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ESS Moderator & Reflector Plug

Design, machining, welding and testing

IWSMT 13

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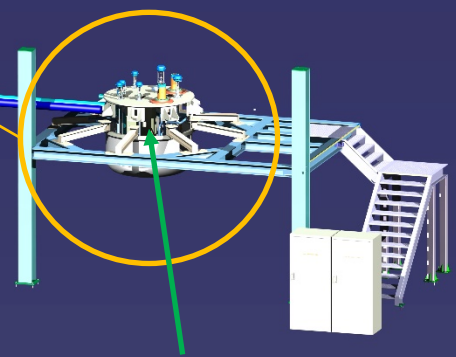
Outline

- Moderator & Reflector System Project status
- Frame and structural support (Twister)
- Main dimensions of Twister
- Assembly of Twister
- Moderator & Reflector Plug
- Moderator & Reflector Plug pre tests
- Cold Moderators design solution
- Cold Moderators manufacturing
- Thermal Moderator design solution
- Thermal Moderator manufacturing
- Assembling of cold and thermal Moderator
- Lower thermal Moderator and Irradiation Module
- Beryllium-Reflector design solution
- Be-Reflector manufacturing
- 1st and 2nd Burst test cold Moderator

Moderator & Reflector System

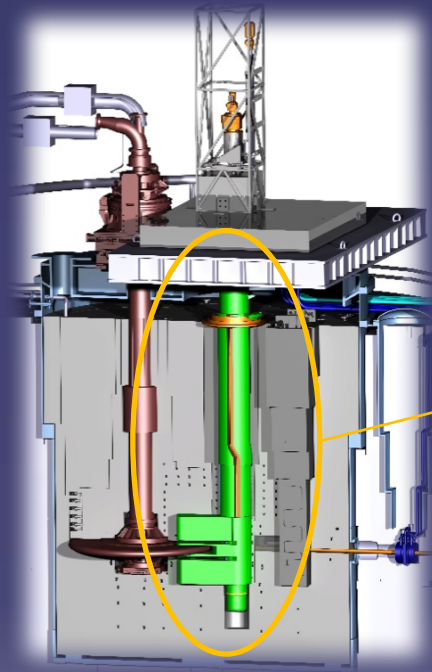
Project status

Cryostat
(CDR Dec. 2016)



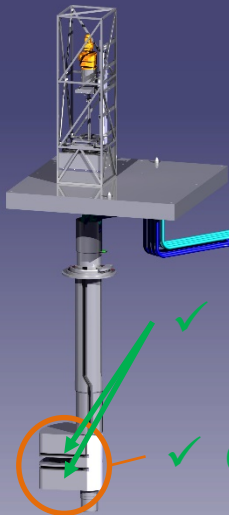
✓ LH2 Pumps
(CDR May 2016)

✓ Rotation Unit
(CDR May 2016)



Twister
(CDR Feb. 2017)

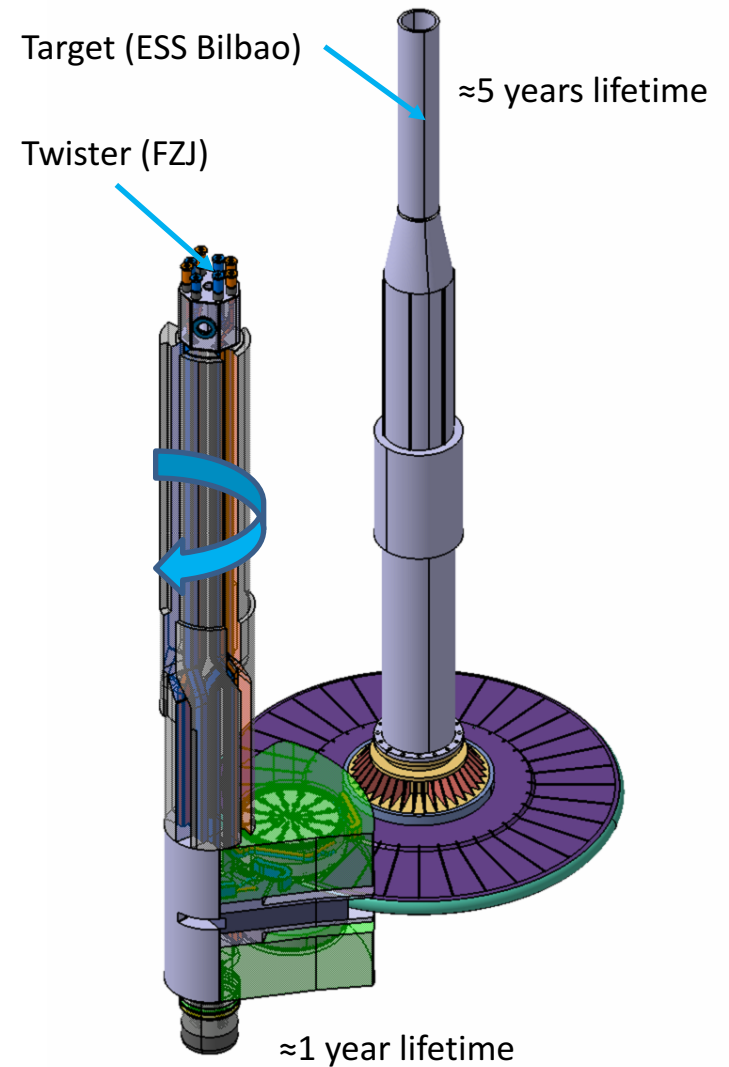
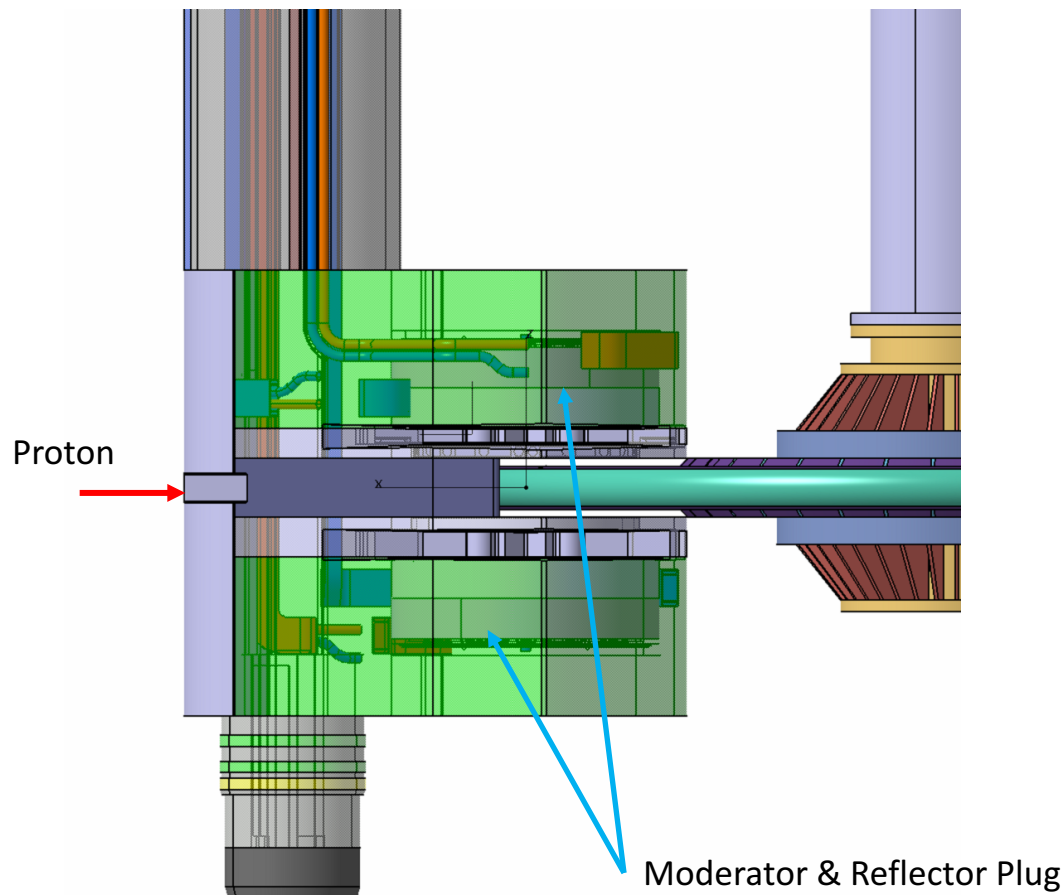
✓ Transfer lines
(CDR May 2016)



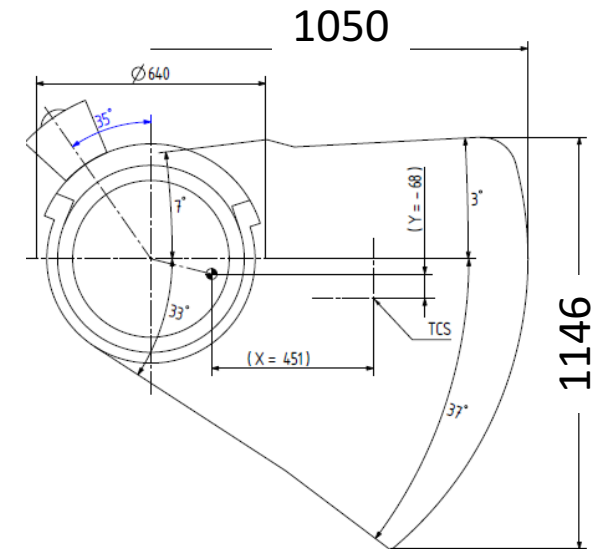
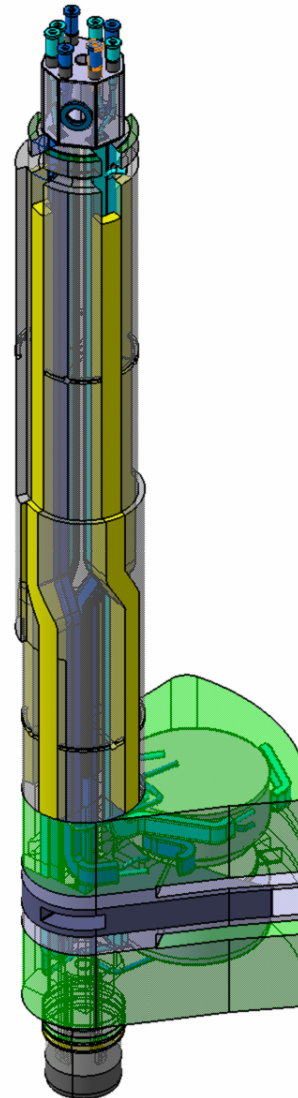
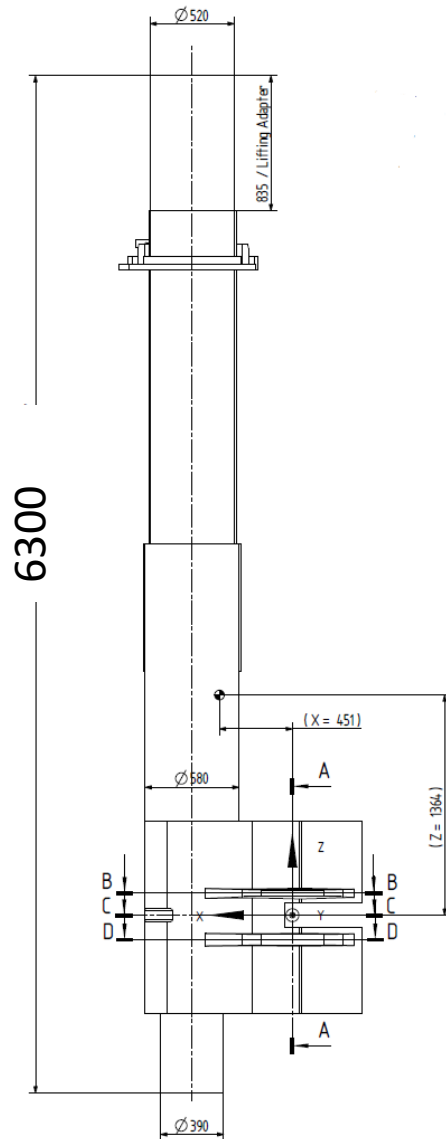
✓ Be raw material (CDR May 2016)

✓ Cold Moderators, thermal Moderators, Reflectors (CDR Oct. 2016)

Frame and structural support (Twister)

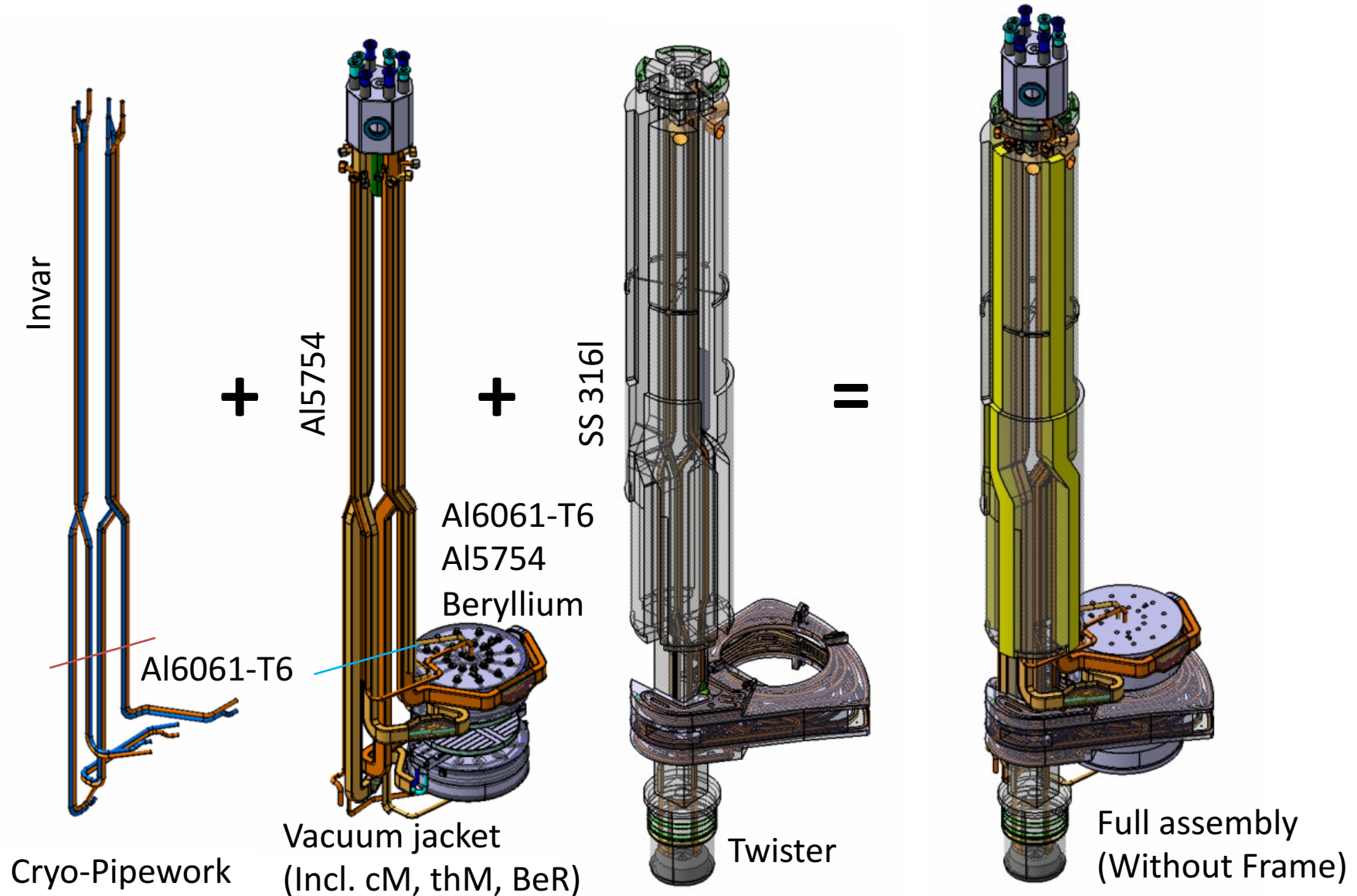


Main dimensions of the Twister

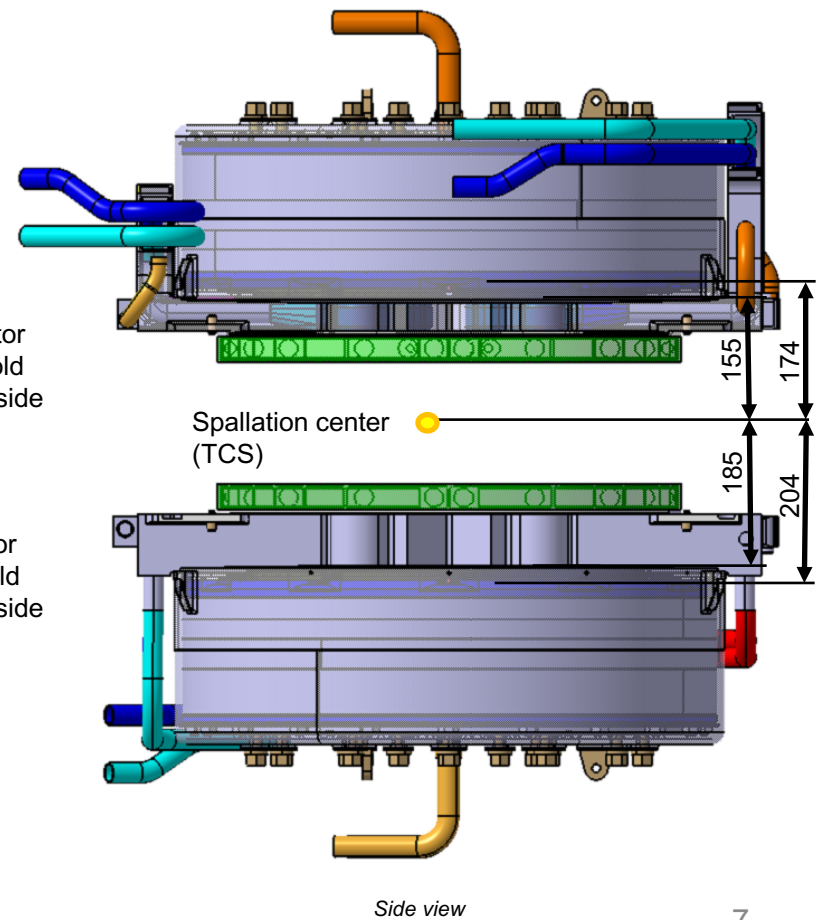
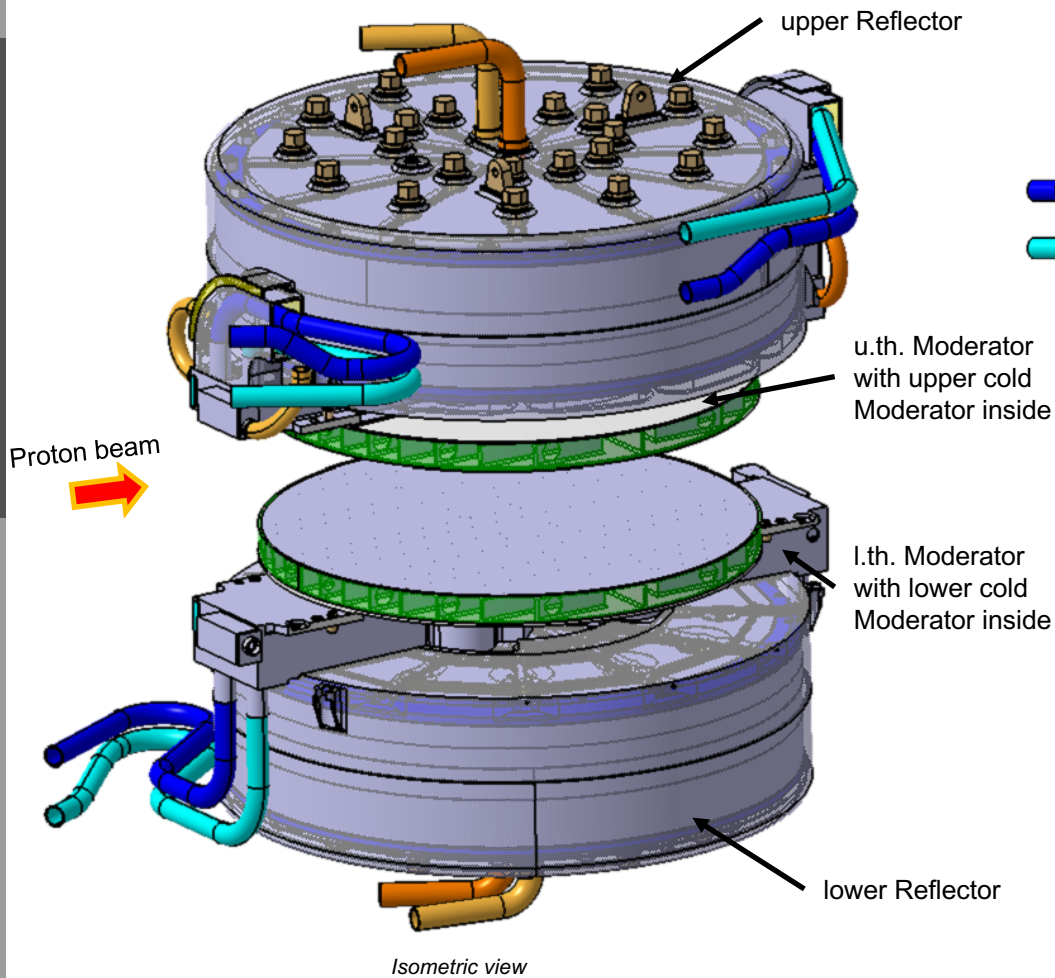


Material		Unit
316L	15530	kg
Aluminium	290	kg
Beryllium	280	kg
Invar 36	100	kg
Total Weight	16200	kg

Assembly of Twister



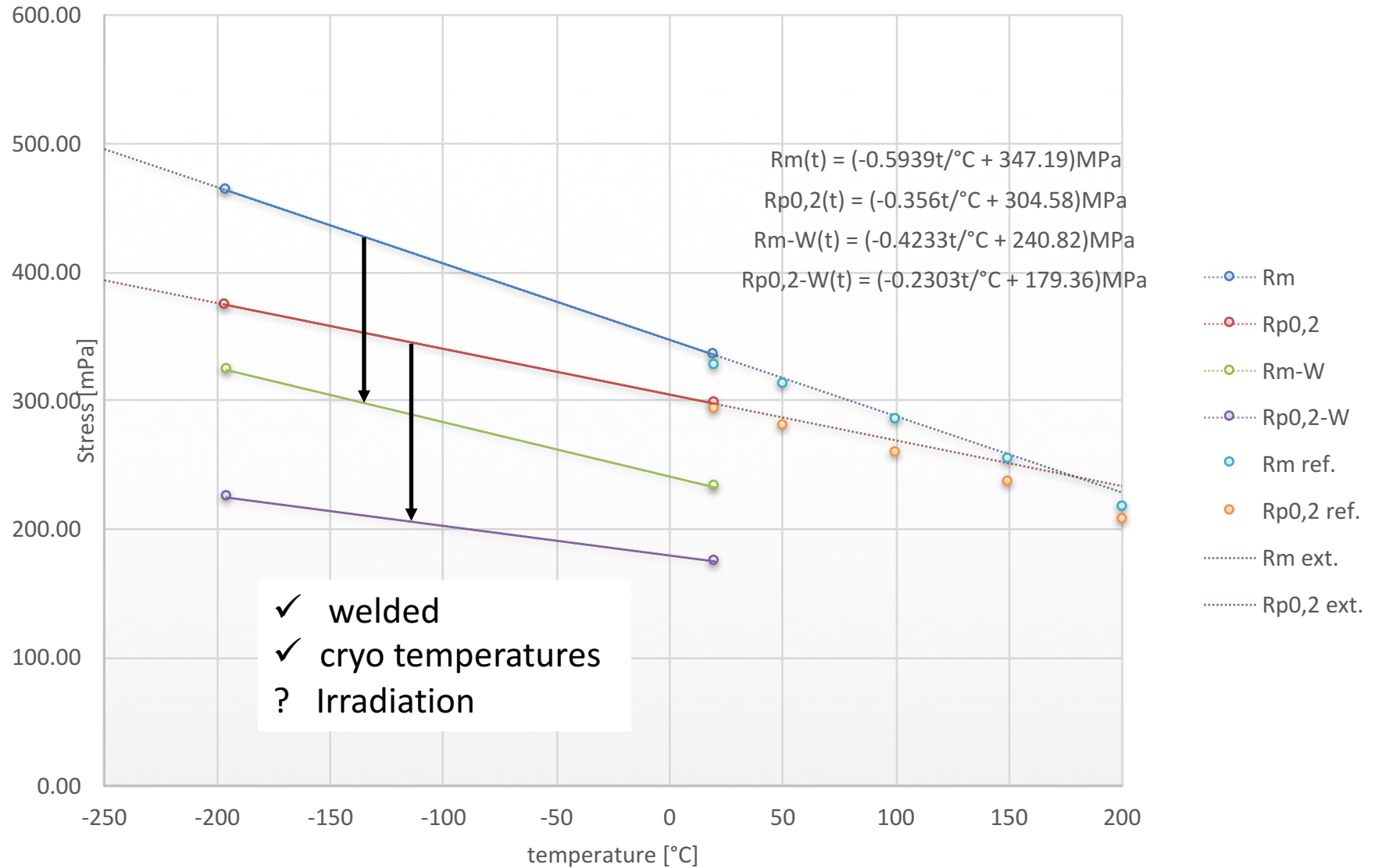
Moderator & Reflector Plug



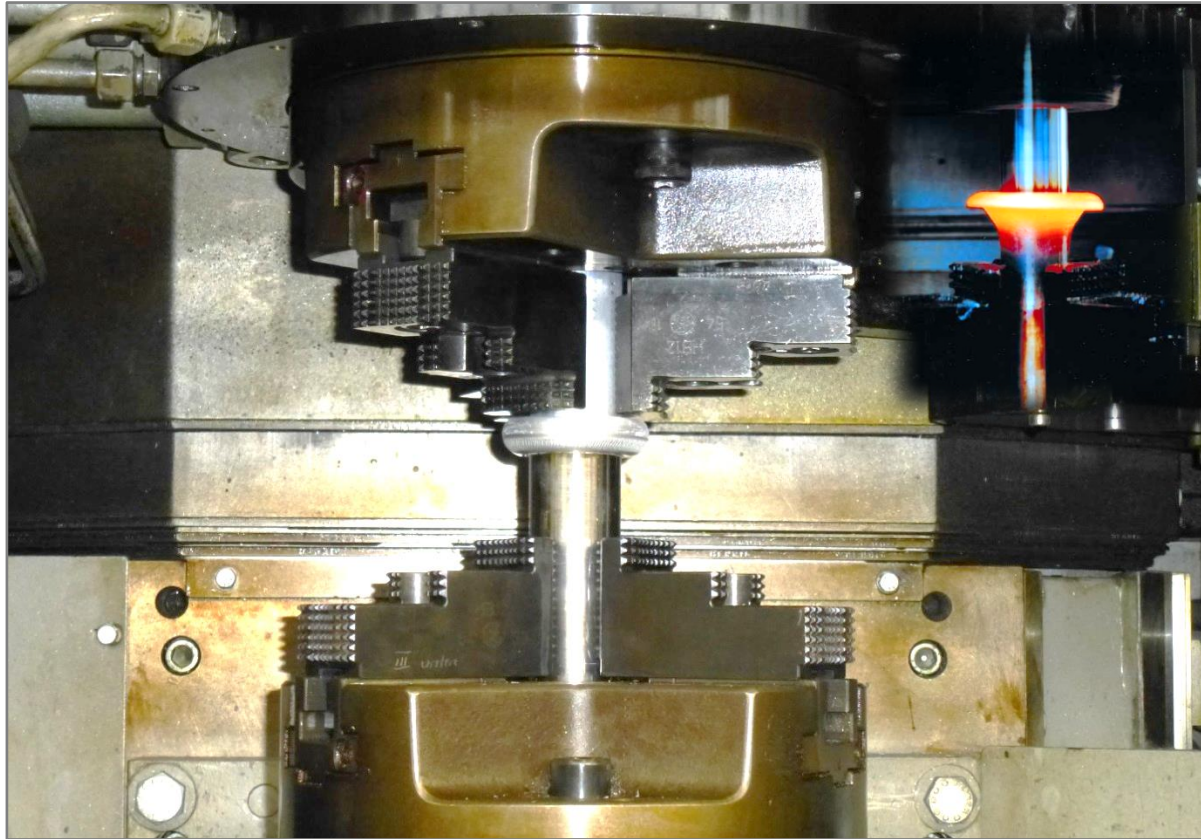
Pre tests: 6061-T6 properties at cryo-temperatures (welded and unwelded)



Yield strength and tensile strength of 6061-T6



Pre Test 2: Friction welding tests (Cryo-Pinework)



→ Burst pressure 229...237 bar

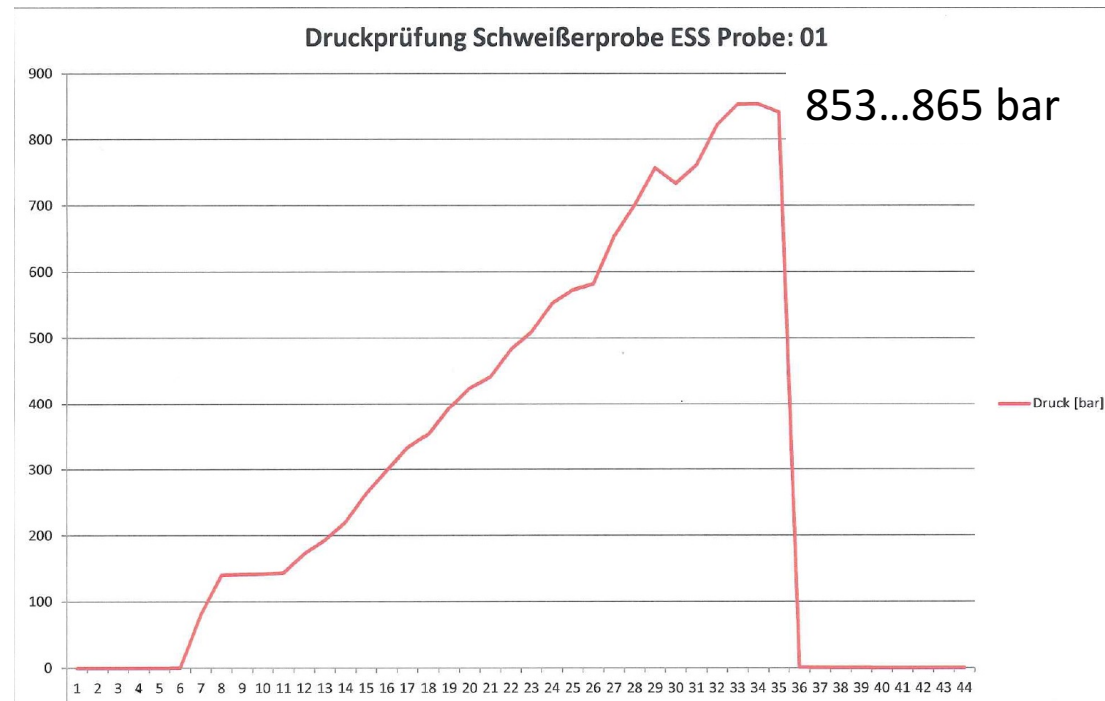


Pre test 3: Welding of Invar-SS (Cryo-Connectors)

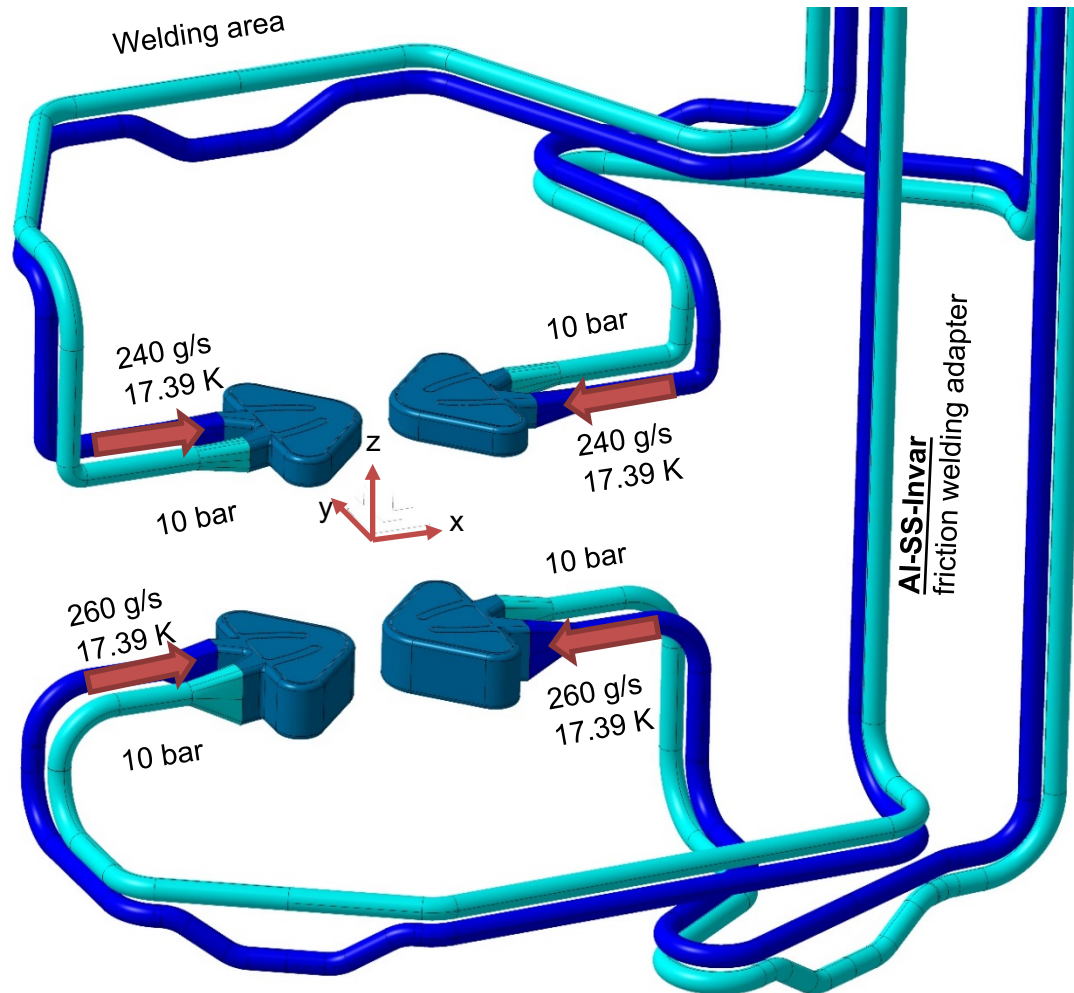


Filler 1.3912

Operation pressure will be 10 bar....

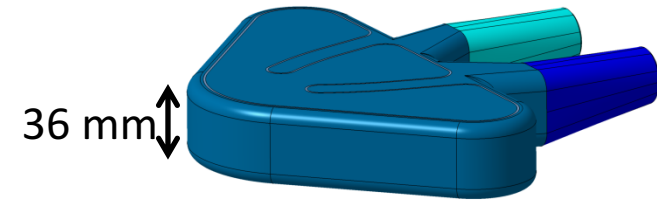
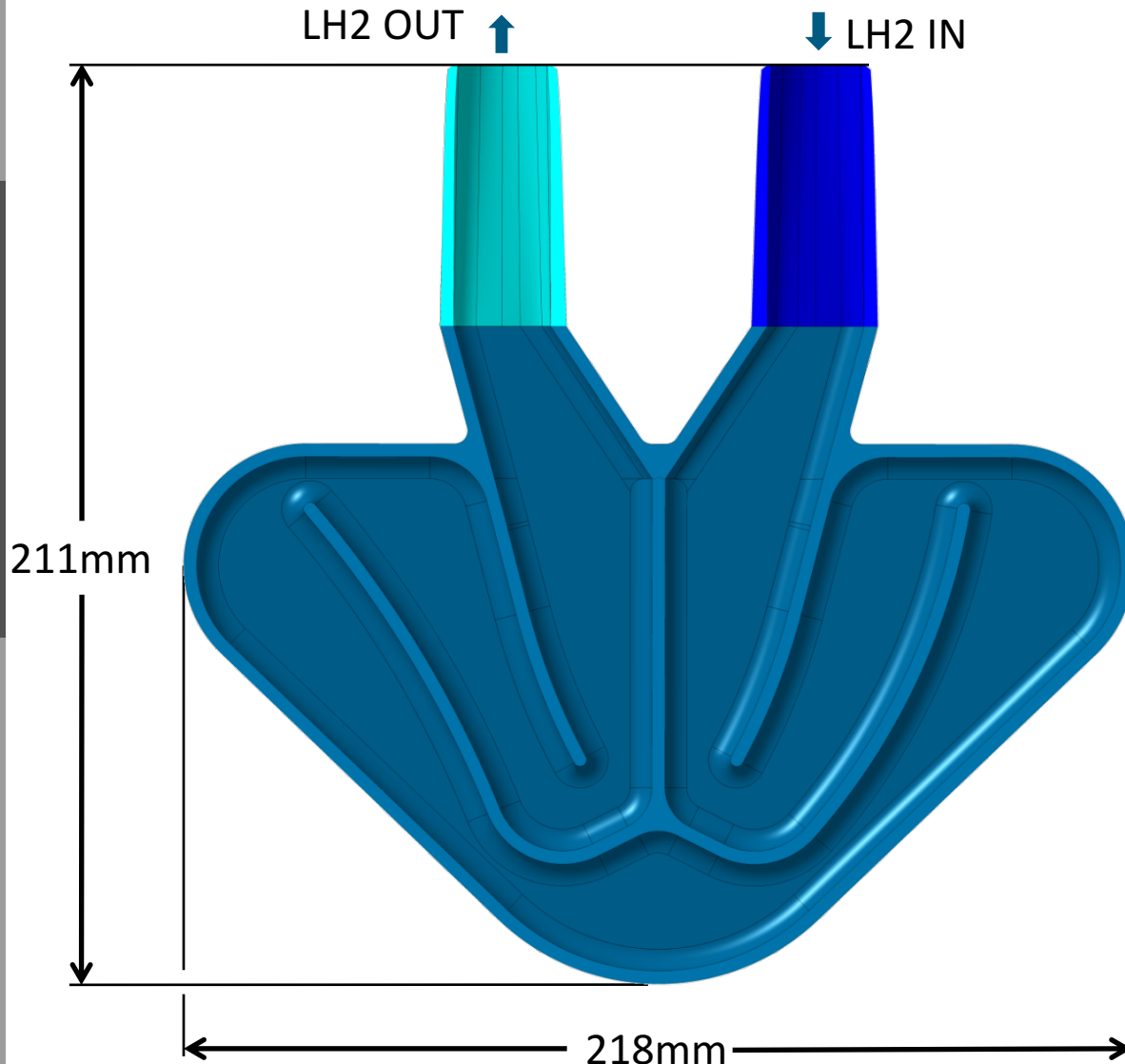


Cold Moderator design solution

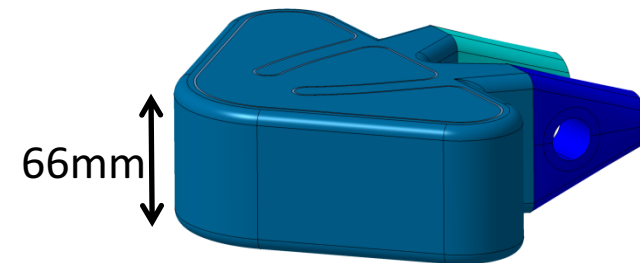


Invar necessary to reduce thermal expansion, but Invar loses the low expansion in the high irradiation area!
 → compromise: Invar pipework start 1 m far away....

Cold M. design solution – main dimensions

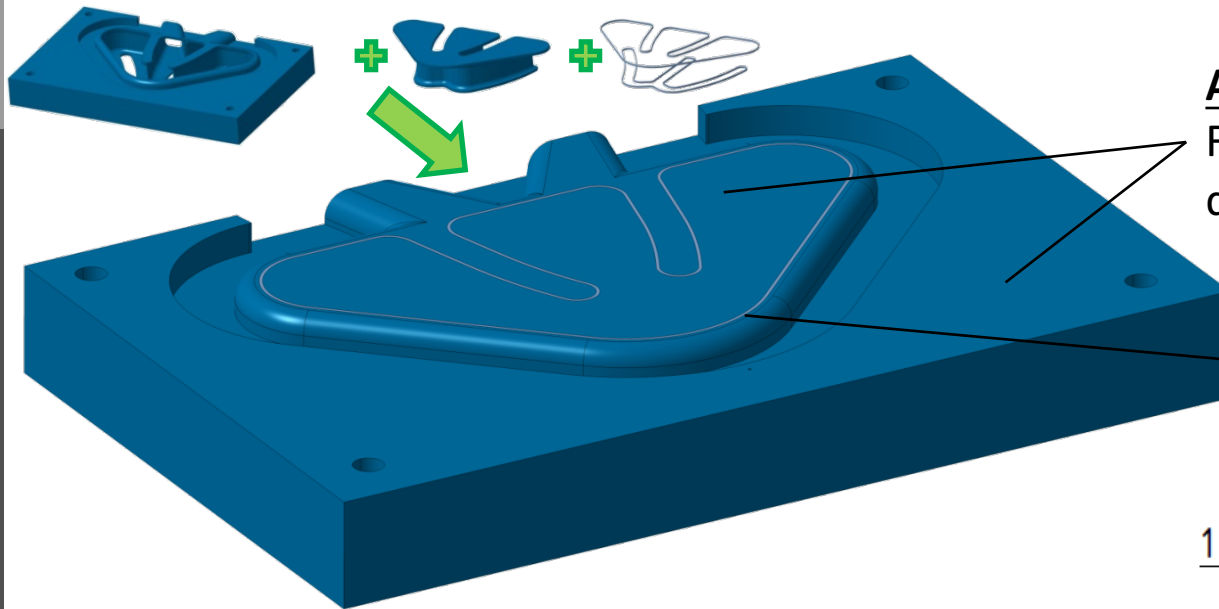


upper cold Moderator – **ucM**
(inner height = 30 mm, ca. 0.7 kg)



lower cold Moderator – **lcM**
(inner height = 60 mm, ca.1.17 kg)

Cold M. manufacturing – 1st step eBeam-welding

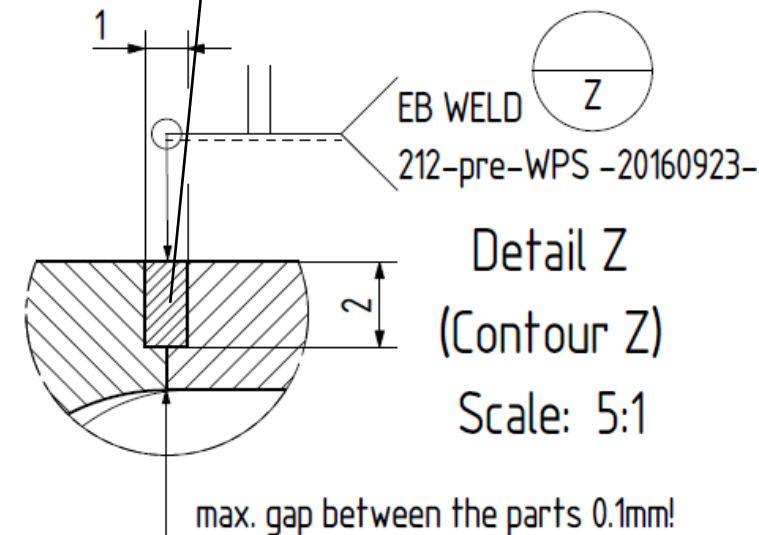
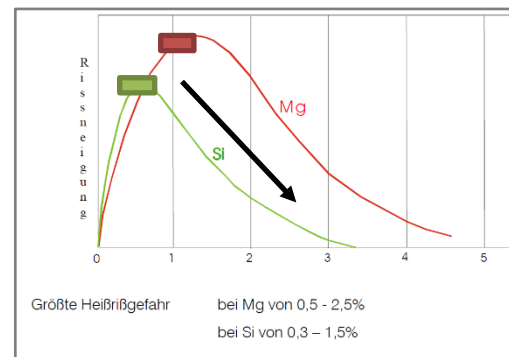


Al6061-T6 Vessel and Frame (to avoid deformation during welding)

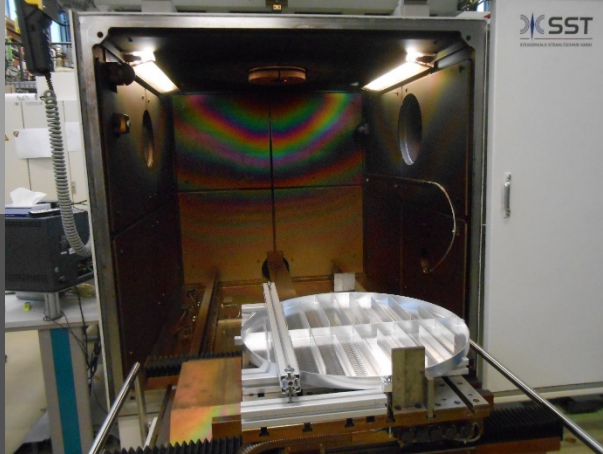
Al4047 (AlSi12) Filler (endless sheet strips)

Al6061-T6

- Si=0.4...0.8; Mg=0.8...1.2
- heat crack risk very high!
- Filler necessary to increase the Si content!



Cold M. manufacturing – 1st step eBeam-welding



eBeam welding machine



ultrasonic bath

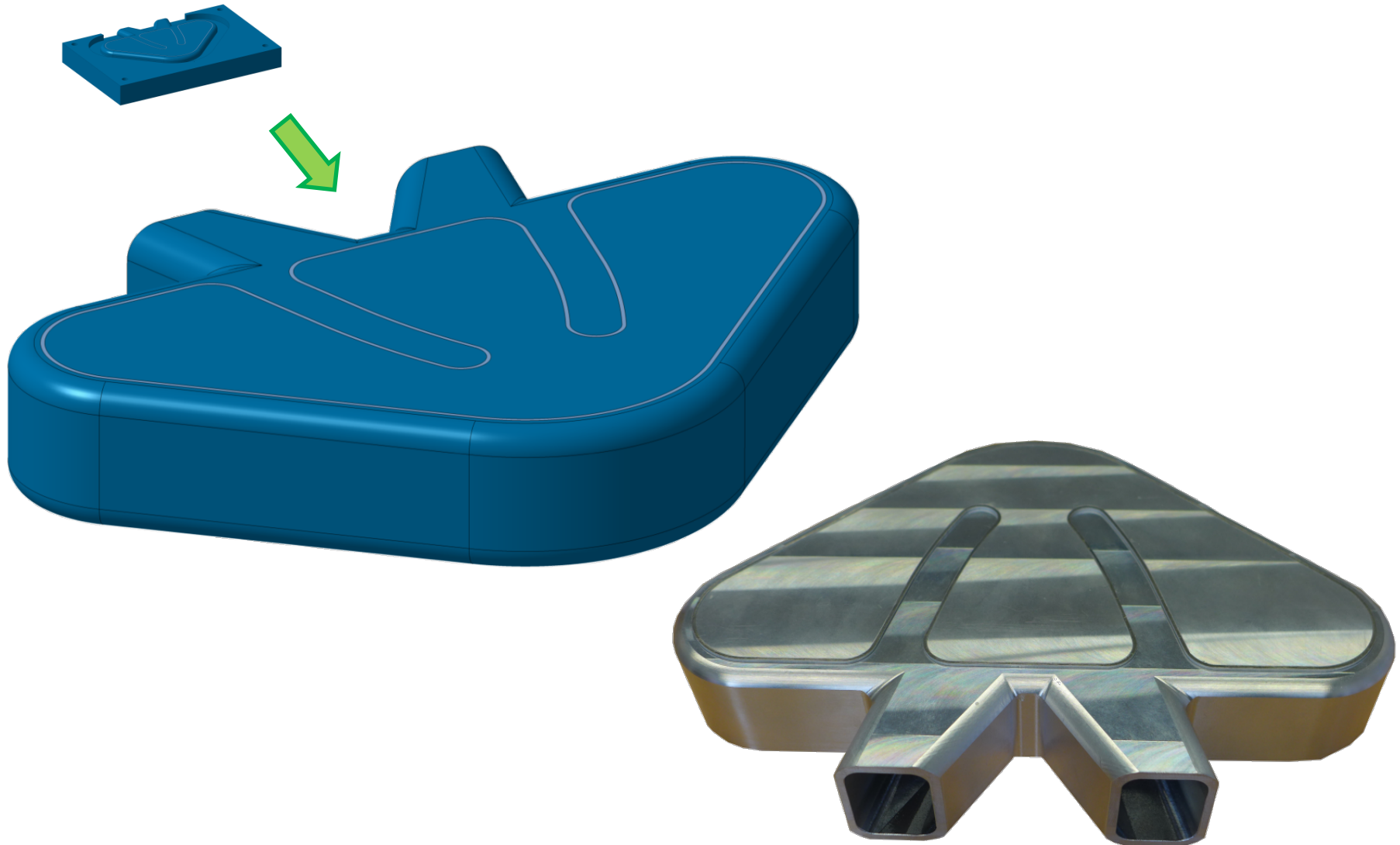


pickling bath (20 % HF 80 % H₂O)

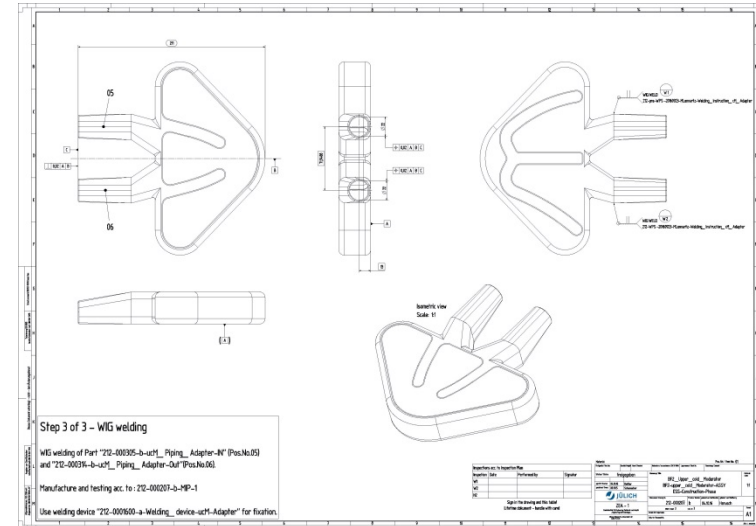
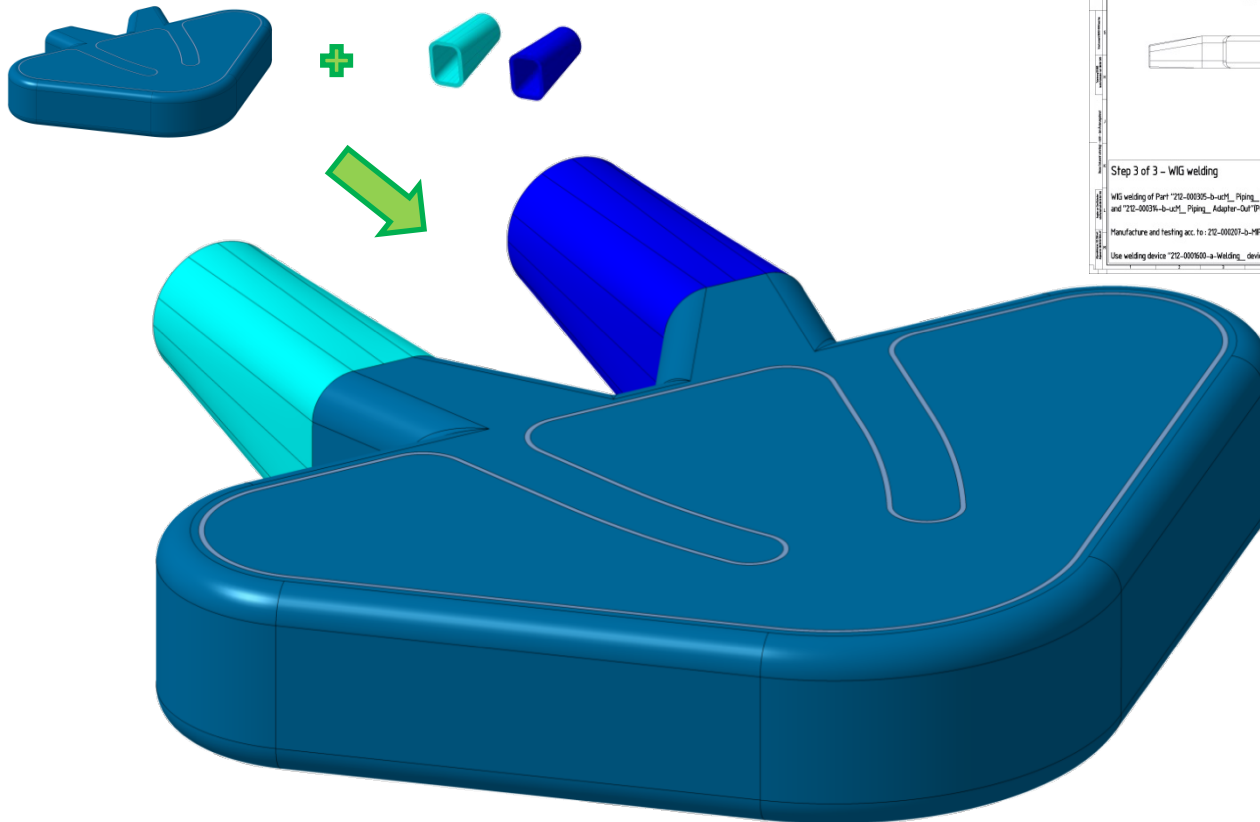
Additional:

- Al build very fast an oxide layer which have a negative effect for the quality of the weld
 - using welding process in an vacuum chamber (eBeam)
 - pickling to remove oxide layer
 - degreasing by ultrasonic bath, filled with alcohol before and after pickling
 - drying after degreasing
 - after drying, the rebuild of the oxide layer shall be stopped by vacuum packing
- High tolerances necessary for uniform weld seam
- Don't use EDM, laser cutting and so on in the weld area (negative surface effect for w.)
- Filler shall have minimum 12 % Silicon (welding area shall have >2% Si)
- Filler shall be a endless sheet strips (no breaks in the welding process)

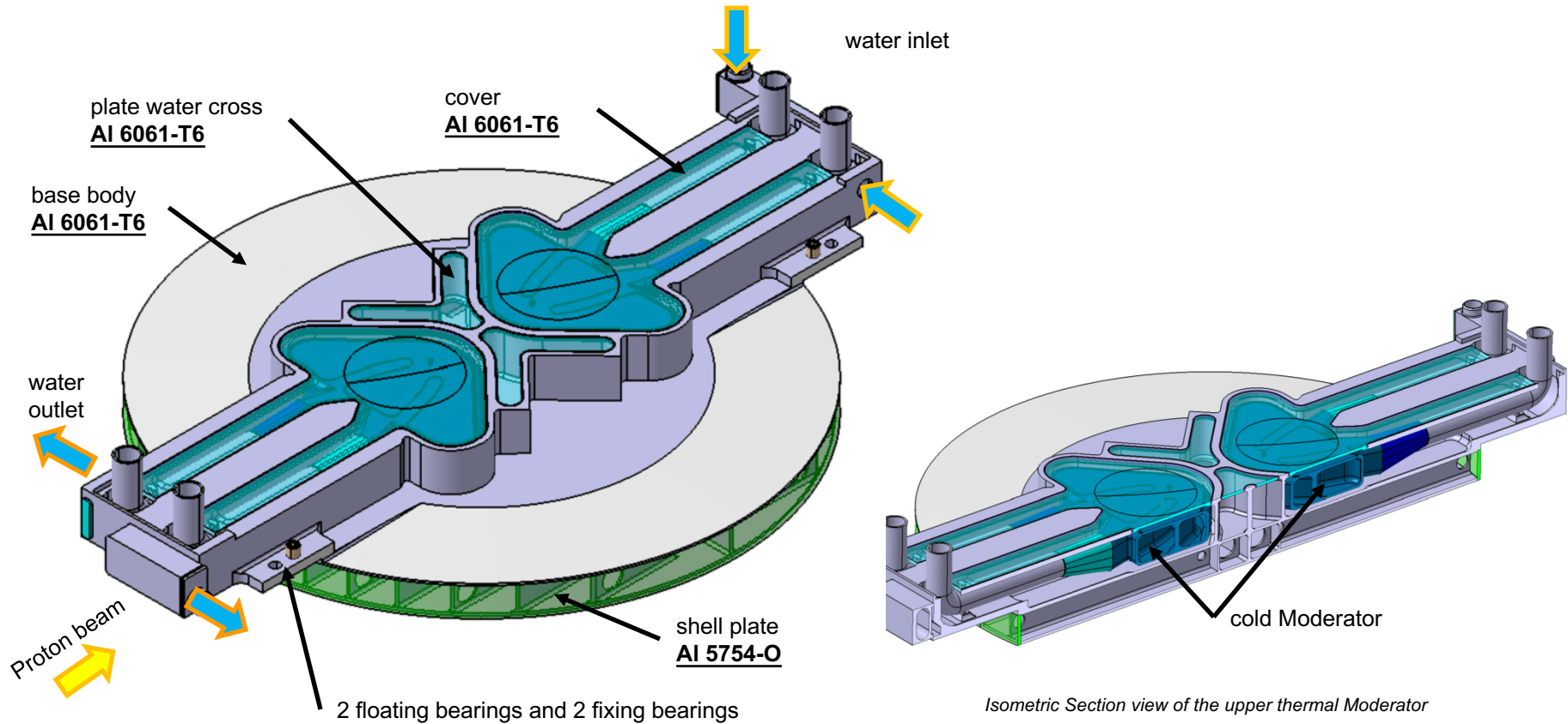
Cold M. manufacturing – 2nd step EDM



Cold M. manufacturing– 3rd step welding of the In- & Outlet Adapters



Thermal Moderator design solution



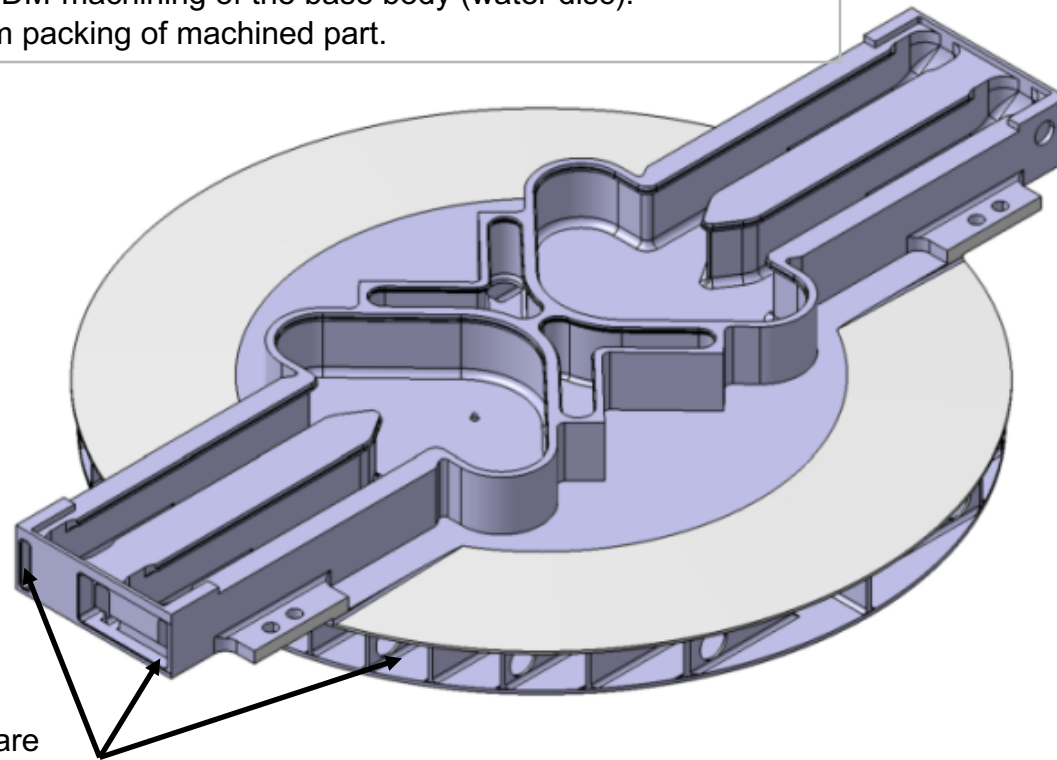
Isometric view of the upper thermal Moderator

Isometric Section view of the upper thermal Moderator

Thermal Moderator manufacturing

Step 1:

- Re-stamping and cutting of thermal Moderator parts
- First milling and EDM-machining of the base body (water disc).
- Clean and vacuum packing of machined part.



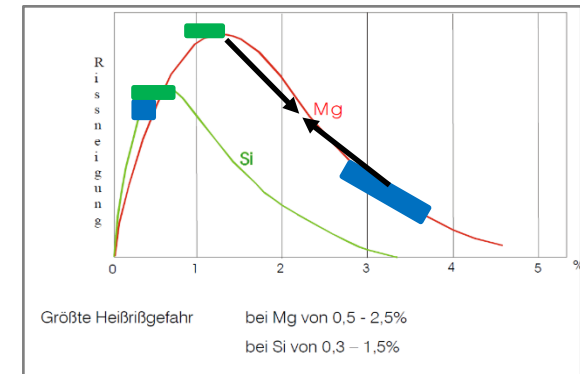
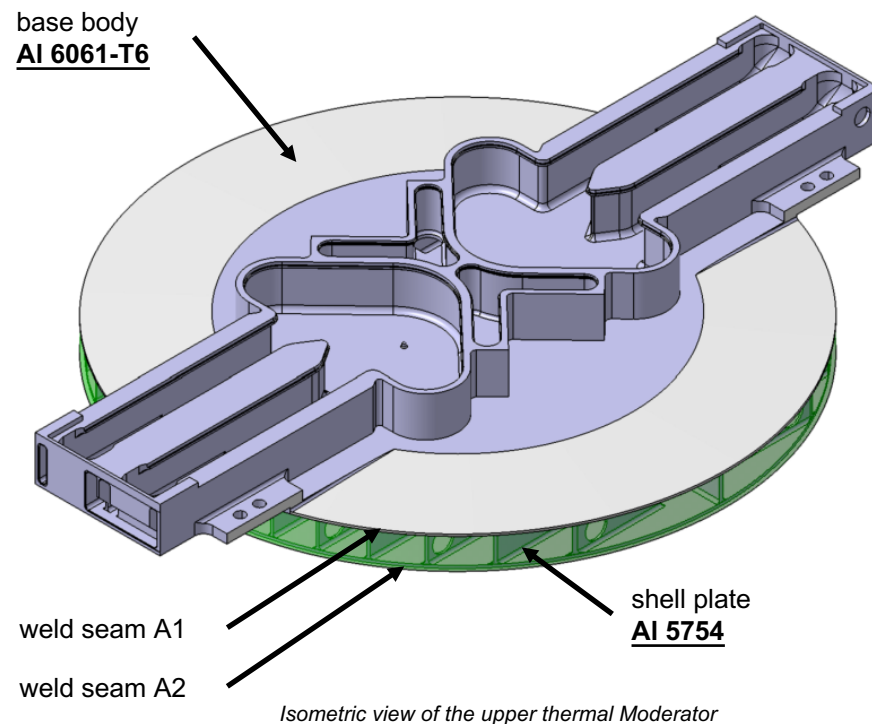
All water channels are
EDM-machined

base body, Al 6061-T6
(full block)

Thermal Moderator manufacturing

Step 2:

- Positioning of shell plate
- e-Beam welding of water disc with ring (without filler!).
- Final milling of the base body.
- Clean and vacuum packing of machined part.



Al 5754 [Si=0.4; Mg=2.6...3.6]

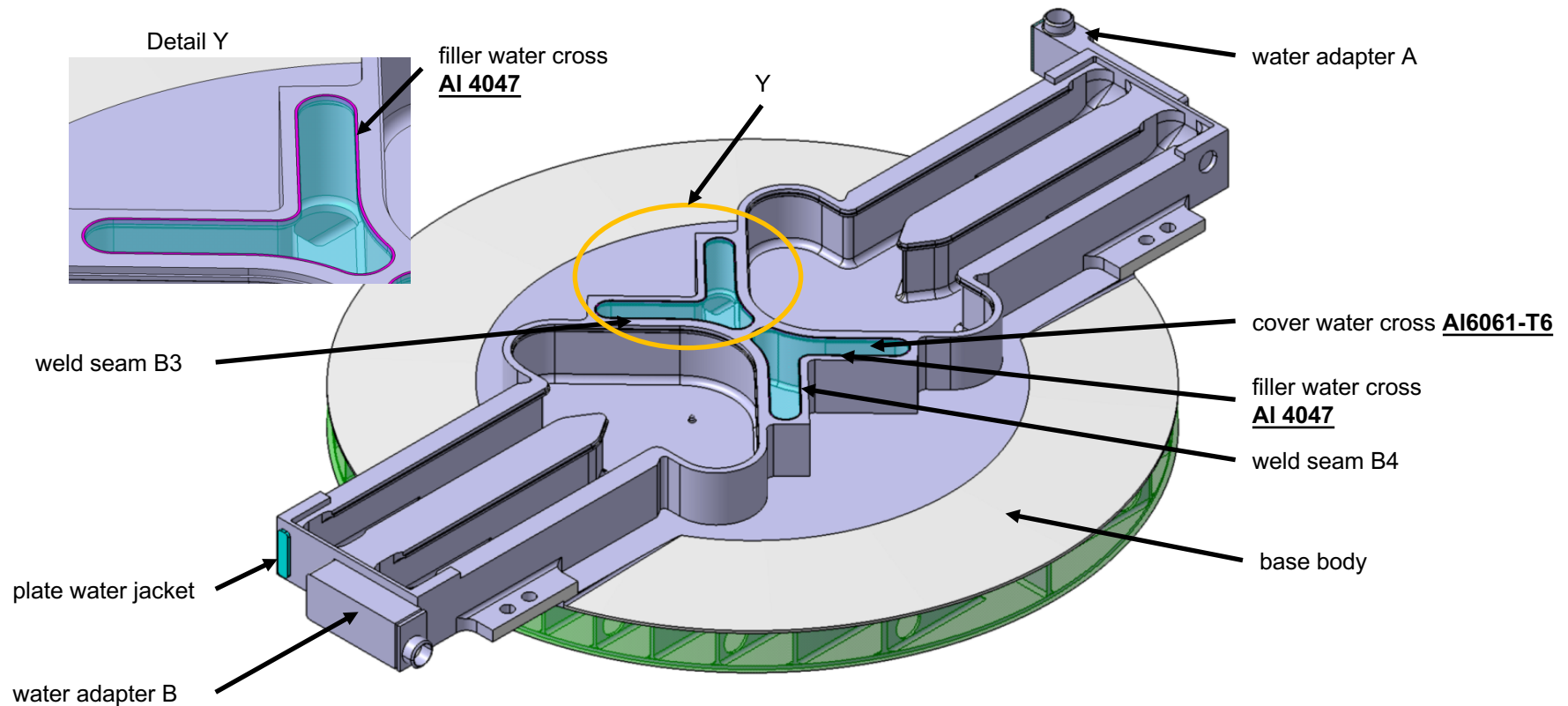
Al6061-T6 [Si=0.4...0.8; Mg=0.8...1.2]

-medium heat crack risk, but the rotationally symmetrical geometry will not block the fast shrinkage during solidification... Therefore, in this case, no filler acceptable!

Thermal Moderator manufacturing

Step 3:

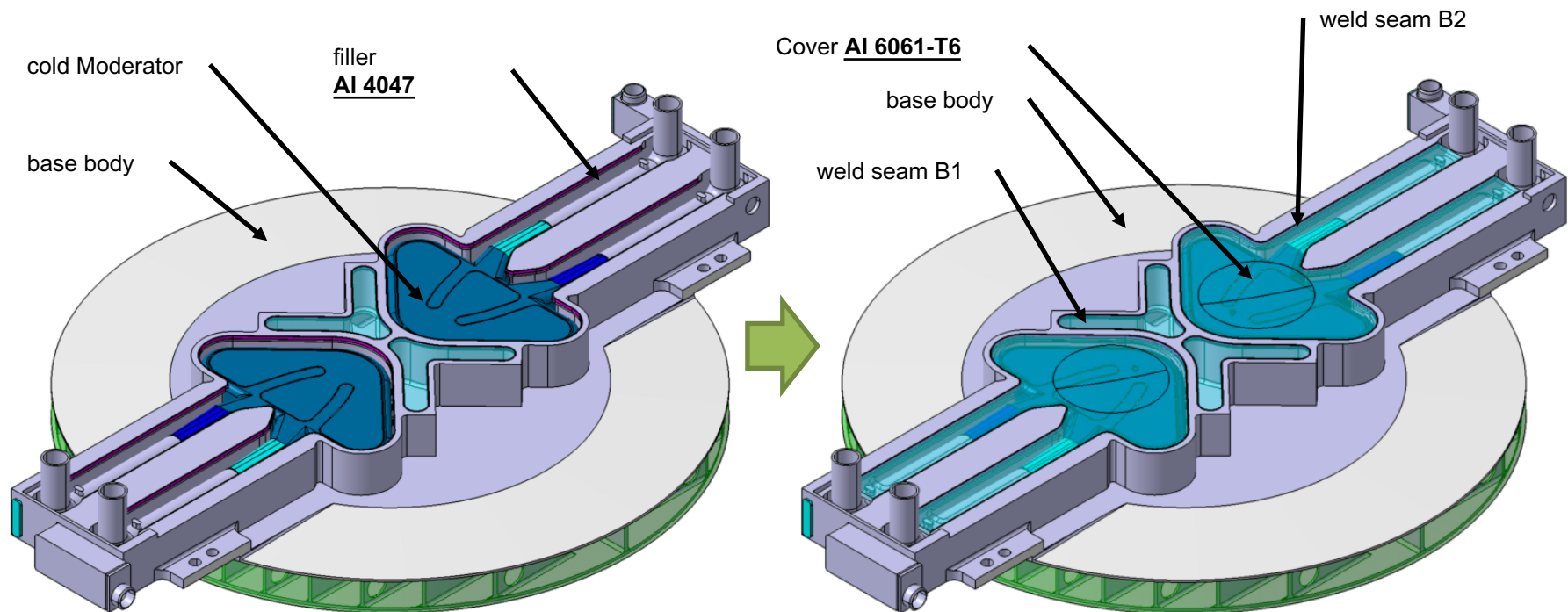
- Positioning of the 2 filler and the 2 cover plates of the water cross in the base body.
- e-Beam welding of the 2 cover plates of the water cross with the base body.
- The 2 plates of the water jacket, the water adapter A and water adapter B are welded with the base body.



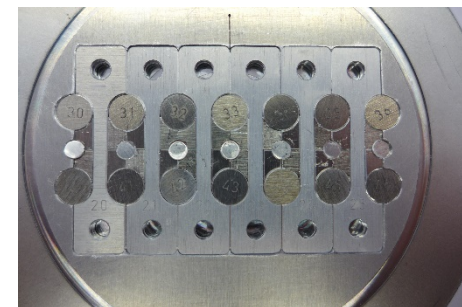
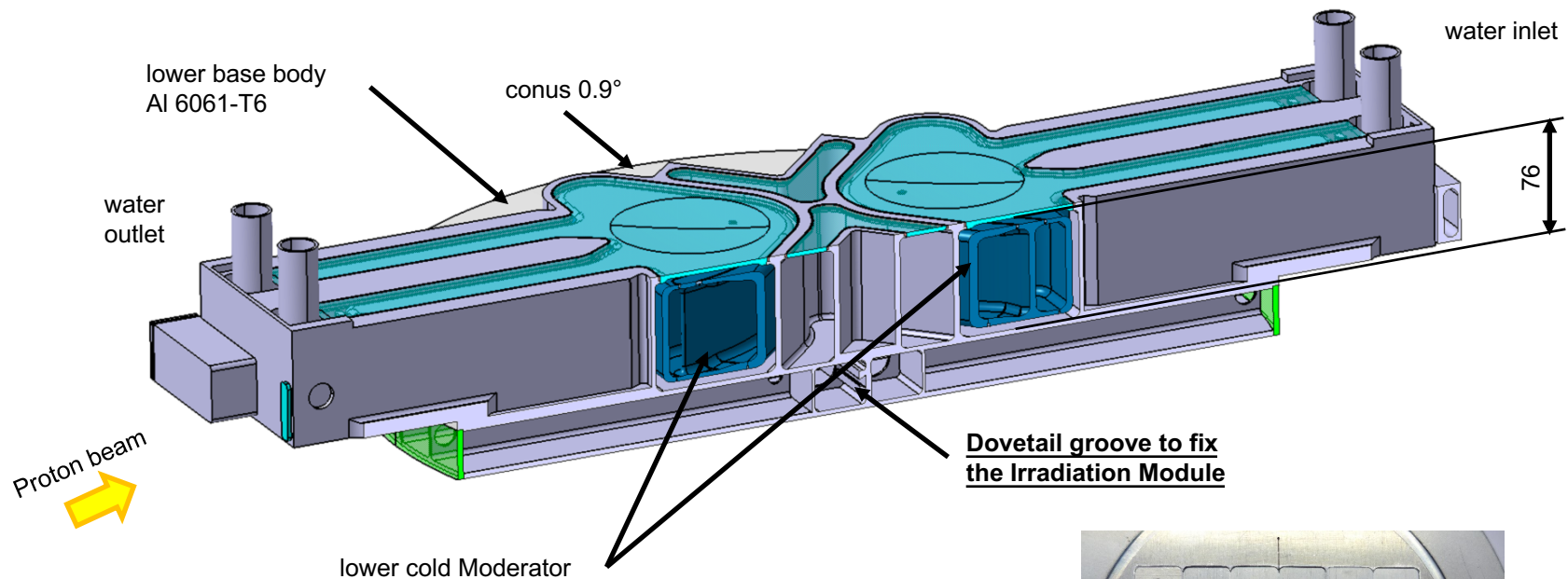
Assembling of cold and thermal Moderator

Step 4:

- The 2 cold moderators are placed into the base body.
- The 2 fillers are positioned in the base body.
- The weld seam B1 and B2 are e-beam welded.
- Clean and vacuum packing of the thermal moderator units



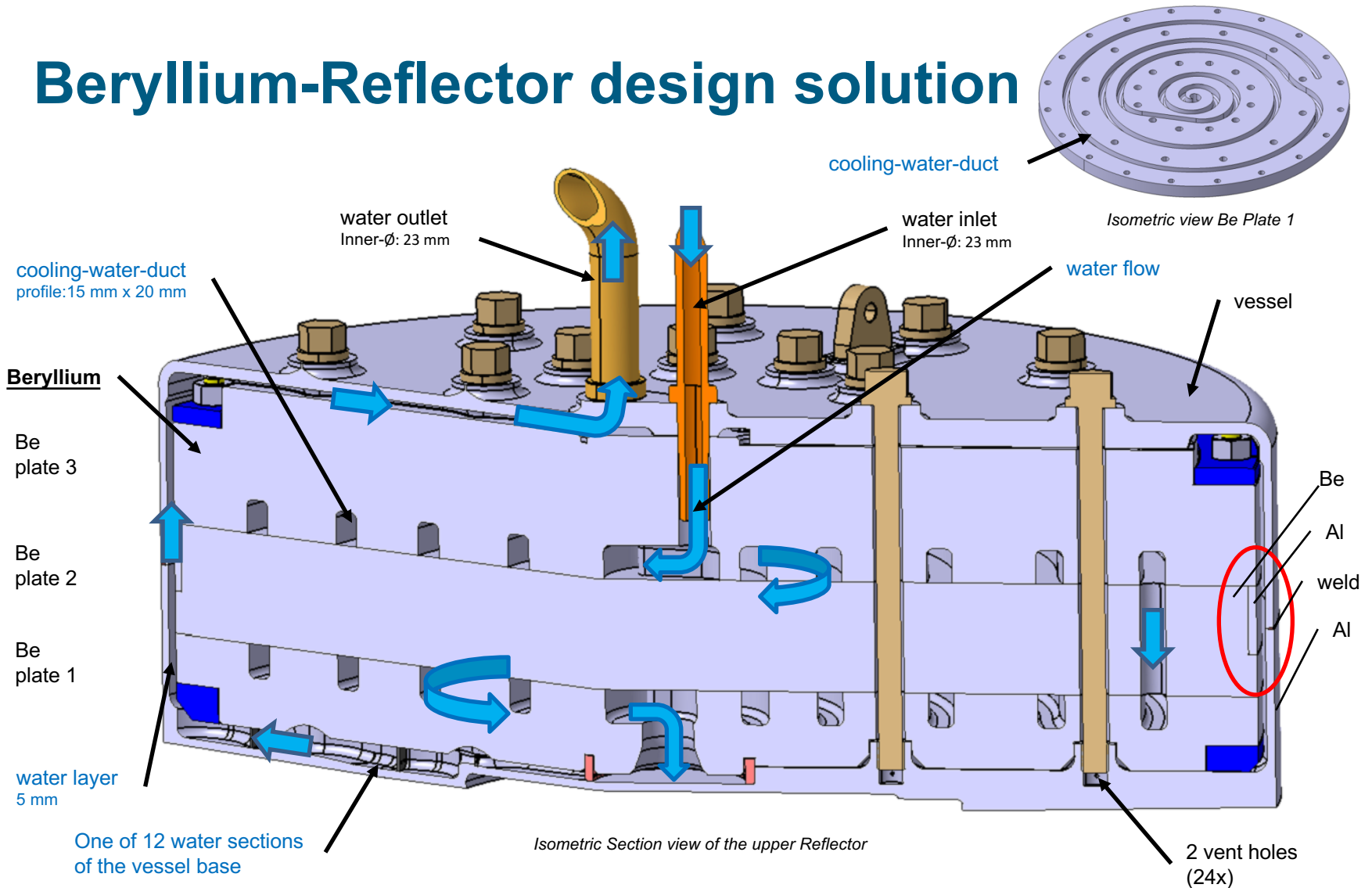
Lower th. Moderator / Irradiation Module



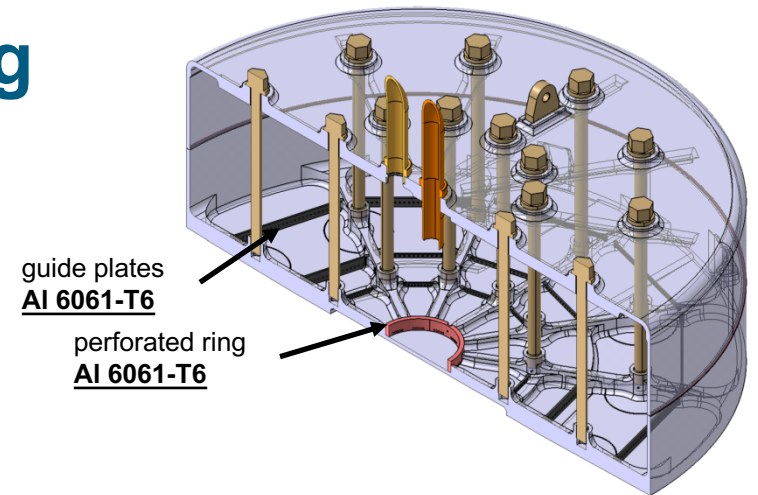
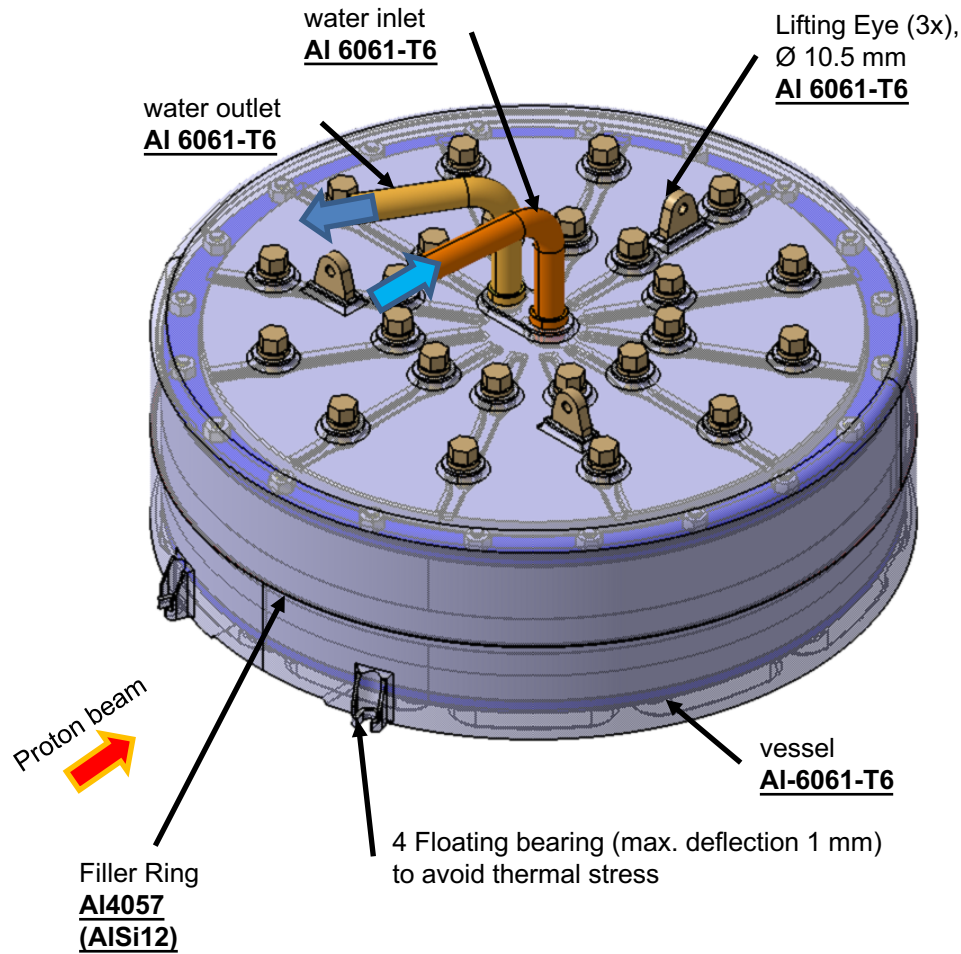
≈60 mm

Target Sample

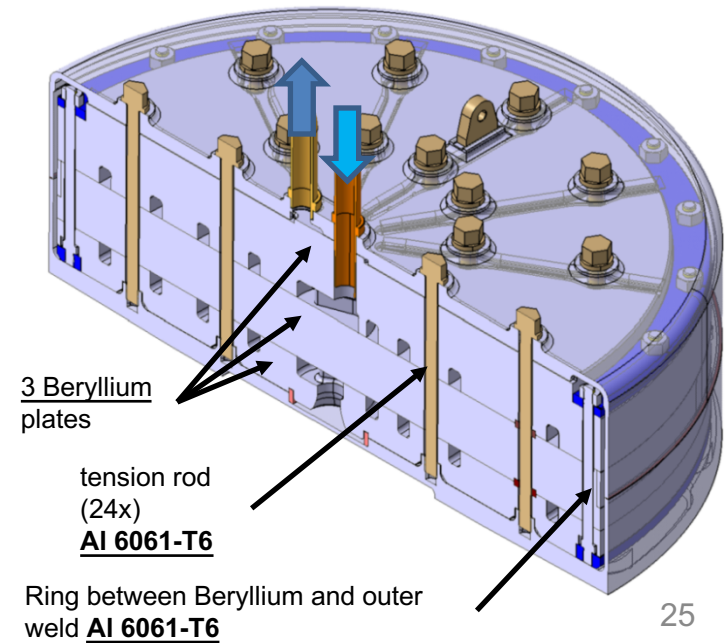
Beryllium-Reflector design solution



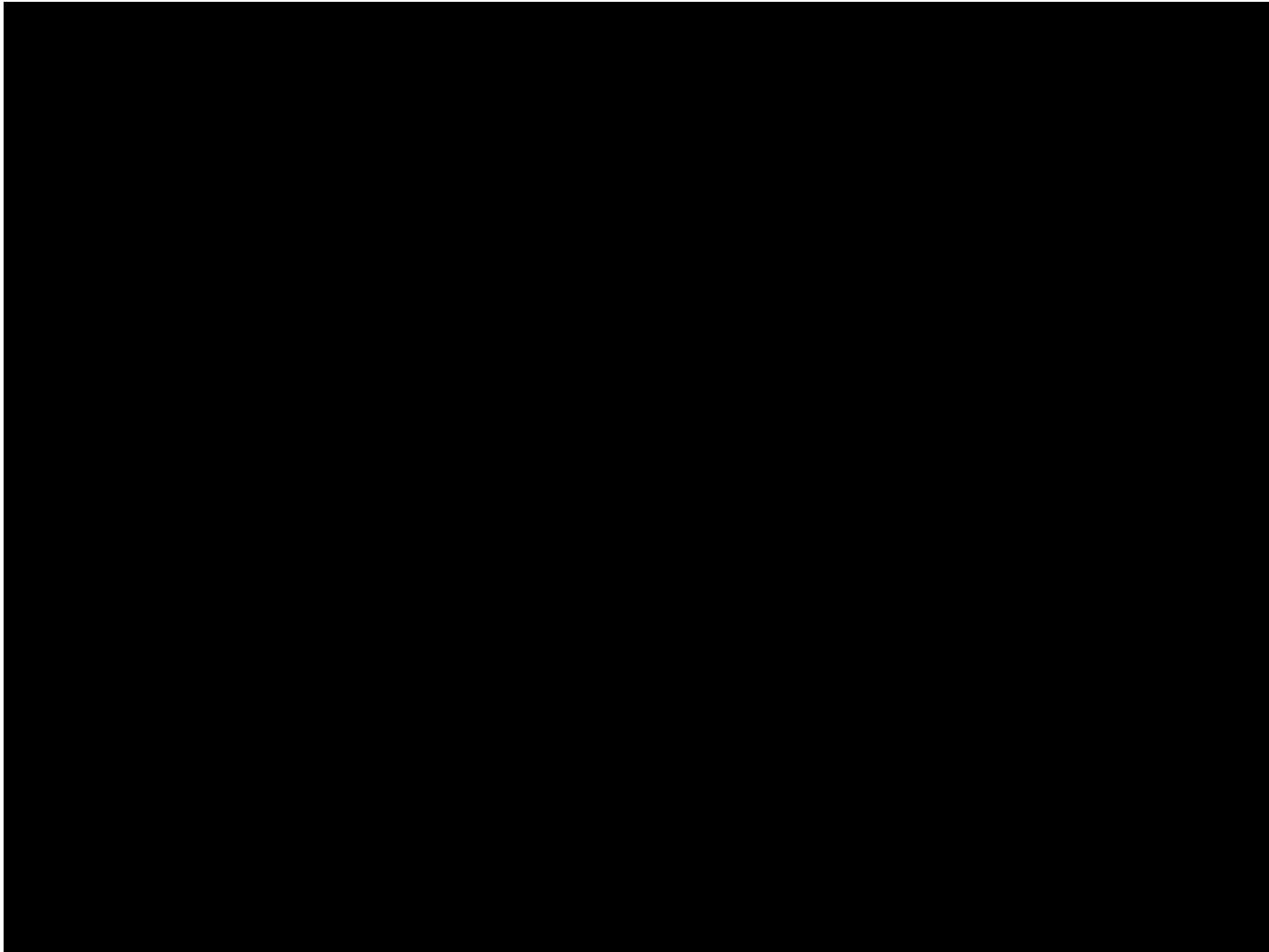
Be-Reflector manufacturing



Isometric Section view of the upper Reflector without Be



1st Burst test cold Moderator



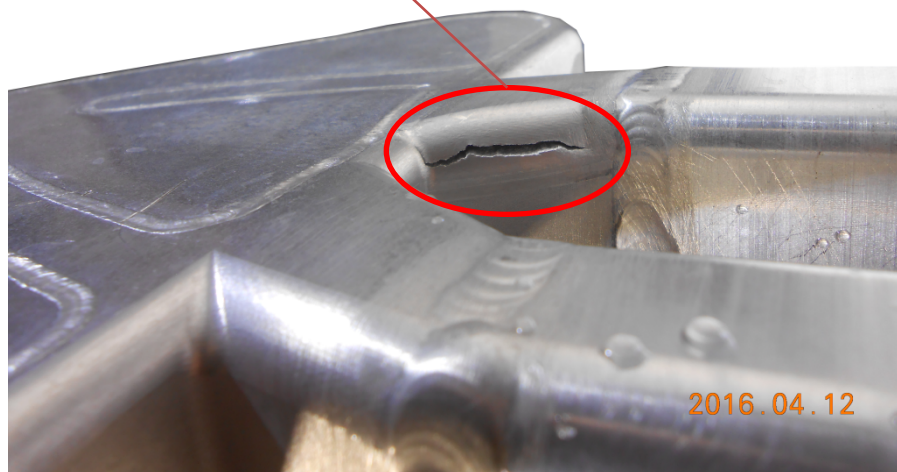
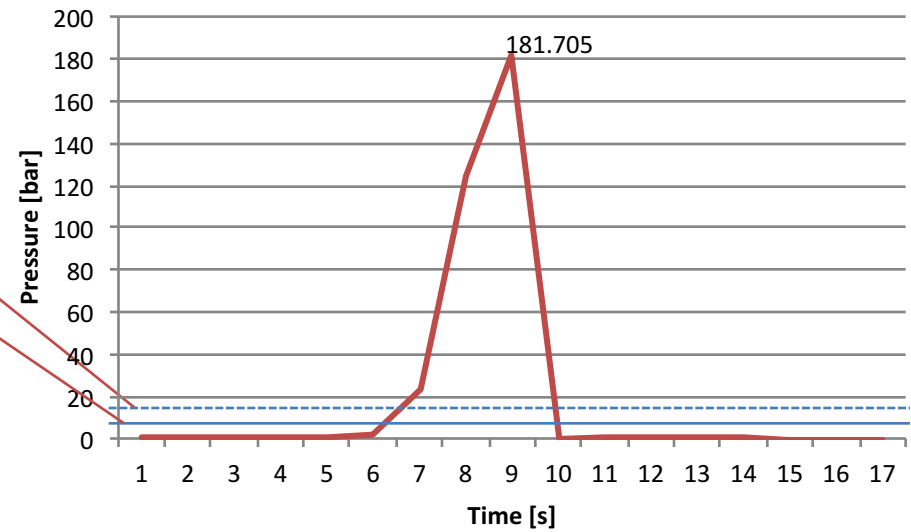
1st Burst test cold Moderator

Burst test

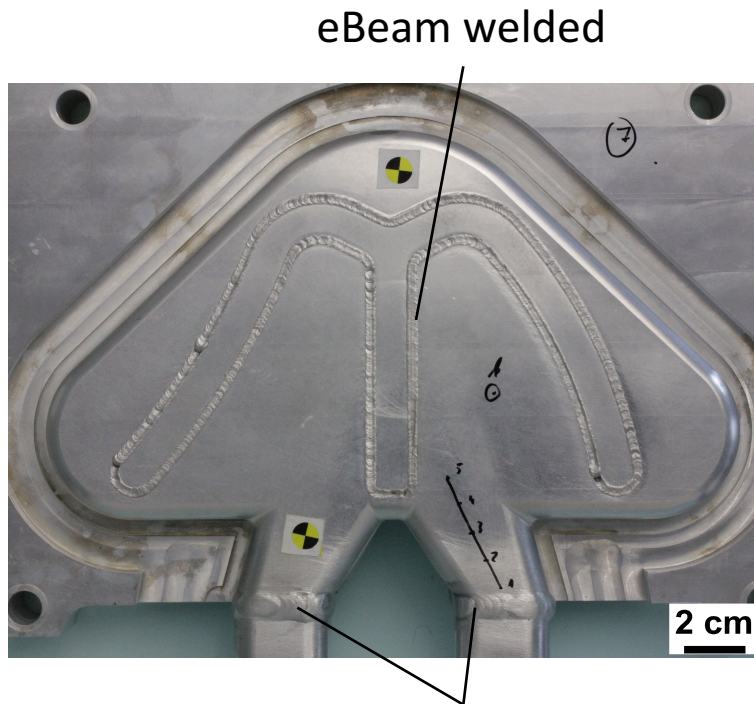
Design pressure
17 bar

Operation pressure
10 bar

why here?



1st Burst test cold Moderator



Hand welded adapter for burst test

Area which has lost the T6 conditions

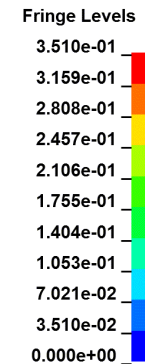
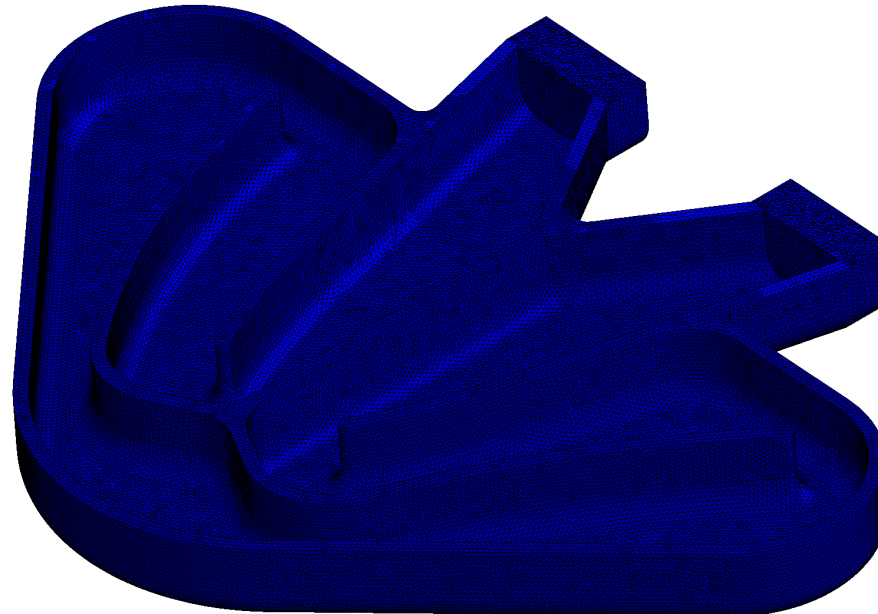
Messpunkt 1	58 HV 20	R_m 185 N / mm ²
Messpunkt 2	78 HV 20	R_m 248 N / mm ²
Messpunkt 3	96 HV 20	R_m 308 N / mm ²
Messpunkt 4	102 HV 20	R_m 326 N / mm ²
Messpunkt 5	106 HV 20	R_m 338 N / mm ²
Messpunkt 6	109 HV 20	R_m 347 N / mm ²
Messpunkt 7	110 HV 20	R_m 350 N / mm ²

Expected yield strength for Al6061-T6...

1st Burst test cold Moderator

Numerical simulation

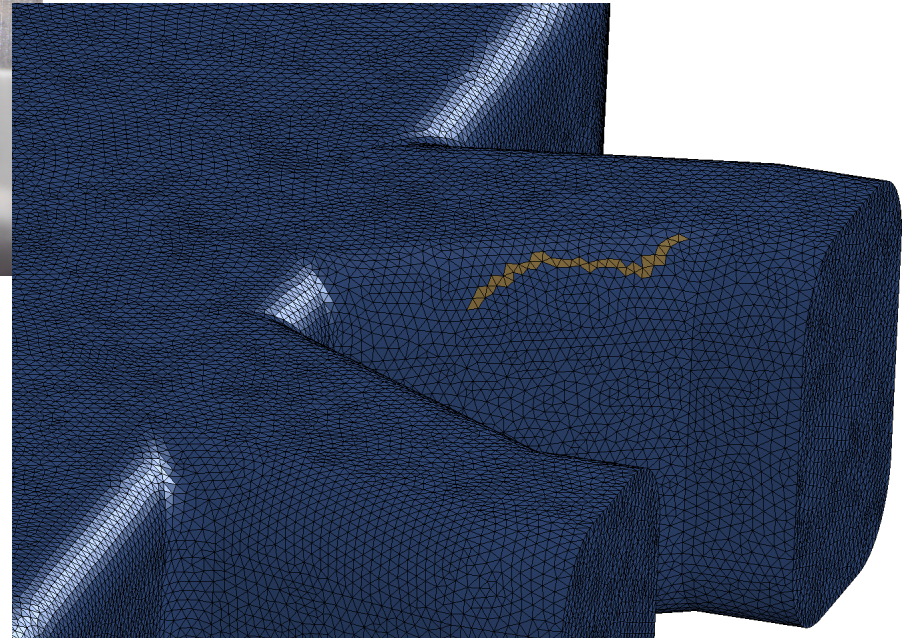
Bersttest ESS-Moderator
 Time = 0
 Contours of Effective Stress (v-m)
 min=0, at elem# 1
 max=0, at elem# 1
 max displacement factor=20
 section min = 0, near node# 57726
 section max = 0, near node# 57726



simulation including different material areas (Al6061-T6 and Al6061-T6)....

1st Burst test ESS-Moderator

compare theory and practice



2nd Burst test cold Moderator (LN2)



115 bar without visible influence,
then leaking valve.

Next try coming soon...

Thank you for your attention!

