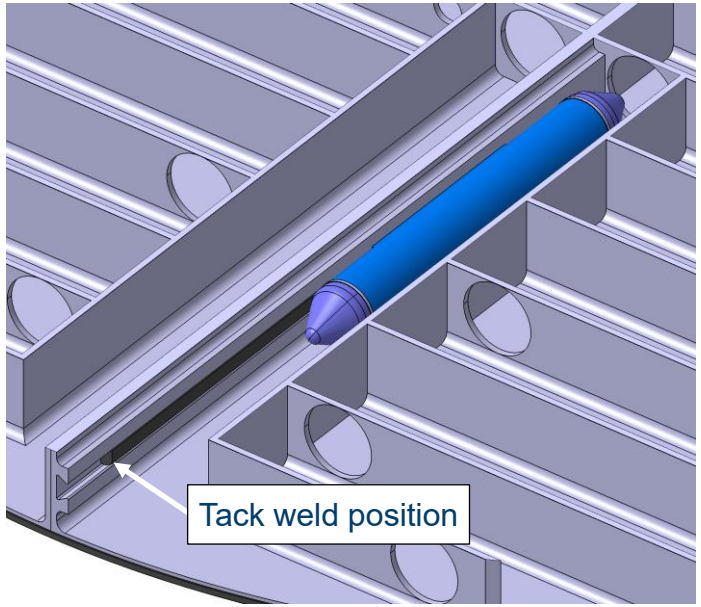
DESIGN SOLUTION MRP-II

Thermal Moderator – Manufacturing

(4): Milling of EB weld seam preparations
(5): Tack welding of the Irradiation Module & EB welding of water channels



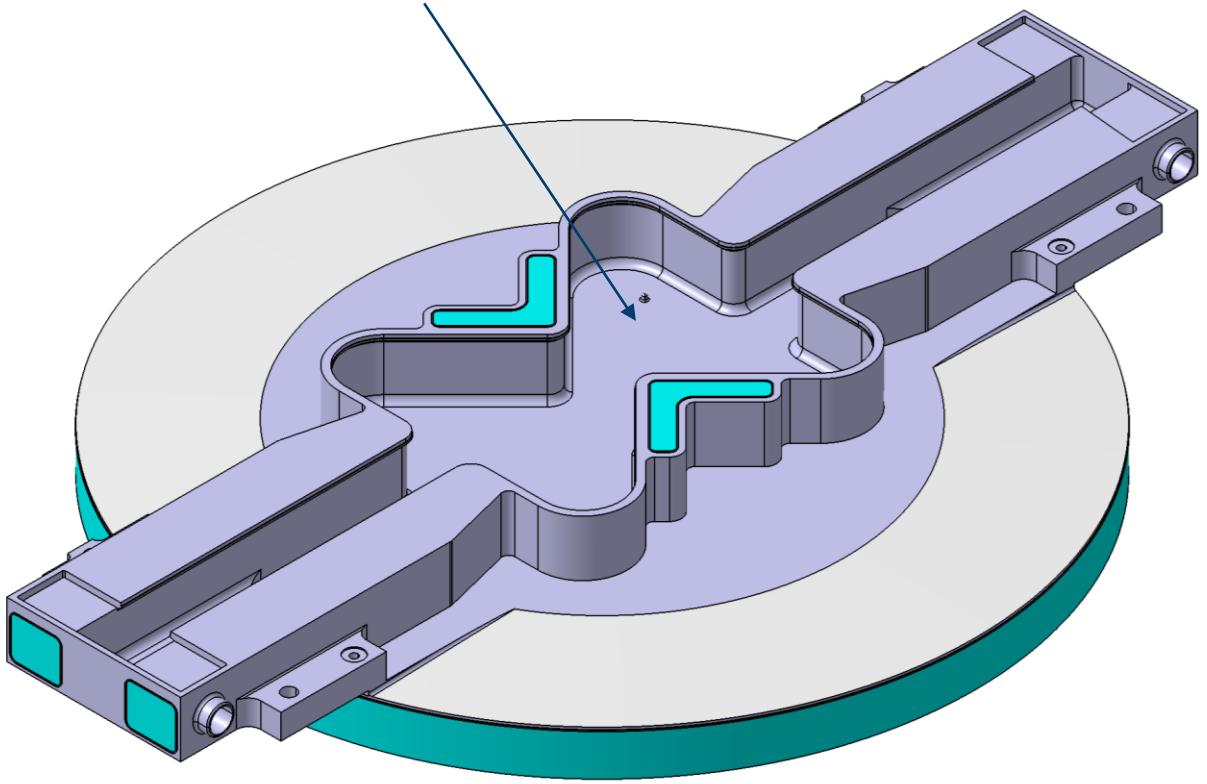




DESIGN SOLUTION MRP-II

Thermal Moderator – Manufacturing

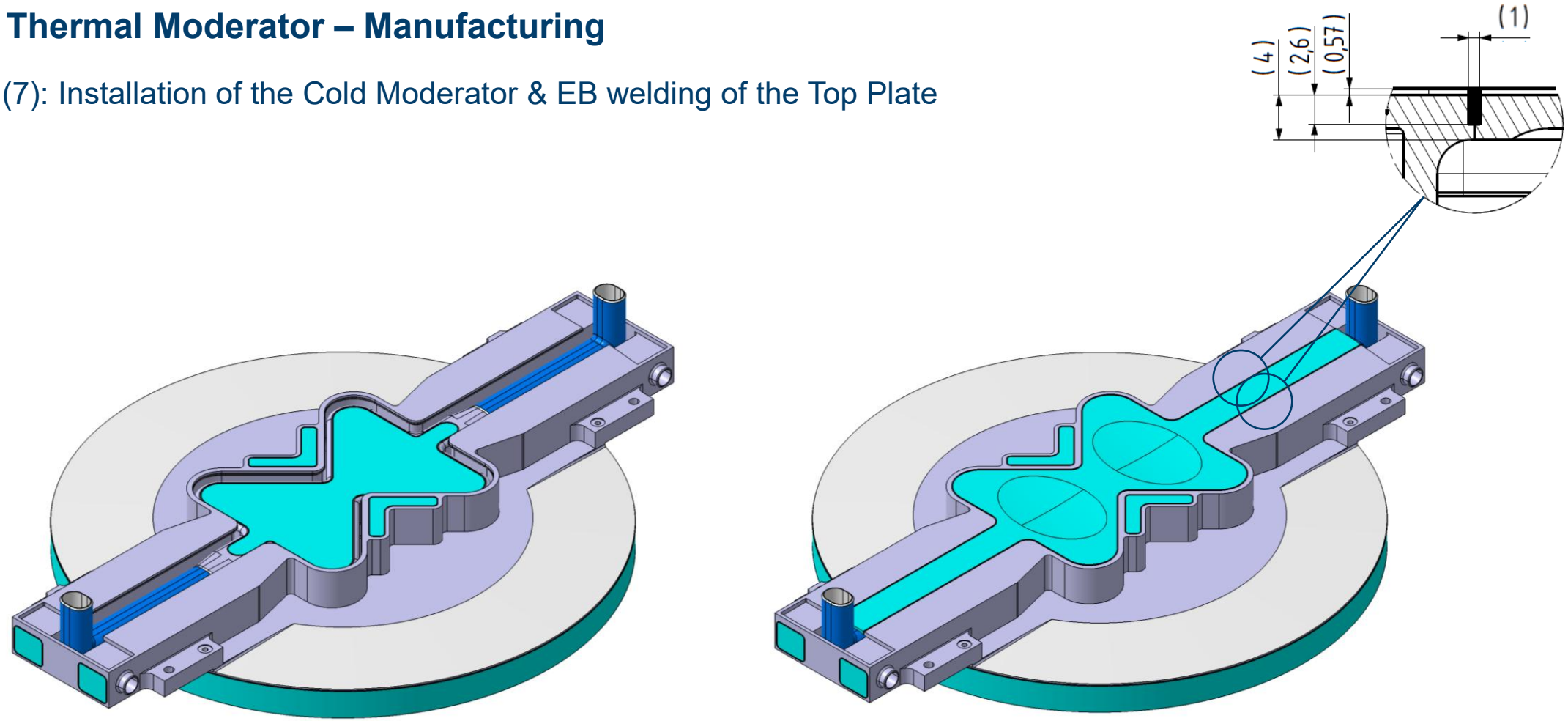
(6): Final milling of inner cavity for the Cold Moderator



DESIGN SOLUTION MRP-II

Thermal Moderator – Manufacturing

(7): Installation of the Cold Moderator & EB welding of the Top Plate



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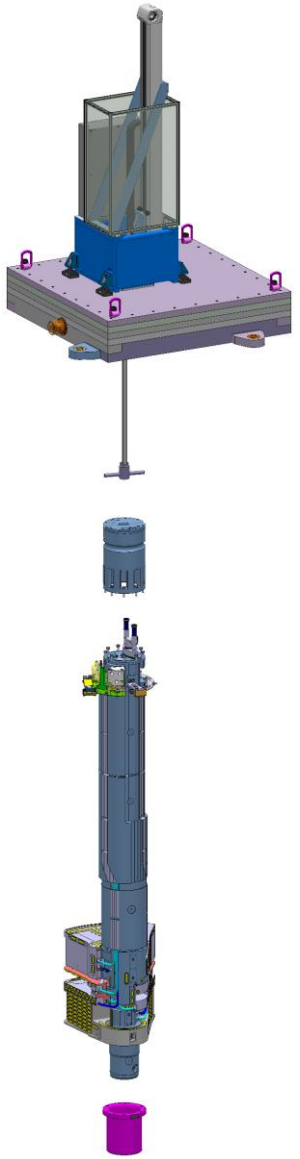
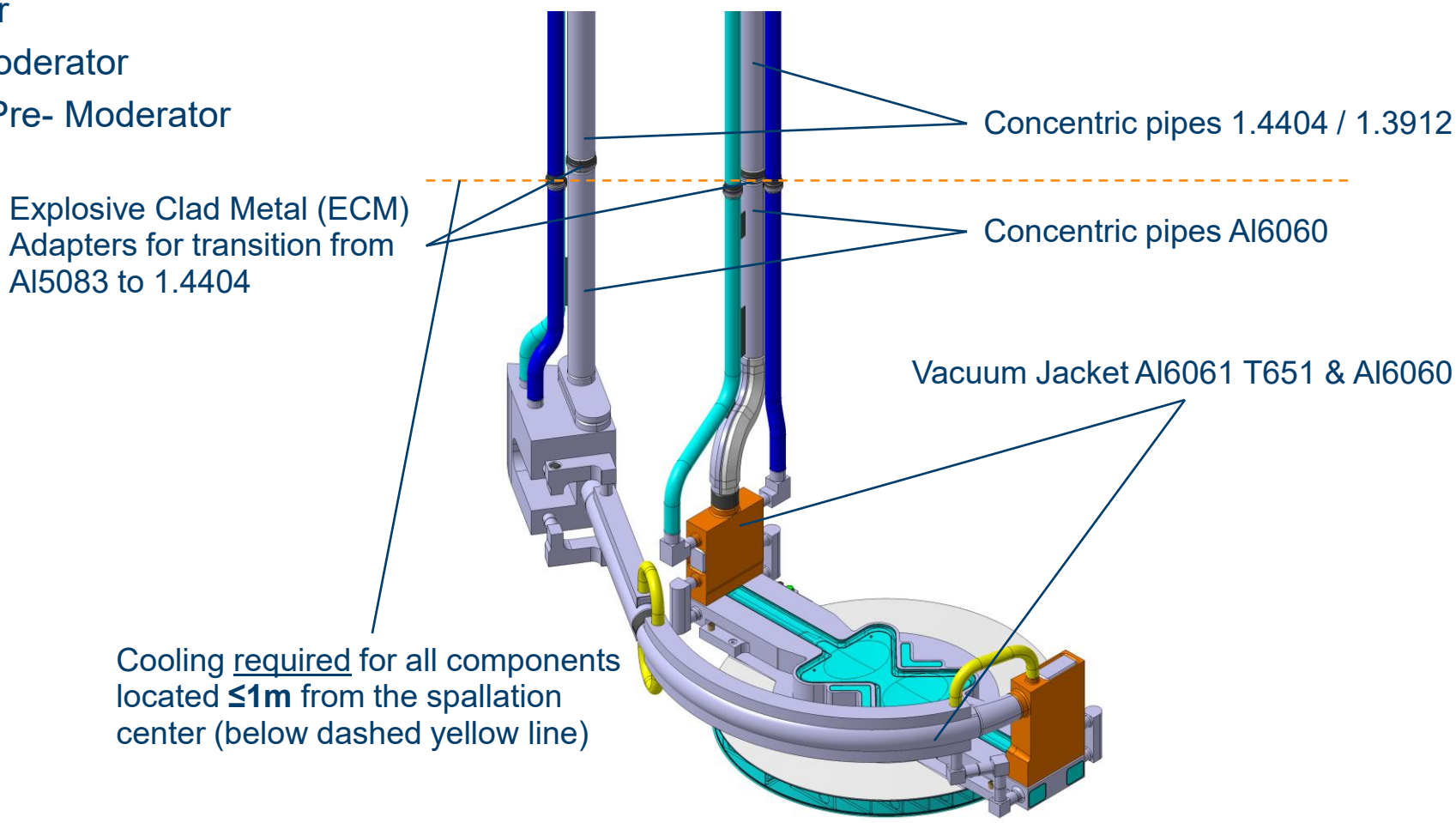


DESIGN SOLUTION MRP-II

Vacuum Jackets & Vacuum Chamber

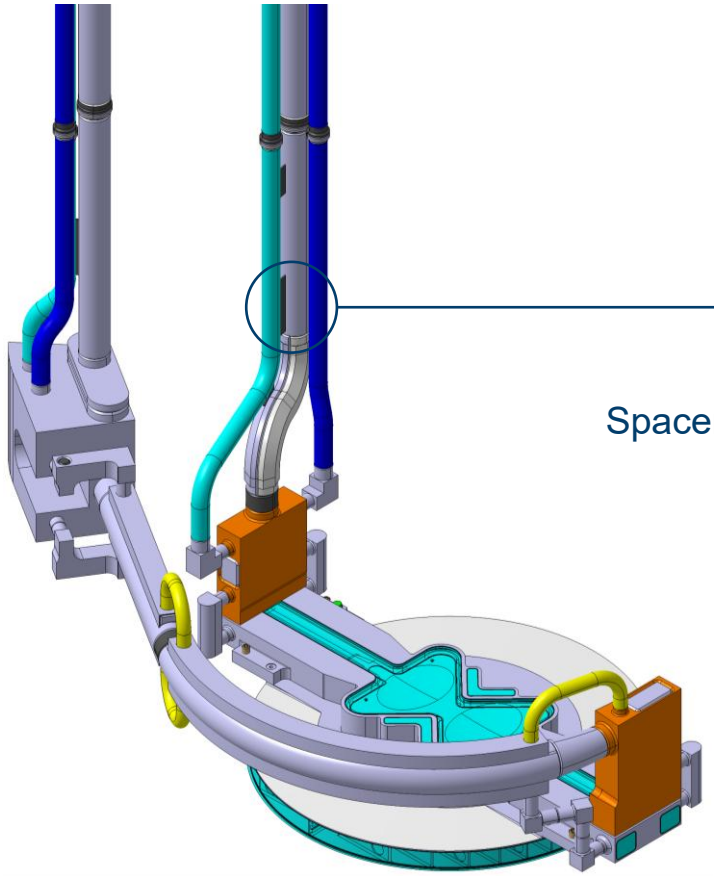
- LH_2 supply for Cold Moderator
- Insulation vacuum for Cold Moderator
- Water supply for Thermal- & Pre- Moderator

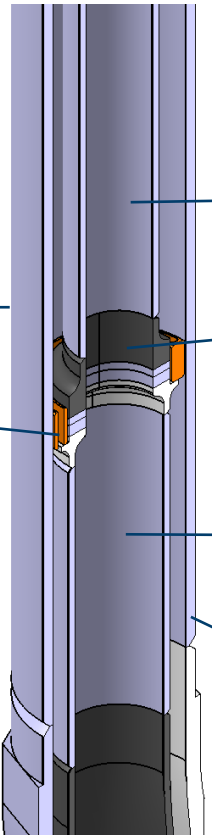


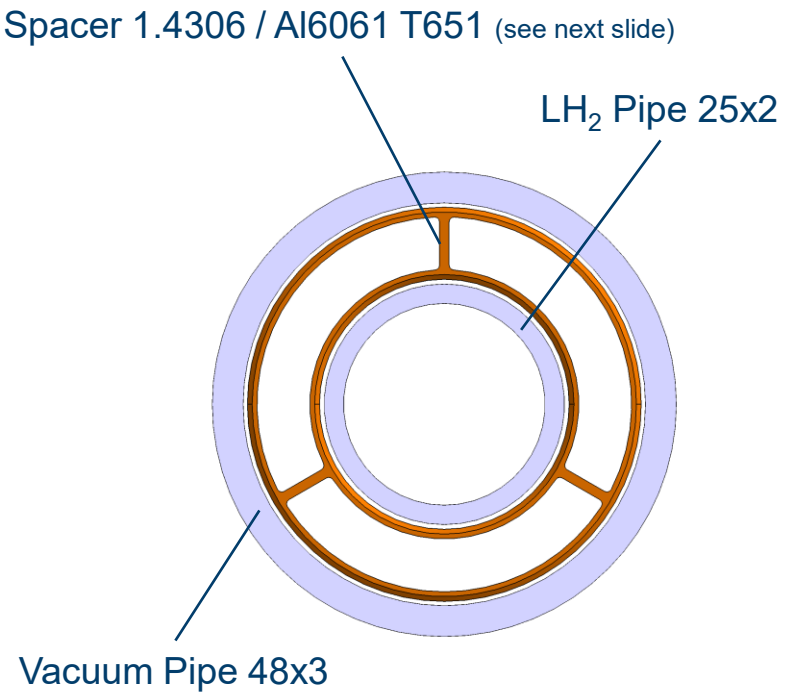
DESIGN SOLUTION MRP-II

Vacuum Jackets & Vacuum Chamber

- Concentric pipes with spacers to center the position of the inner pipe
- Optimized heat transfer by minimized usage of material for the spacers
- Explosion Clad Adapters used for the transition from SS or Invar to Al



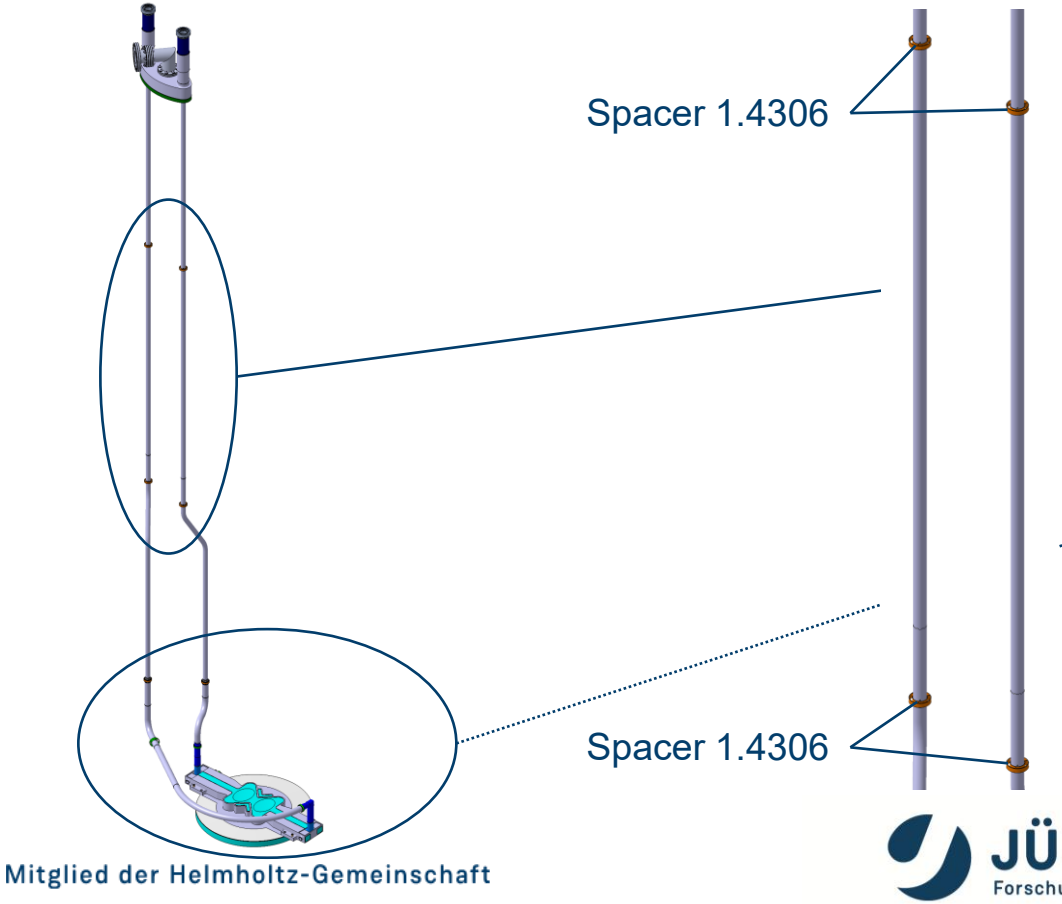


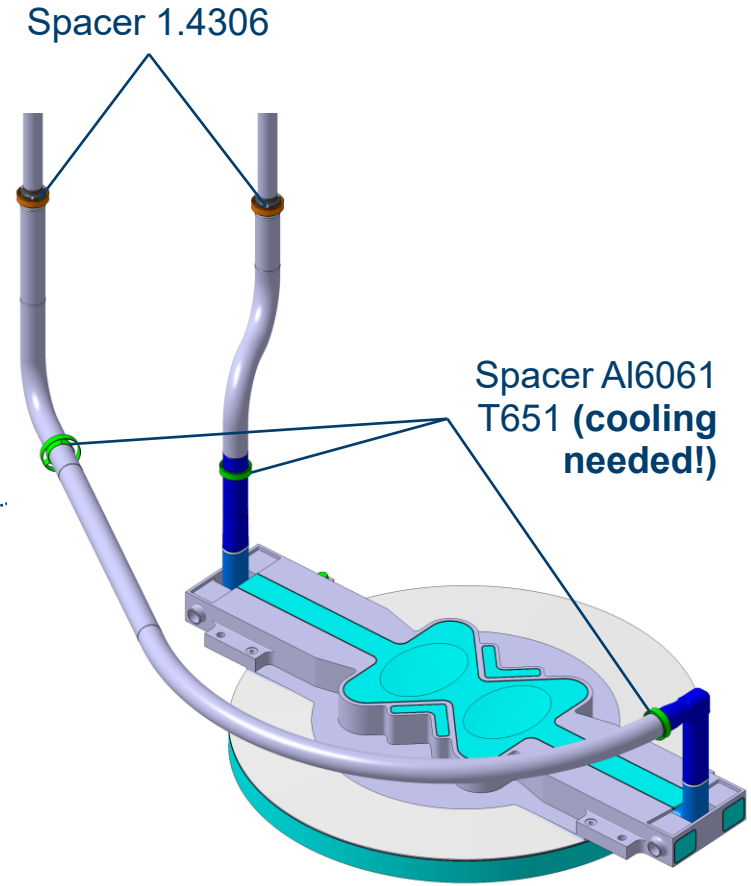


DESIGN SOLUTION MRP-II

Vacuum Jackets & Vacuum Chamber

- Reduced heat transfer with stainless steel spacers (orange, no cooling needed)
- Al spacers are used close to the spallation center to reduce particle heat input
- ➢ Al spacers (green) are tack welded to the LH_2 pipes to avoid overheating

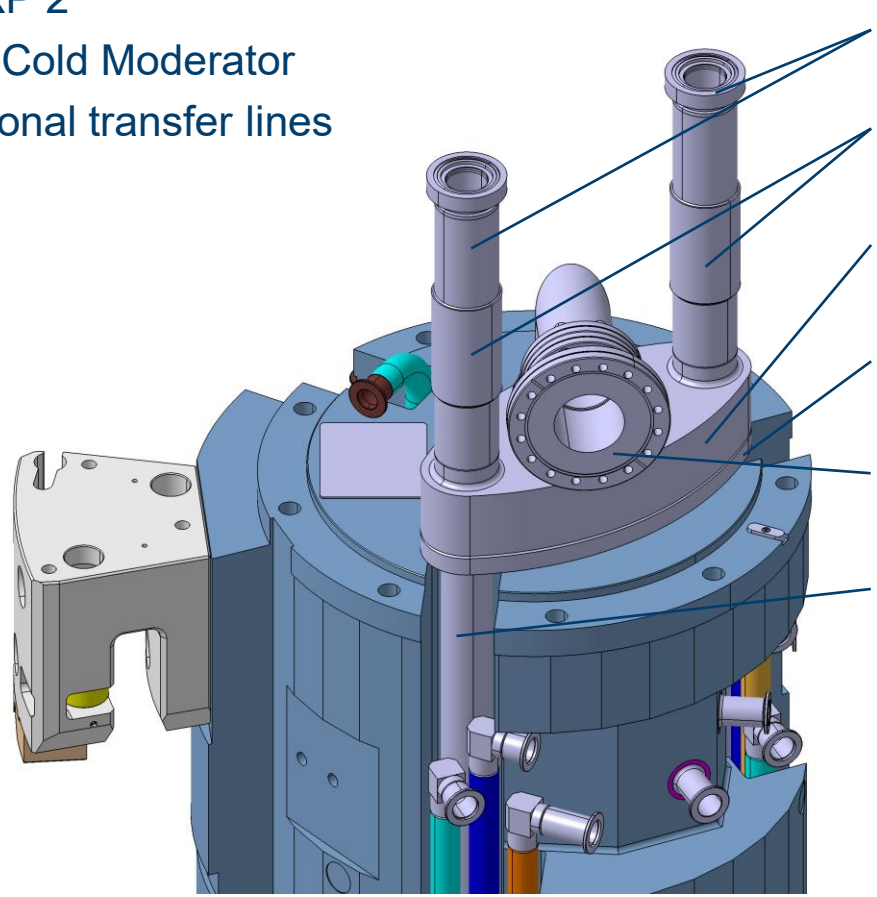




DESIGN SOLUTION MRP-II

Vacuum Jackets & **Vacuum Chamber**

- Vacuum Chamber on top of MRP 2
- Provides insulation vacuum for Cold Moderator
- Connection to the LH_2 conventional transfer lines via Cryo Couplings
- m ~ 25 kg

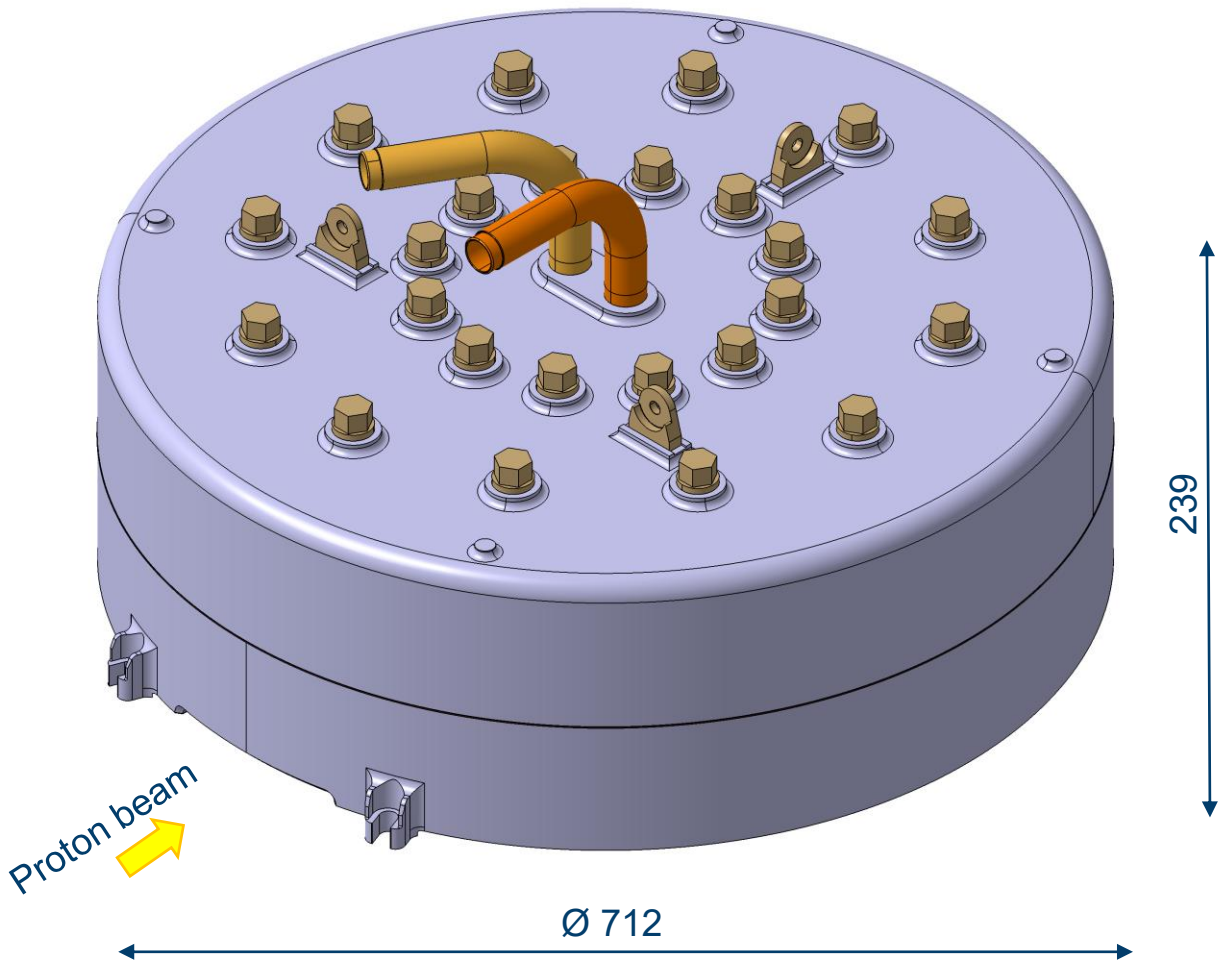


CONTENT

DESIGN SOLUTION MRP-II

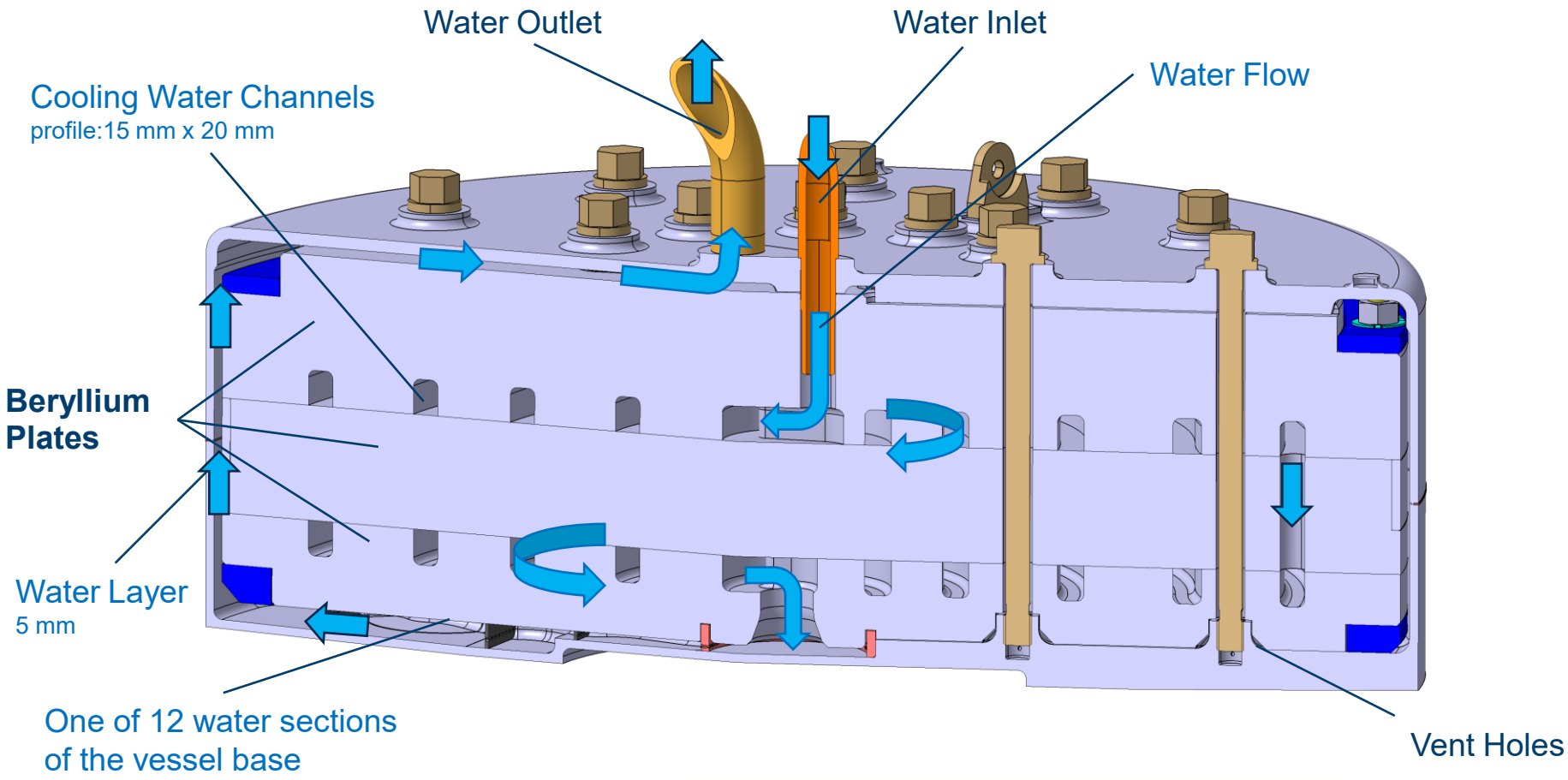
Beryllium Reflector – Overview

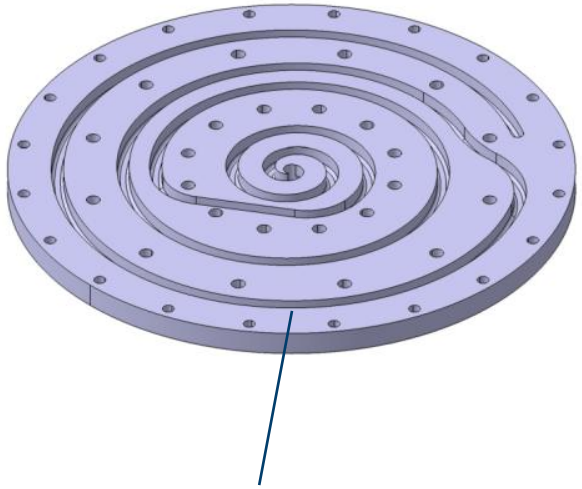
- Pressure vessel made of Al6061 T651
- EB welded with filler material Al4047
- Light water at an inlet temp. of T_{in} = 293.15 K with a temp. increase of dT ≤ 42 K
- Design pressure 5 bar
- Operating pressure 4 bar
- Heat deposition of ca. 118 kW
- m = 177.6 kg (without water)



DESIGN SOLUTION MRP-II

Beryllium Reflector – Waterflow

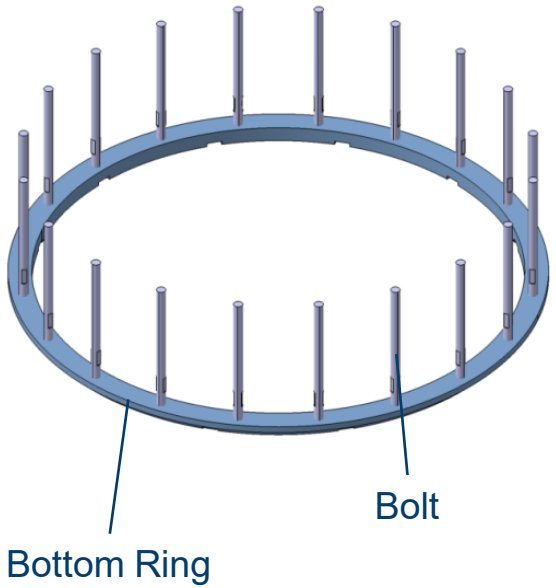


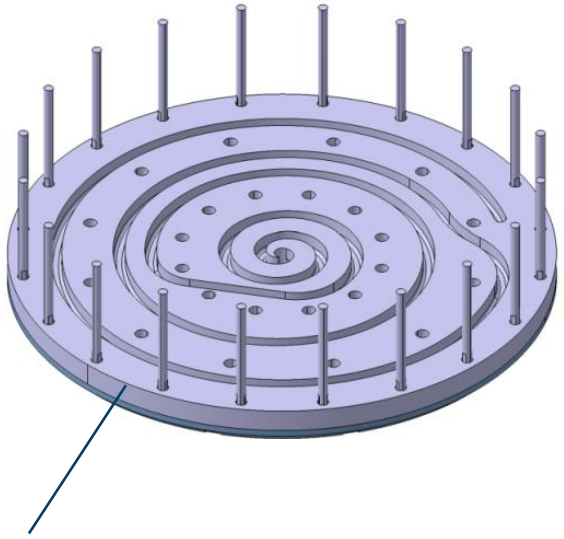


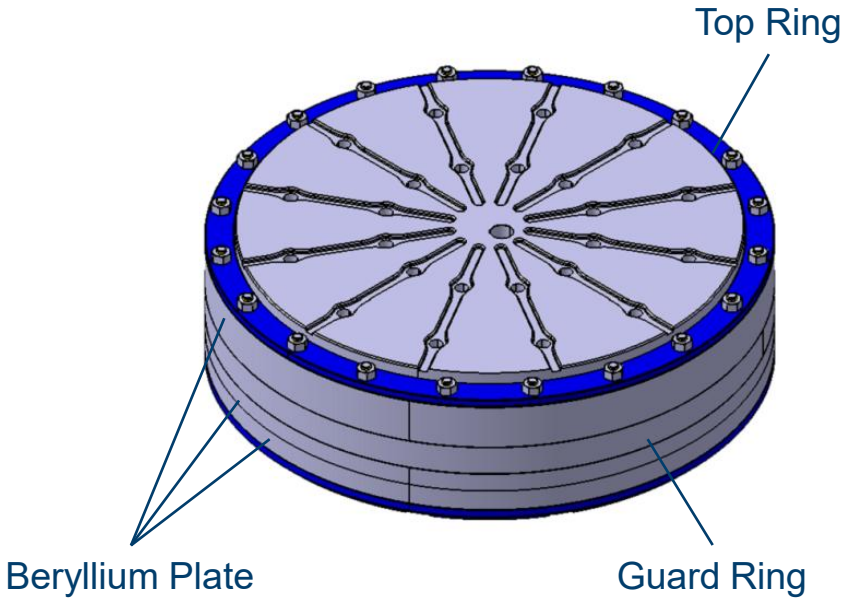
DESIGN SOLUTION MODERATOR-REFLECTOR SYSTEM

Beryllium Reflector – Assembly

- Stacking of 3 Beryllium Plates
- Guard Ring of Al6061 T651 – protects the Beryllium Plate during EB welding from being hit by the electron-beam
- Stack secured by bolted Bottom & Top Ring



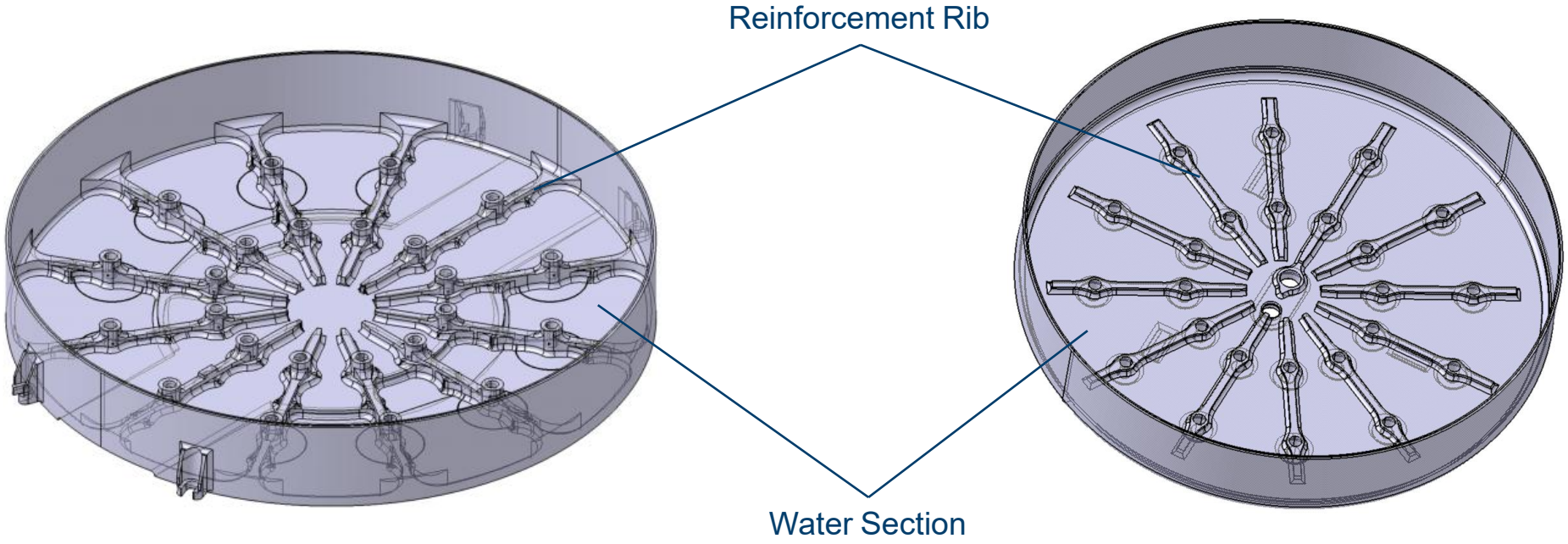




DESIGN SOLUTION MRP-II

Beryllium Reflector – Assembly

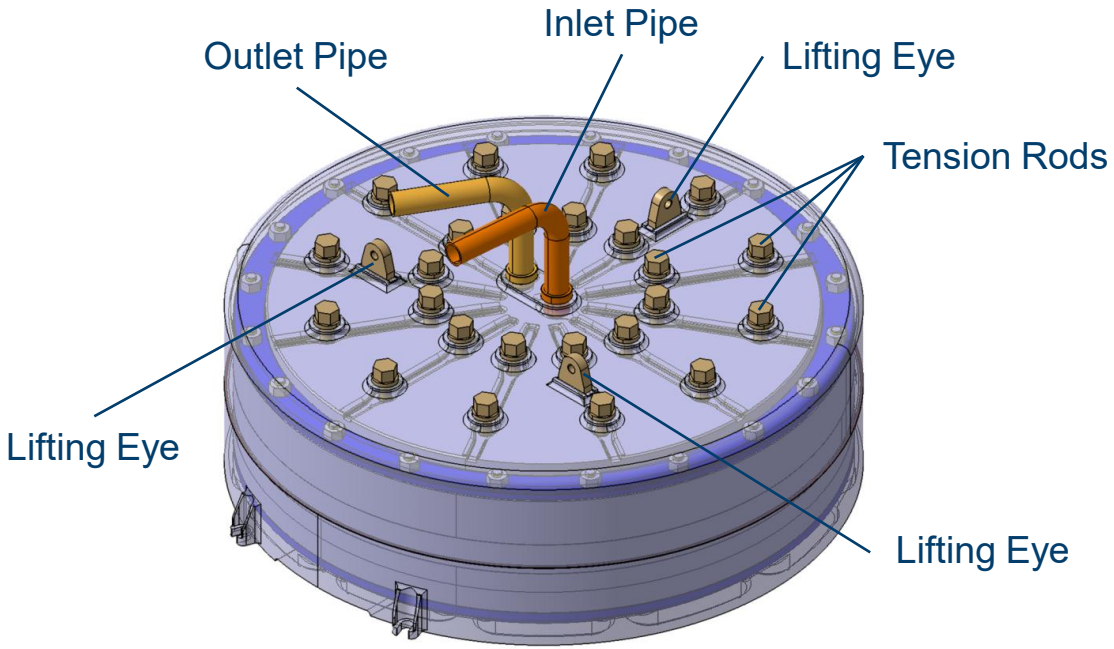
- Vessel Top and Bottom milled from a solid Block of Al6061 T651
- Split into 12 water section by reinforcement ribs

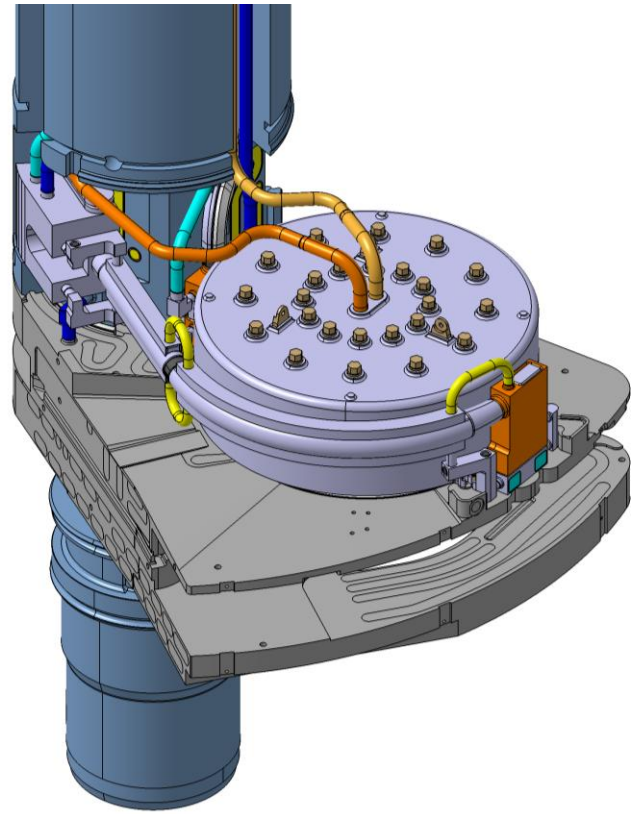


DESIGN SOLUTION MRP-II

Beryllium Reflector – Assembly

- TIG welding of the 24 tension rods to ensure vessel leak tightness
- TIG welding of the 3 lifting eyes
- TIG welding of the Inlet & Outlet pipes
- Ready for installation to the Main Assembly with Shaft & MS





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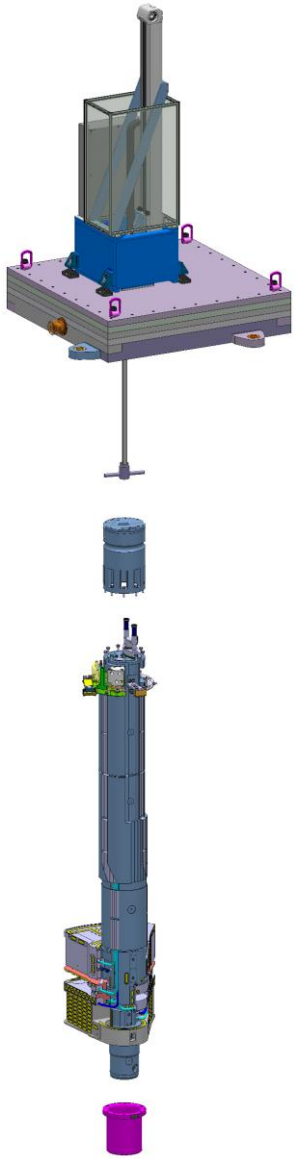
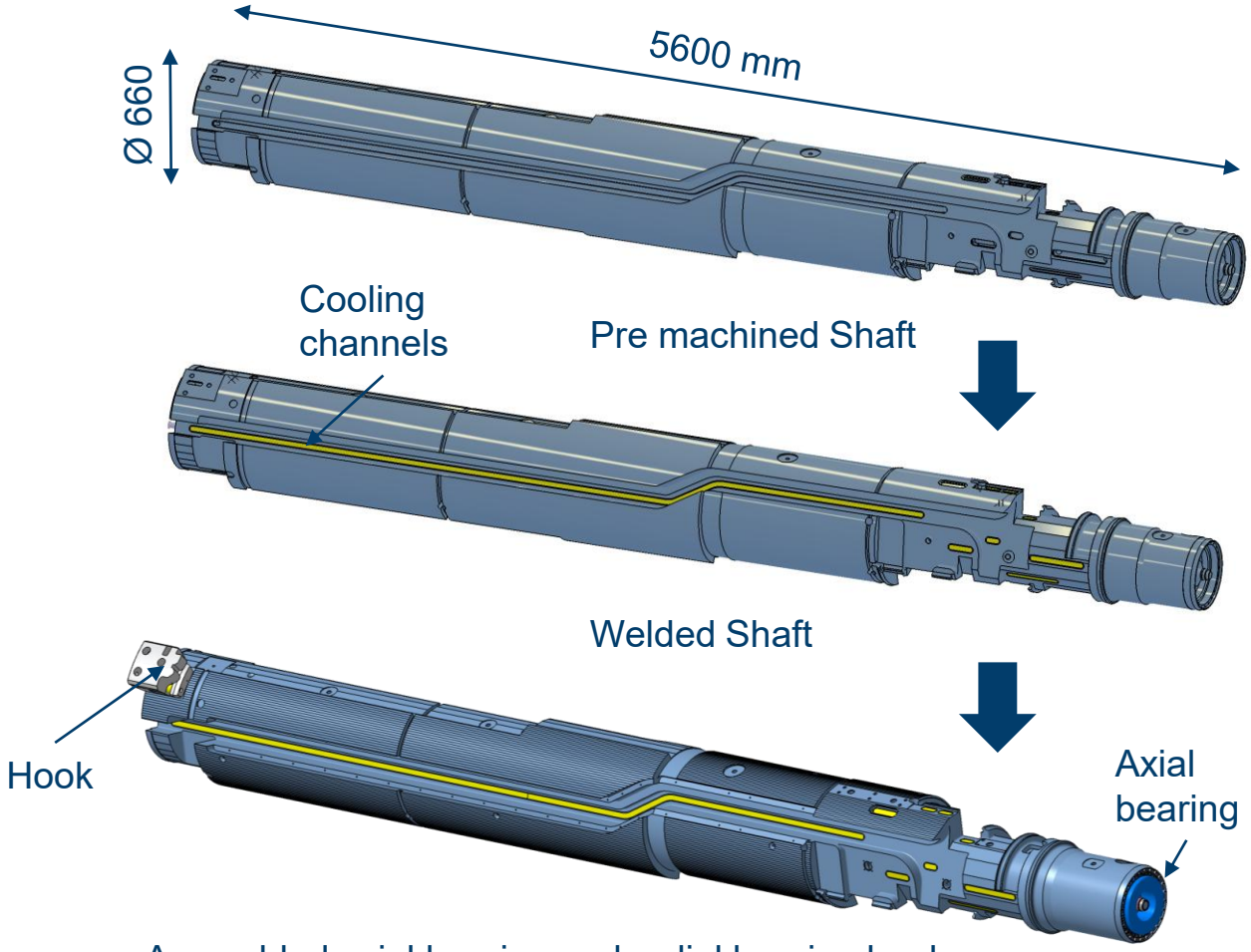


DESIGN SOLUTION MRP-II

Shaft assembly – Overview

➢ *Stepped Shaft for guiding the pipework to the components to be cooled & as a rotation axis to "twist" the MRP into operation or lifting position*

- Pressure vessel made of low-Co stainless steel 304l
- TIG & MAC welded cooling channel covers (yellow)
- Light water at an inlet temp. of T_{in} = 308 K
- Design pressure 10 bar
- Operating pressure 8 bar
- m = 7150 kg (without water)



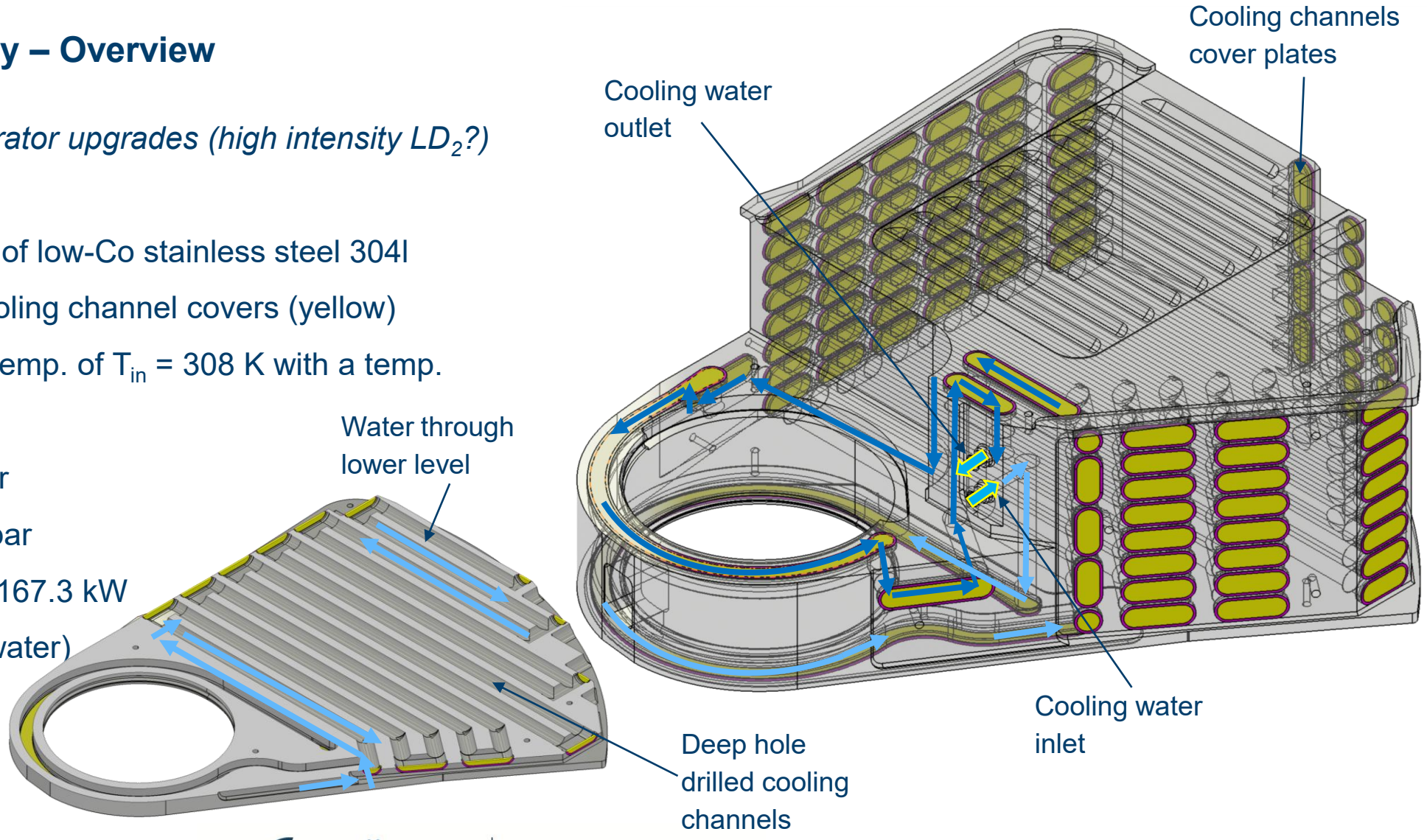
Assembled axial bearing and radial bearing hook

DESIGN SOLUTION MRP-II

Lower Frame assembly – Overview

➢ *Space for future moderator upgrades (high intensity LD_2?)*

- Pressure vessel made of low-Co stainless steel 304l
- TIG & MAC welded cooling channel covers (yellow)
- Light water at an inlet temp. of T_{in} = 308 K with a temp. increase of dT ≤ 33 K
- Design pressure 10 bar
- Operating pressure 8 bar
- Heat deposition of ca. 167.3 kW
- m = 1890 kg (without water)

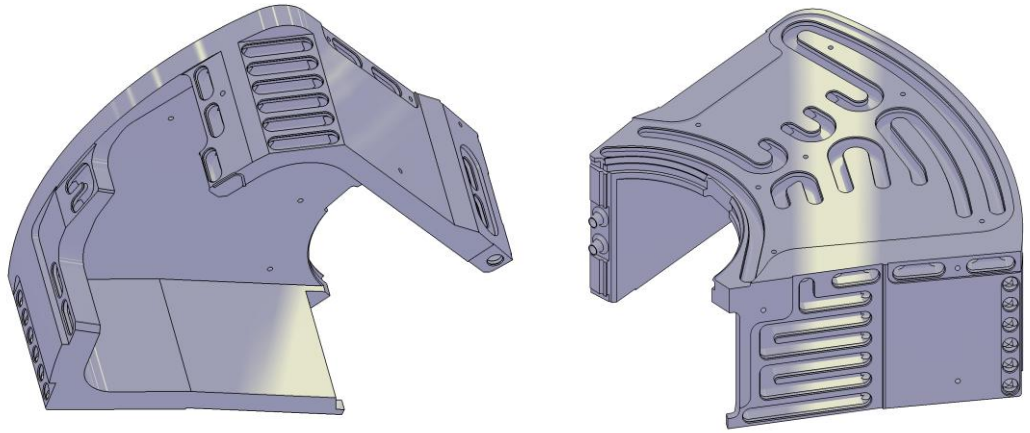


DESIGN SOLUTION MRP-II

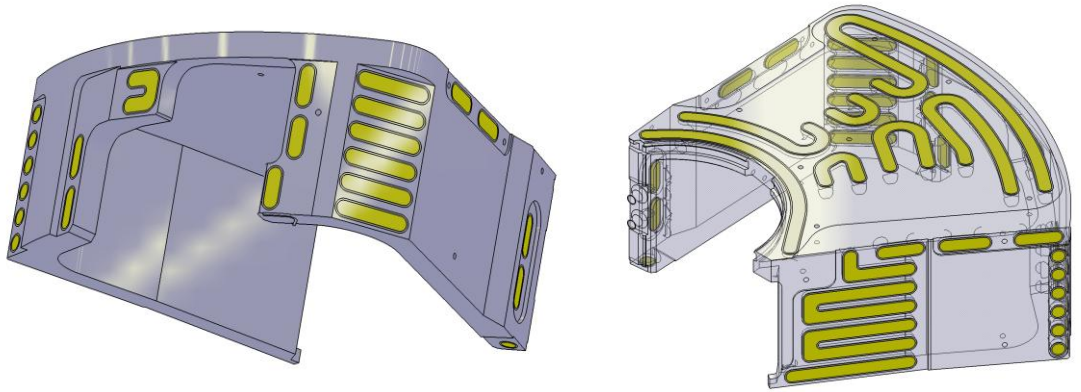
Upper Frame assembly – Overview

- *Housing of the moderator and reflector components or “outer reflector”*

- Pressure vessel made of low-Co stainless steel 304l
- TIG & MAC welded cooling channel covers (yellow)
- Light water at an inlet temp. of T_{in} = 308 K with a temp. increase of dT ≤ 11 K
- Design pressure 10 bar
- Operating pressure 8 bar
- Heat deposition of ca. 28.5 kW
- m = 582 kg (without water)



Final machined Upper Frame



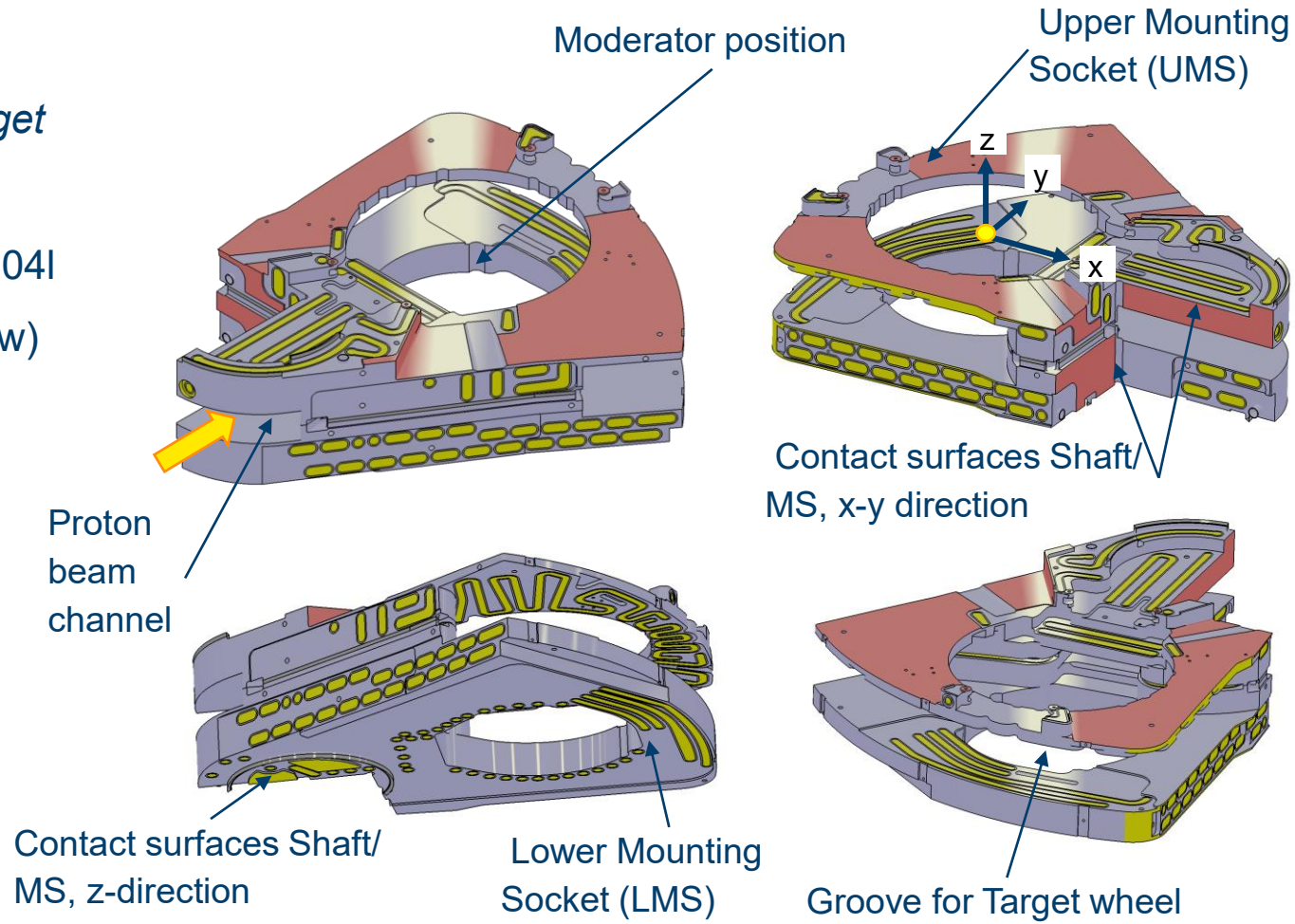
Final TIG/MAG welded Upper Frame

DESIGN SOLUTION MRP-II

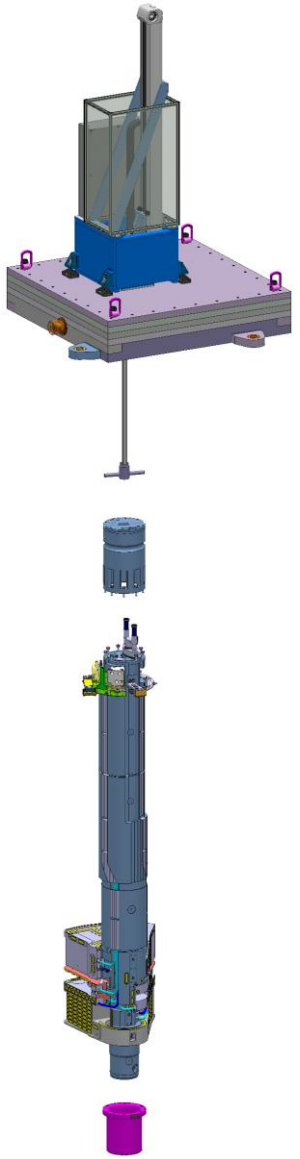
Mounting Socket assembly – Overview

➢ *Interface to Shaft, Moderators, Reflector and Target*

- Pressure vessel made of low-Co stainless steel 304l
- TIG & MAC welded cooling channel covers (yellow)
- Two independent cooling loops
- Light water at an inlet temp. of T_{in} = 308 K with a temp. increase of dT ≤ 15/26 K
- Design pressure 10 bar
- Operating pressure 8 bar
- Heat deposition of ca. 71 kW / ca. 107 kW
- m = 646 kg 242 kg+402 kg (without water)

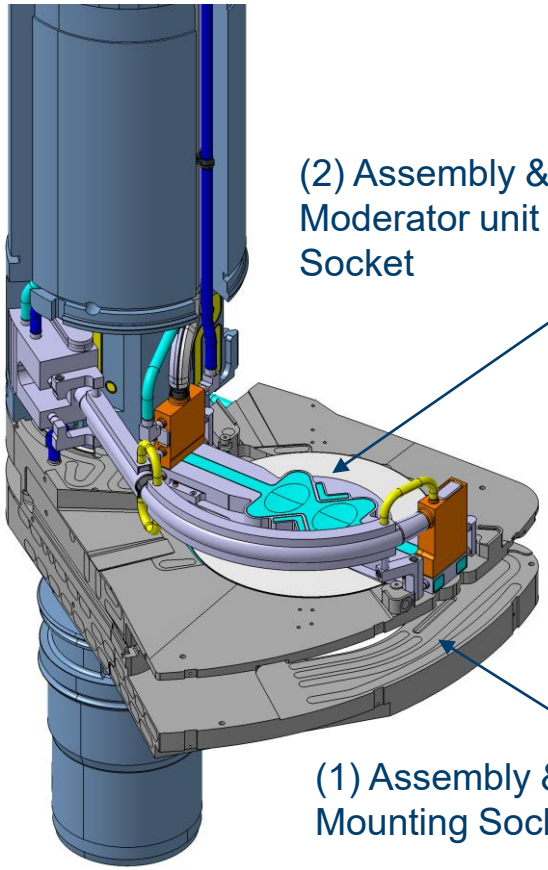


CONTENT



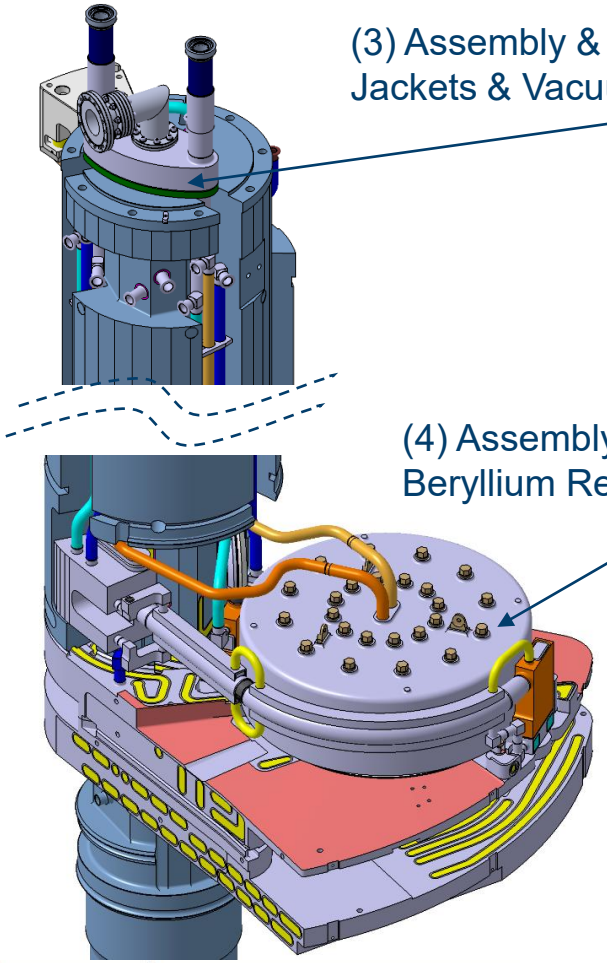
DESIGN SOLUTION MRP-II

Final assembly – Shaft, Mounting Socket and Moderators & Reflector assembly & welding



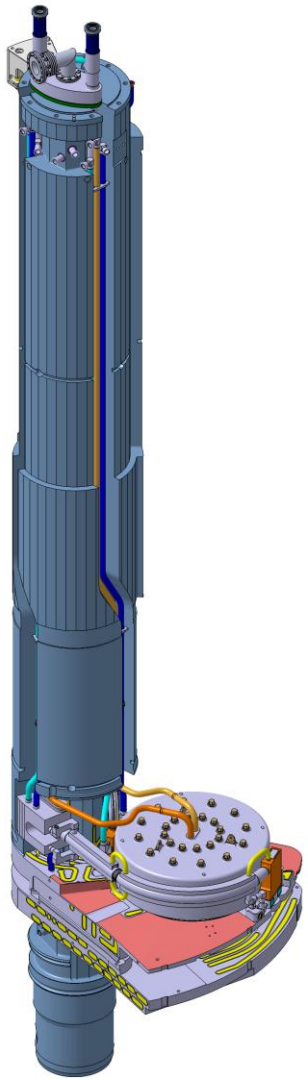
(2) Assembly & welding of Moderator unit into Mounting Socket

(1) Assembly & welding of Mounting Socket to the Saft



(3) Assembly & welding of Vacuum Jackets & Vacuum Chamber

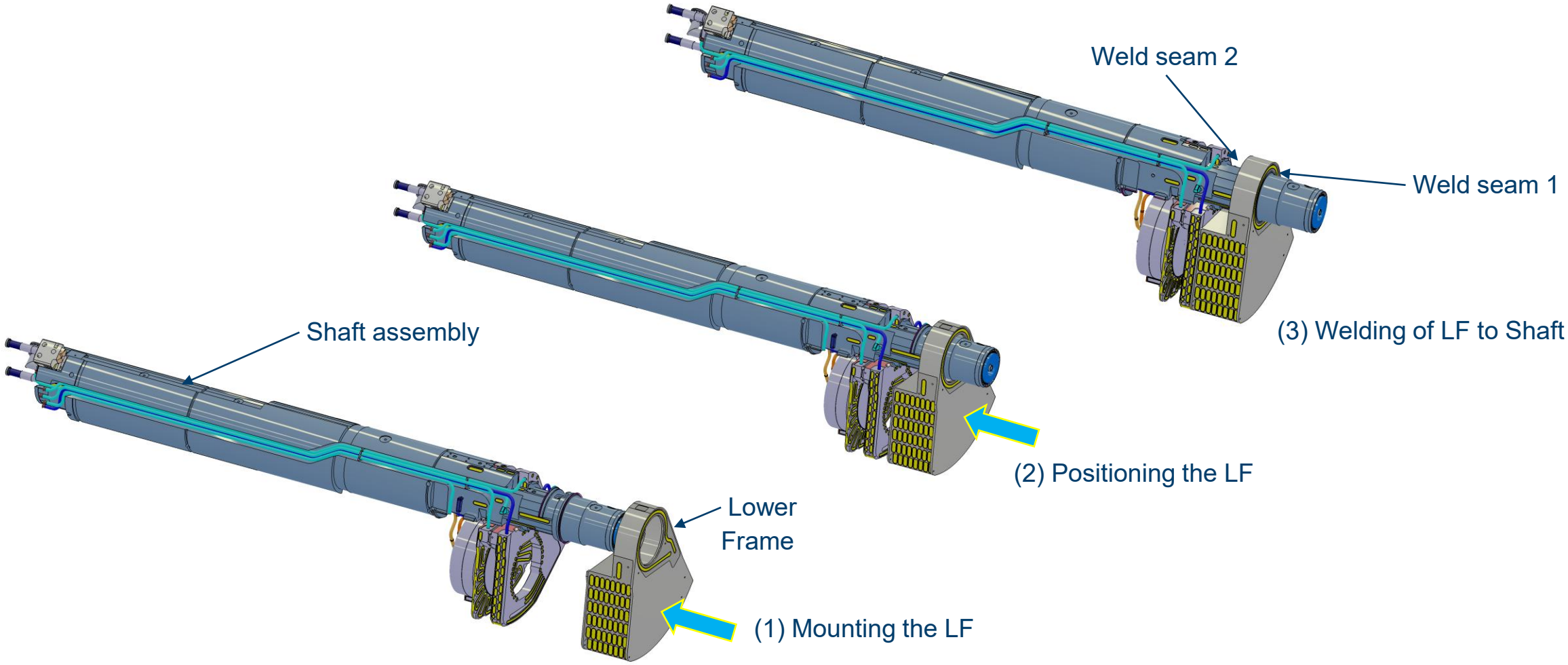
(4) Assembly & welding of Vacuum Beryllium Reflector



- MRP ready for first cool down (FAT)

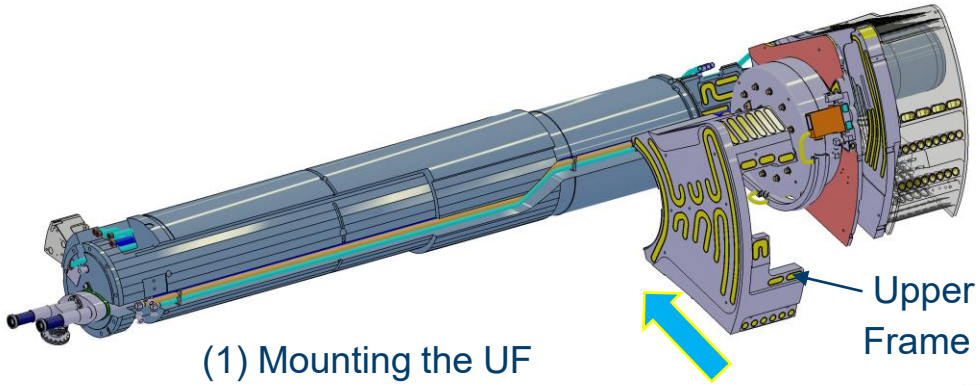
DESIGN SOLUTION MRP-II

Final assembly – Lower Frame assembly & welding



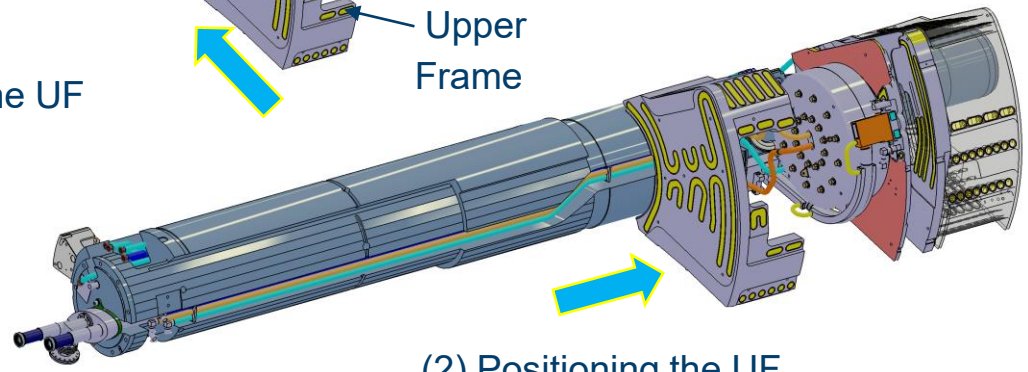
DESIGN SOLUTION MRP-II

Final assembly – Upper Frame assembly & welding

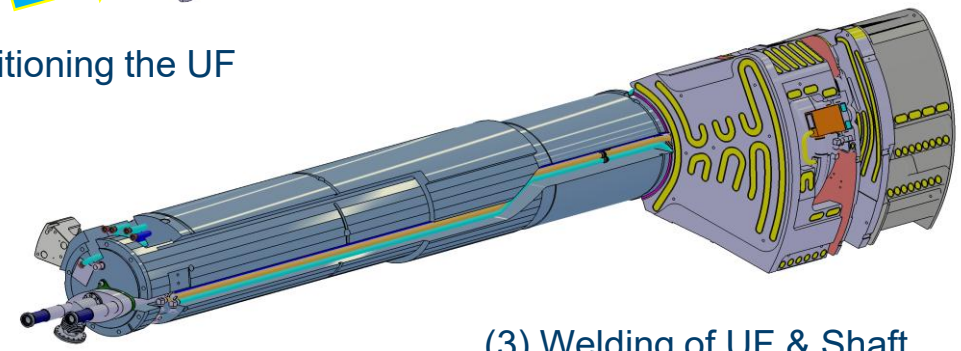


Upper Frame

(1) Mounting the UF



(2) Positioning the UF



(3) Welding of UF & Shaft

DESIGN SOLUTION MRP-II

Final assembly

(1) Assembly & welding of pipework

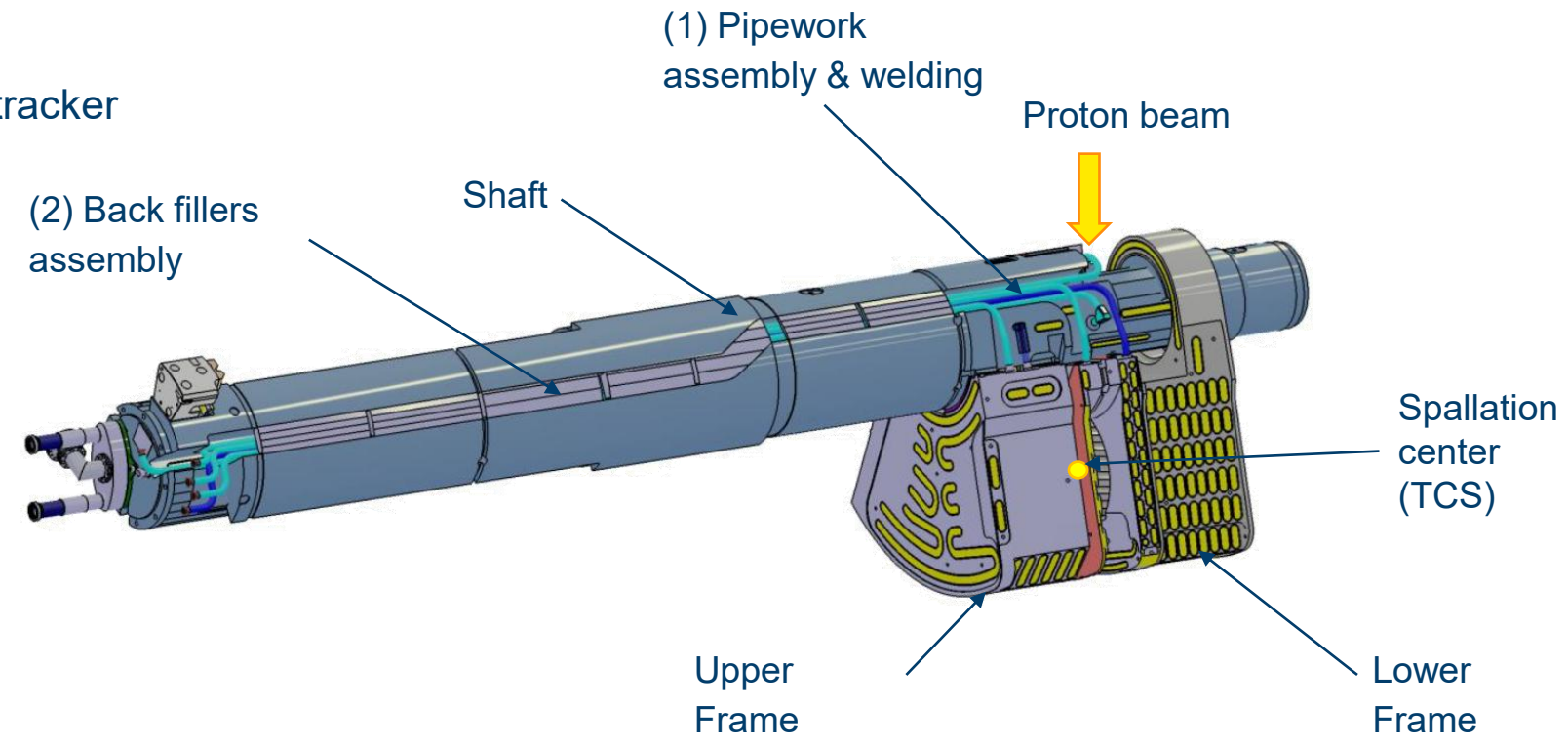
(2) Assembly of back fillers

(3) Final NDT

(4) Dimension check by laser tracker

(5) Final cleaning & packing

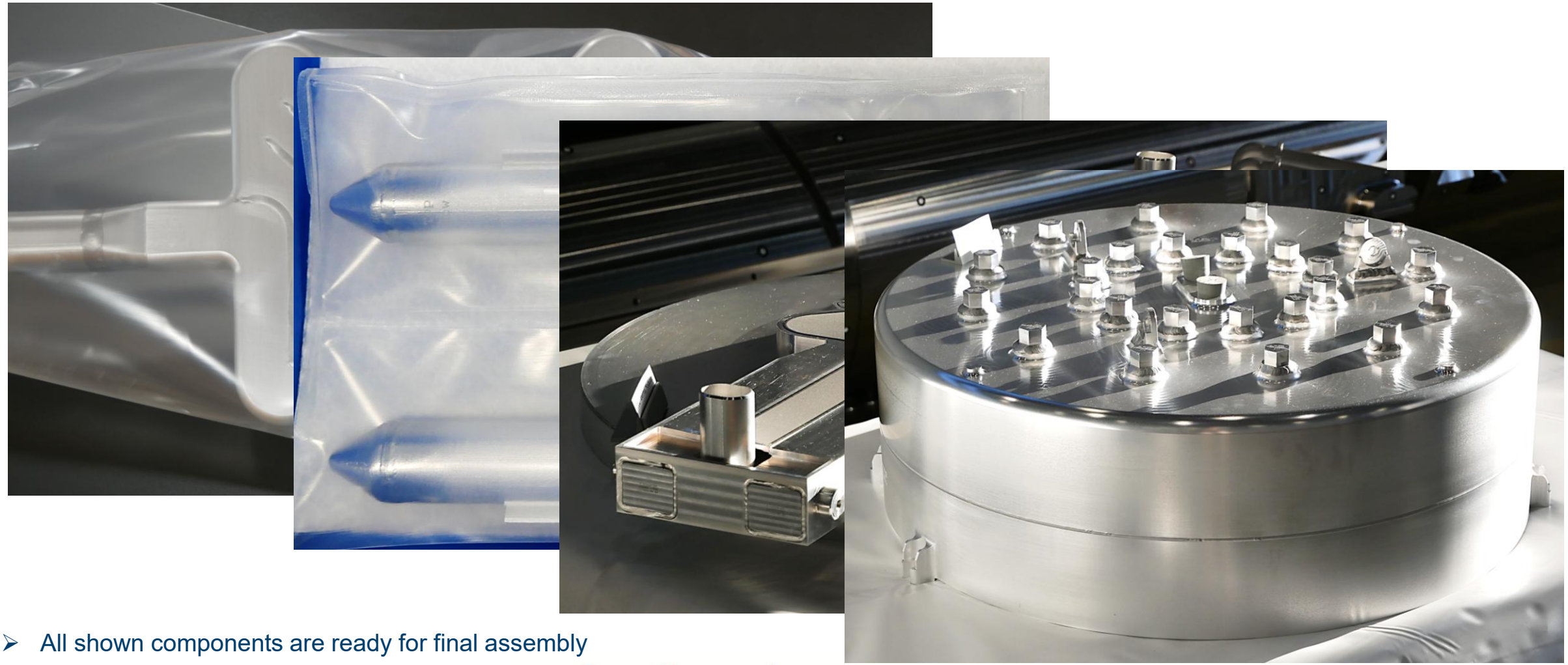
- Total weight 11.350 kg



CONTENT

Production status

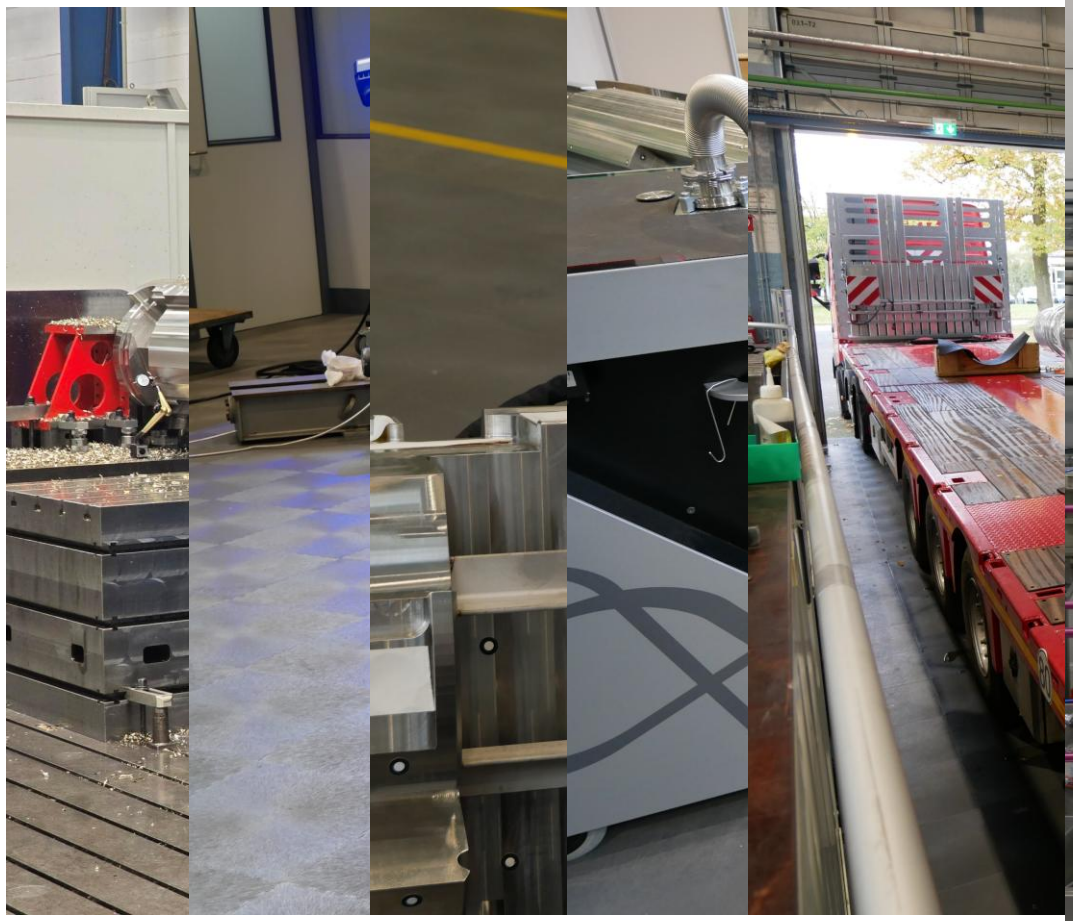
✓ **Cold Moderator, Irradiation Module, thermal Moderator & Beryllium Reflector**

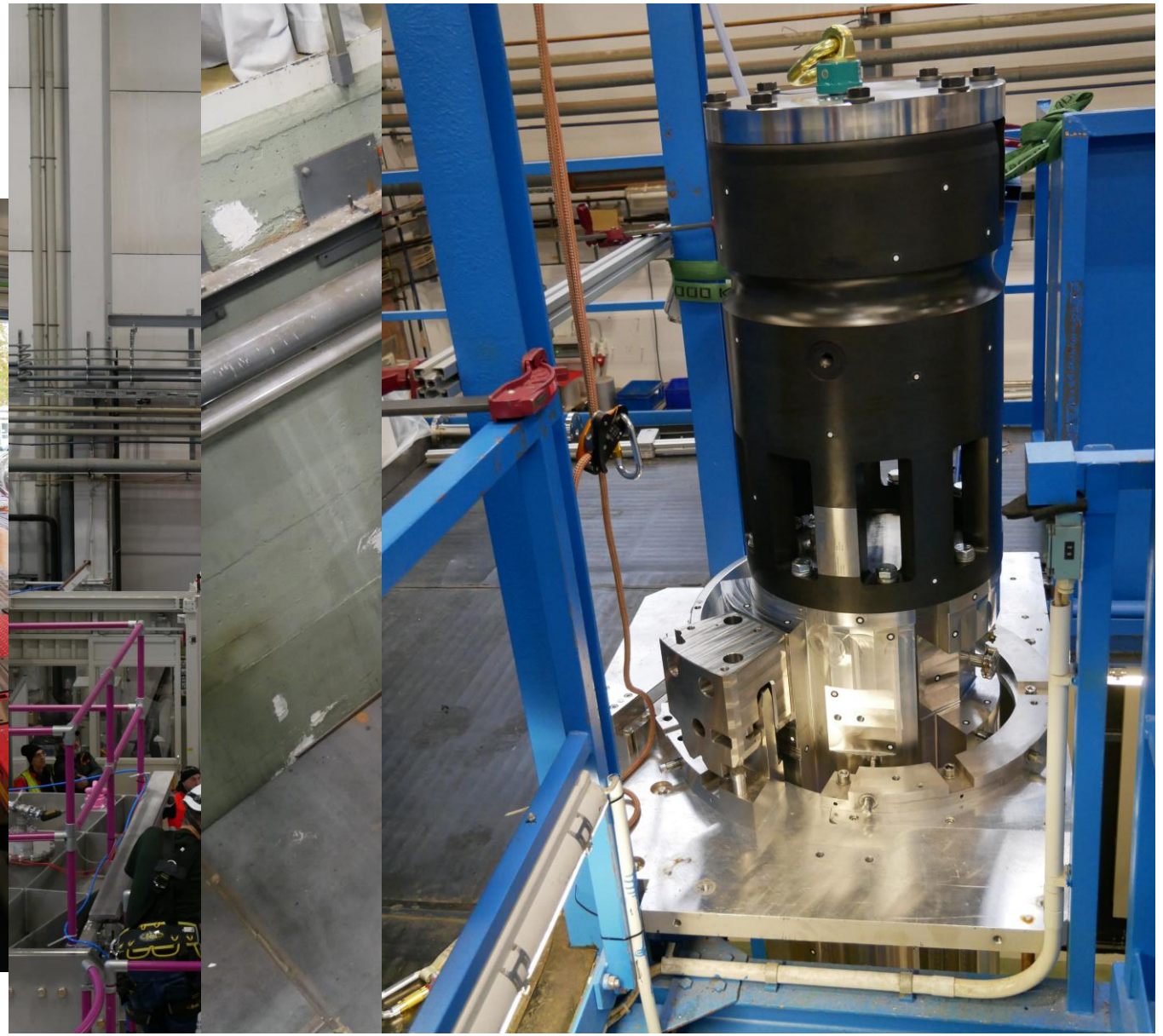


➢ All shown components are ready for final assembly

Production status

✓ **Shaft & Crown assembly**

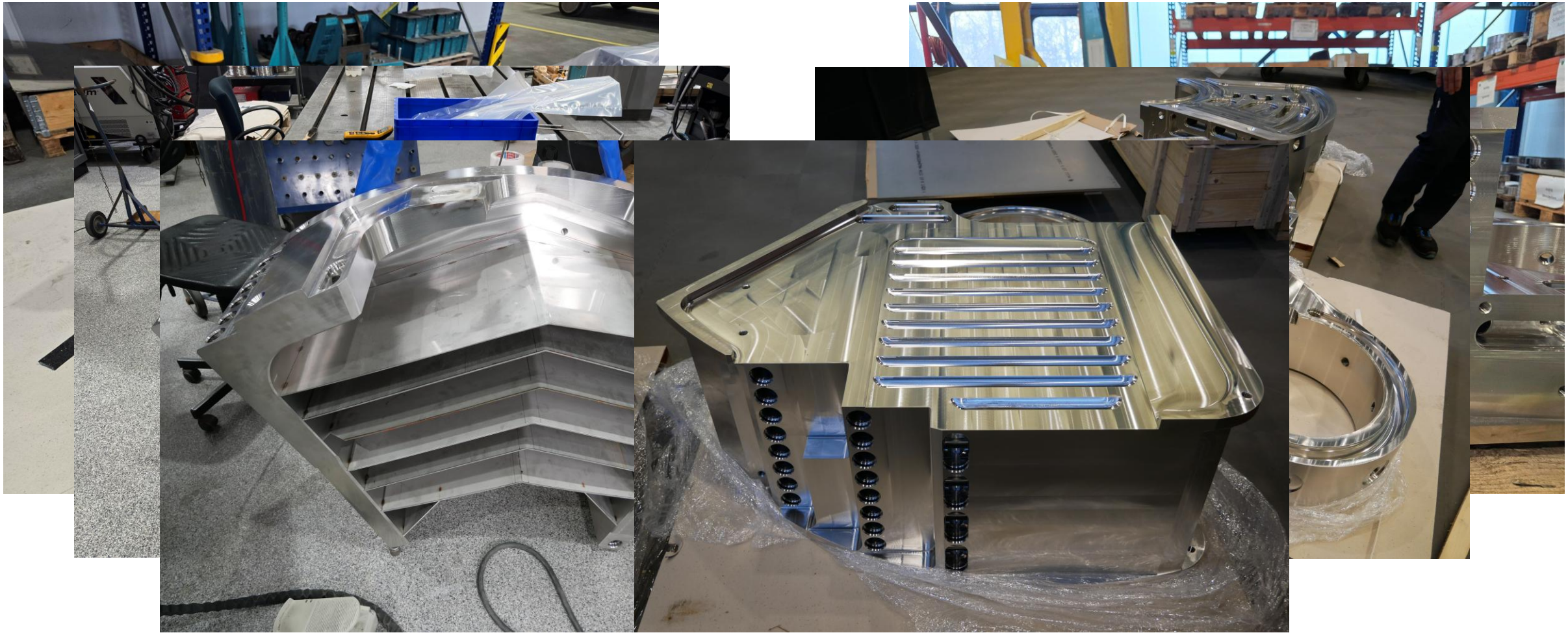




➢ All shown components are ready for final assembly

Production status

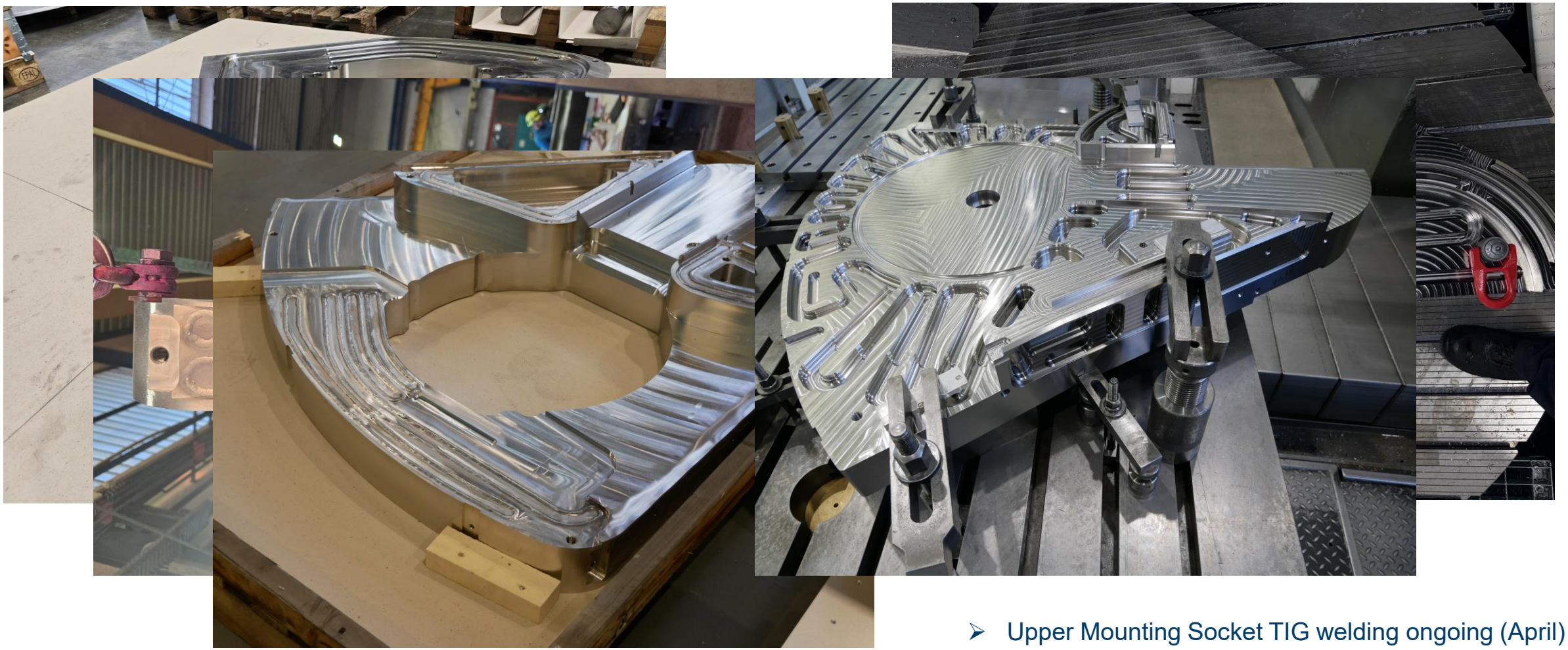
In progress: Upper Frame & Lower Frame



- Upper Frame TIG welding ongoing (April)
- Lower Frame TIG welding in preparation (May)

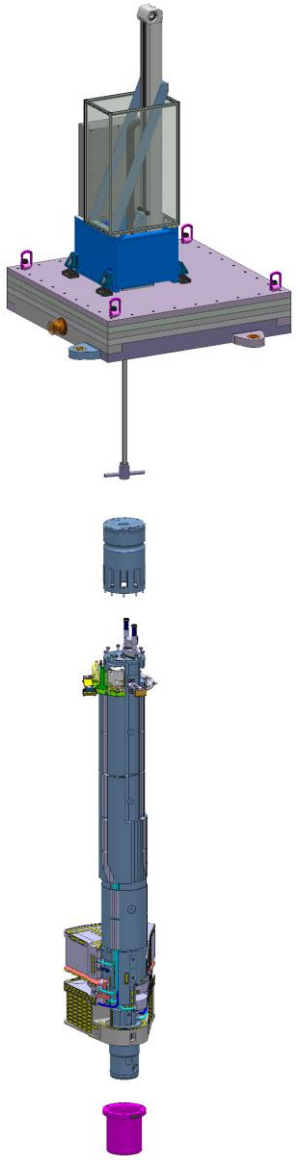
Production status

In progress: Upper Mounting Socket & Lower Mounting Socket



- Lower Mounting Socket ready for final assembly (March)
- Upper Mounting Socket TIG welding ongoing (April)
- Upper + Lower Mounting Socket TIG welding and final milling (May)

CONTENT



SUMMERY & OUTLOOK

- Project intime!
- Completion at approximately >90%

- Most critical assemblies are finalized including NDT, cleaning and documentation:
  - Cold Moderator
  - Irradiation Module
  - Thermal Moderator
  - Beryllium reflector
  - Shaft assembly
  - Crown
  - Rotation Unit (final FAT is scheduled for CW 17 & 18)

- Cool down of cold moderator (with Nitrogen at FZJ) last critical/risky task scheduled for June
- Final assembly scheduled for July to August
- Dimension control, cleaning and packing scheduled for September
- Delivery to ESS mid. October!

THANK YOU FOR YOUR ATTENTION!
QUESTIONS?

Technology@fz-juelich.de / www.fz-juelich.de/zea/zea-1