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# TIK 3.1 and TIK 3.2 ESS Moderator & Reflector System TTB Meeting

16-03-2016 | Y. Beßler

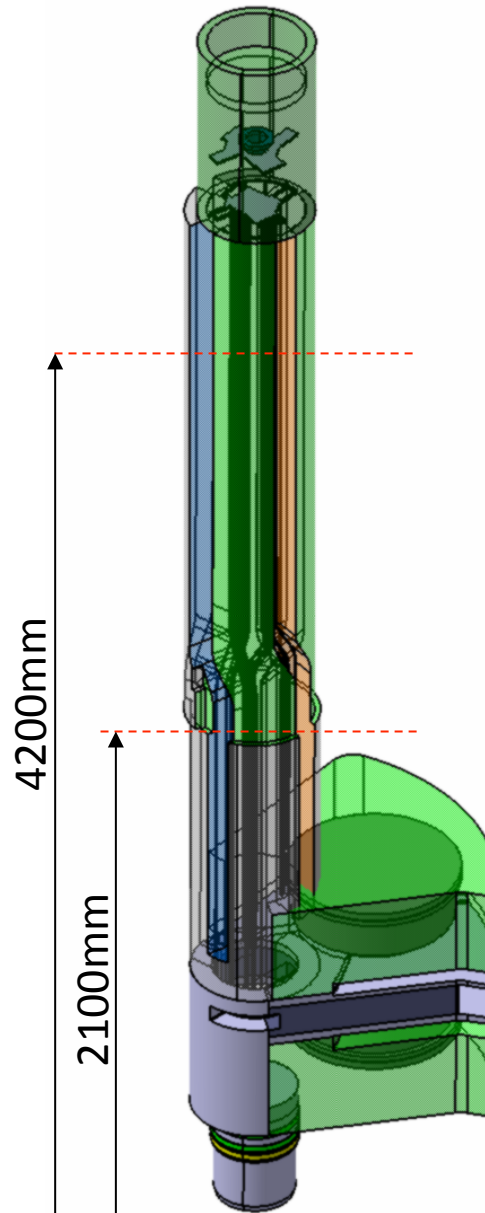
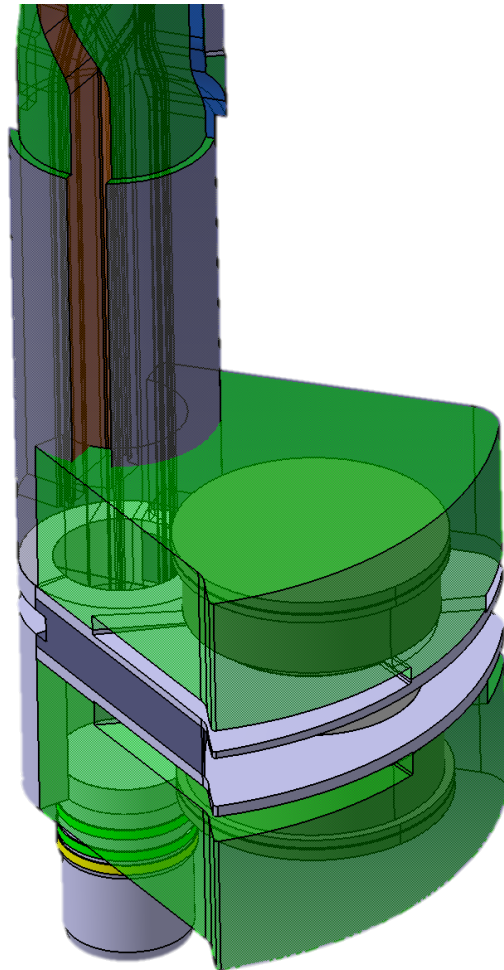
# Outline

- Highlights
- Schedule performance
- Risks and issues
- Near-term plans
- Concluding remarks

## Highlights outline

- Structural support (Twister)
- Rotation Unit
- Cold Moderator
- Thermal Moderator
- Beryllium Reflector
- Assembly of Moderator-Reflector unit
  
- LH2 pipework (CMS)
- LH2 room (CMS)
- LH2 cryostat (CMS)
- LH2 final flow chart (CMS)

## Twister (TIK3.1)



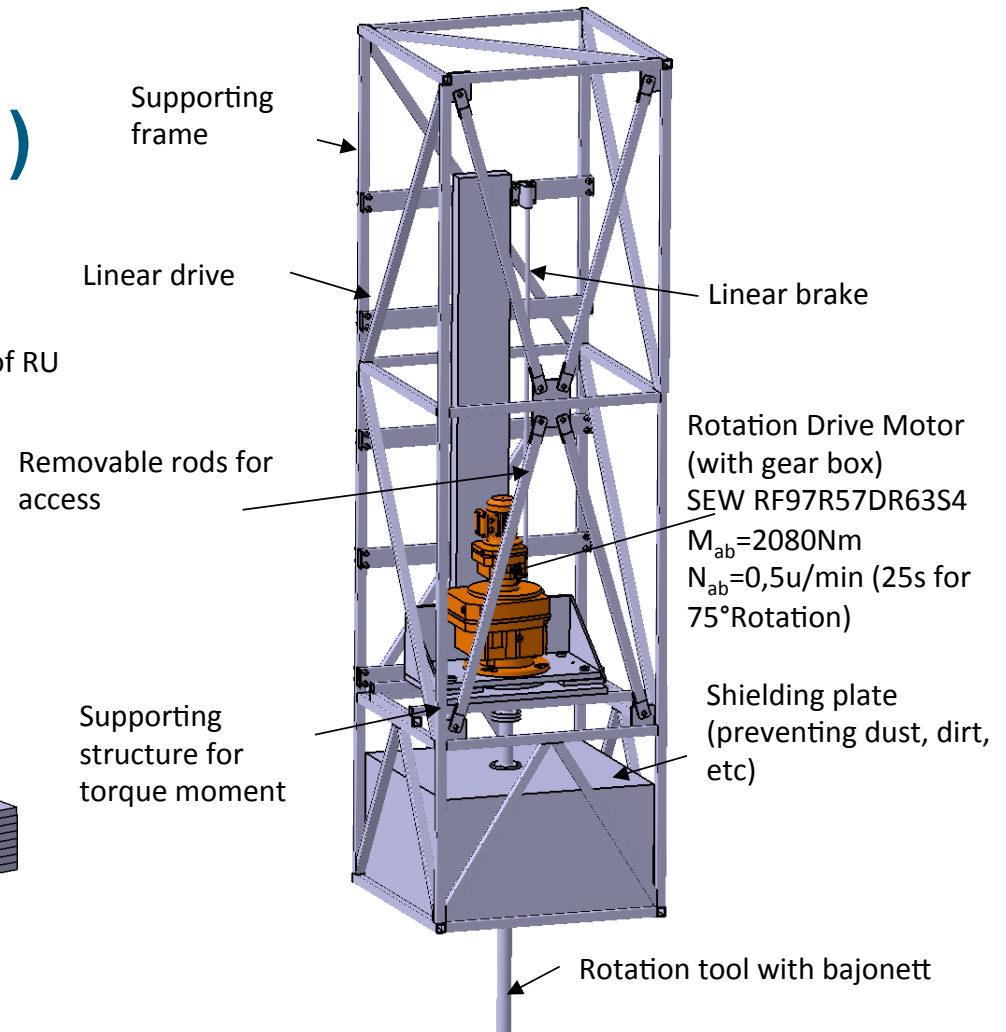
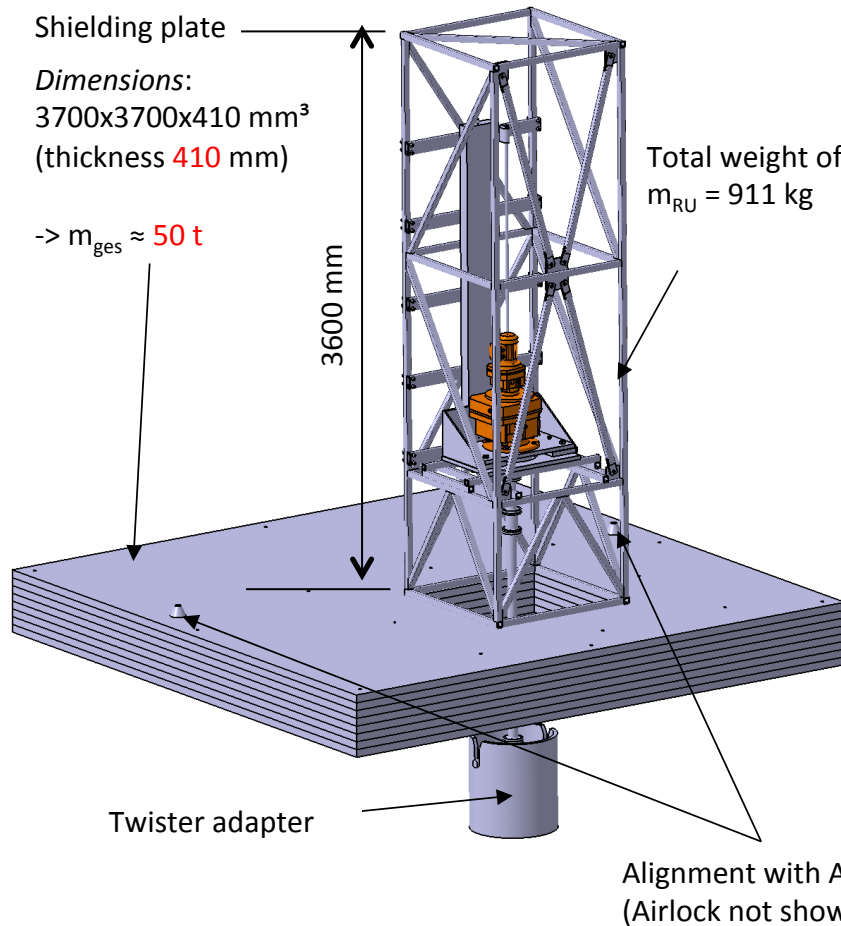
Interface: remote handling:

- ✓ Cutting positions
- Lifting adapter

### To do:

- complete assembly
- hazard analysis (crack H2-pipework)
- welding zone analysis
- full stress analysis with RCC-MRx

# Rotation Unit (TIK3.1)



Interface: airlock/monolith vessel must be ready before April, because of CDR

# Cold Moderator (TIK3.1)

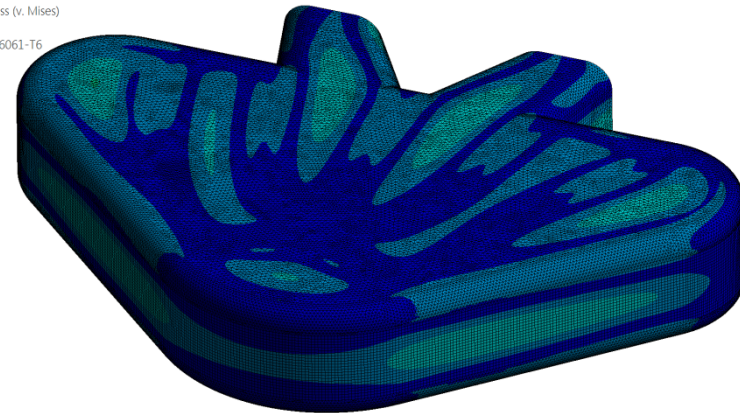
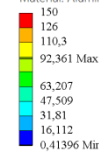
## Status:

- ✓ no global critical stresses
- ✓ flow dynamics
- ✓ heat deposition

## To do:

- welding zone analysis
- full stress analysis with RCC-MRx
- Burst test

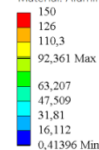
Name: Cold Moderator (Upper)  
Design pressure: 17 bar  
Temperature: 293 K  
Type: Equivalent Stress (v. Mises)  
Unit: MPa  
Material: Aluminium 6061-T6



ANSYS  
R15.0  
Academic

Equivalent stress (von Mises) @ 17 bar design pressure and 293 K

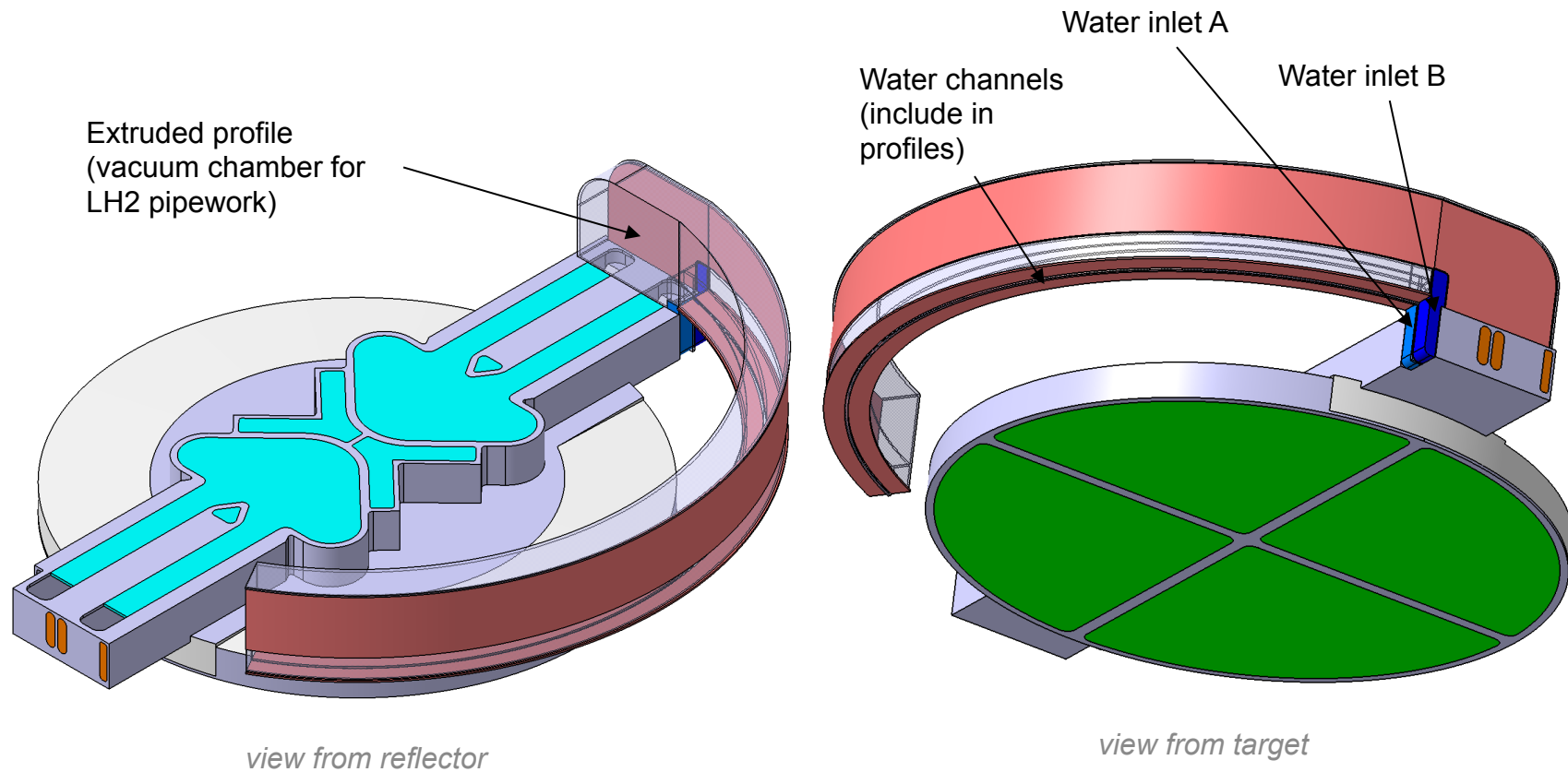
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ANSYS  
R15.0  
Academic

Equivalent stress (von Mises) @ 17 bar design pressure and 293 K

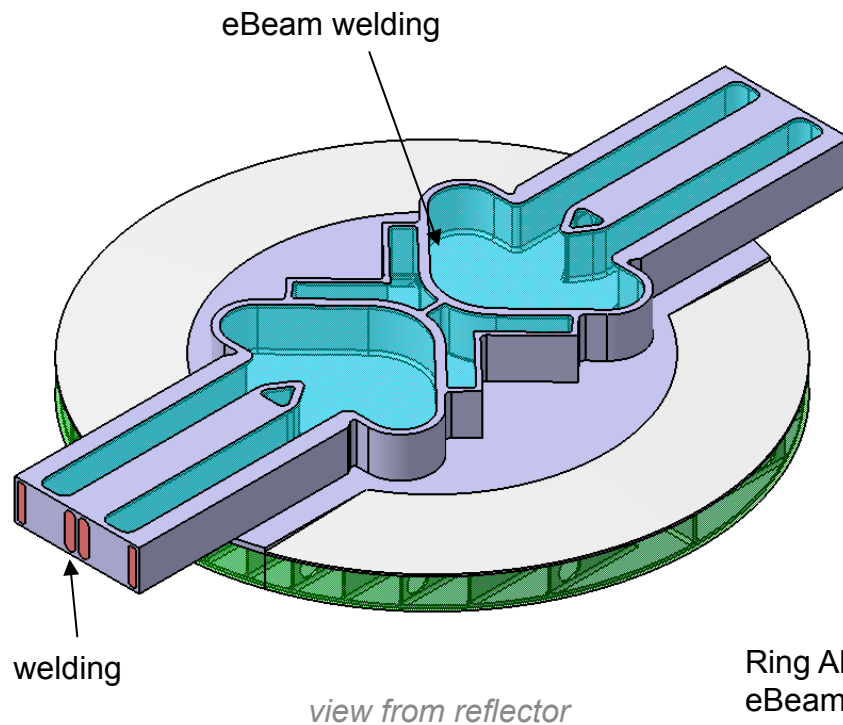
# Thermal Moderator (TIK3.1) V1



Interface: irradiation module final design must be ready before June, because of CDR



# Thermal Moderator (TIK3.1) V2

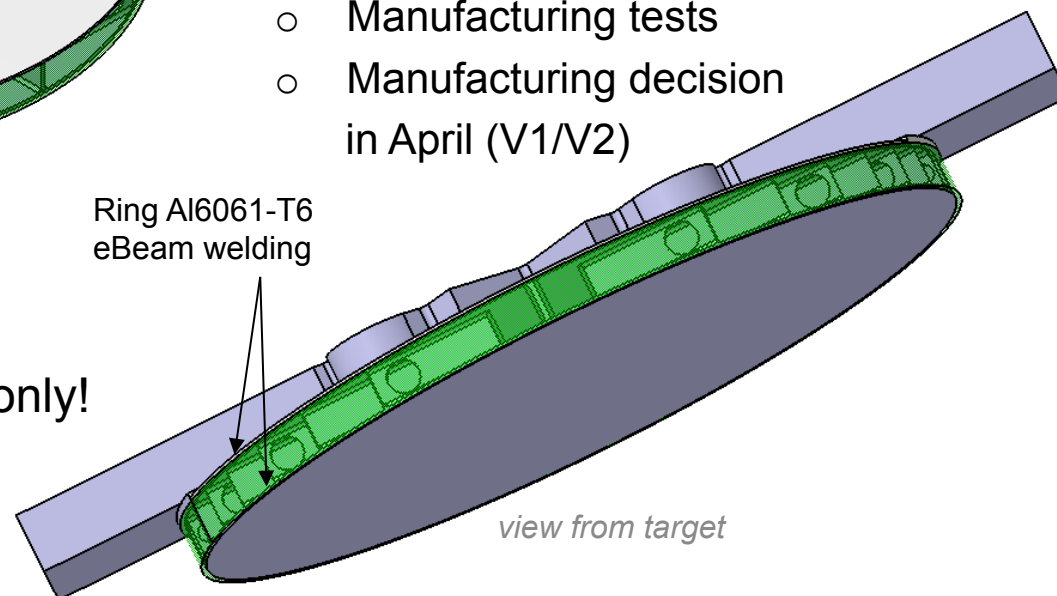


## Status:

- ✓ no global critical stresses
- ✓ flow dynamics
- ✓ heat deposition

## To do:

- welding zone analysis
- full stress analysis with RCC-MRx
- Manufacturing tests
- Manufacturing decision in April (V1/V2)



V2: Water disc, side welding only!



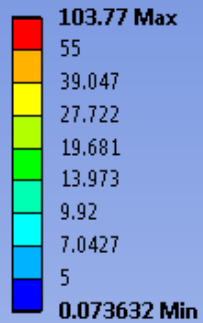
# Thermal moderator FEM (TIK3.1)

## Mechanical layout (draft)

B: 212-BER-20160301-JWolters-WB16.1-Vorauslegung thermischer Moderator - neues Fertigungskonzept - Festigkeit  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
02.03.2016 14:08

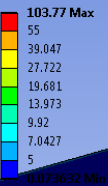
ANSYS  
R16.1

Pressure outer surfaces: 1 bar  
Fluid overpressure: 5 bar  
No thermal loads



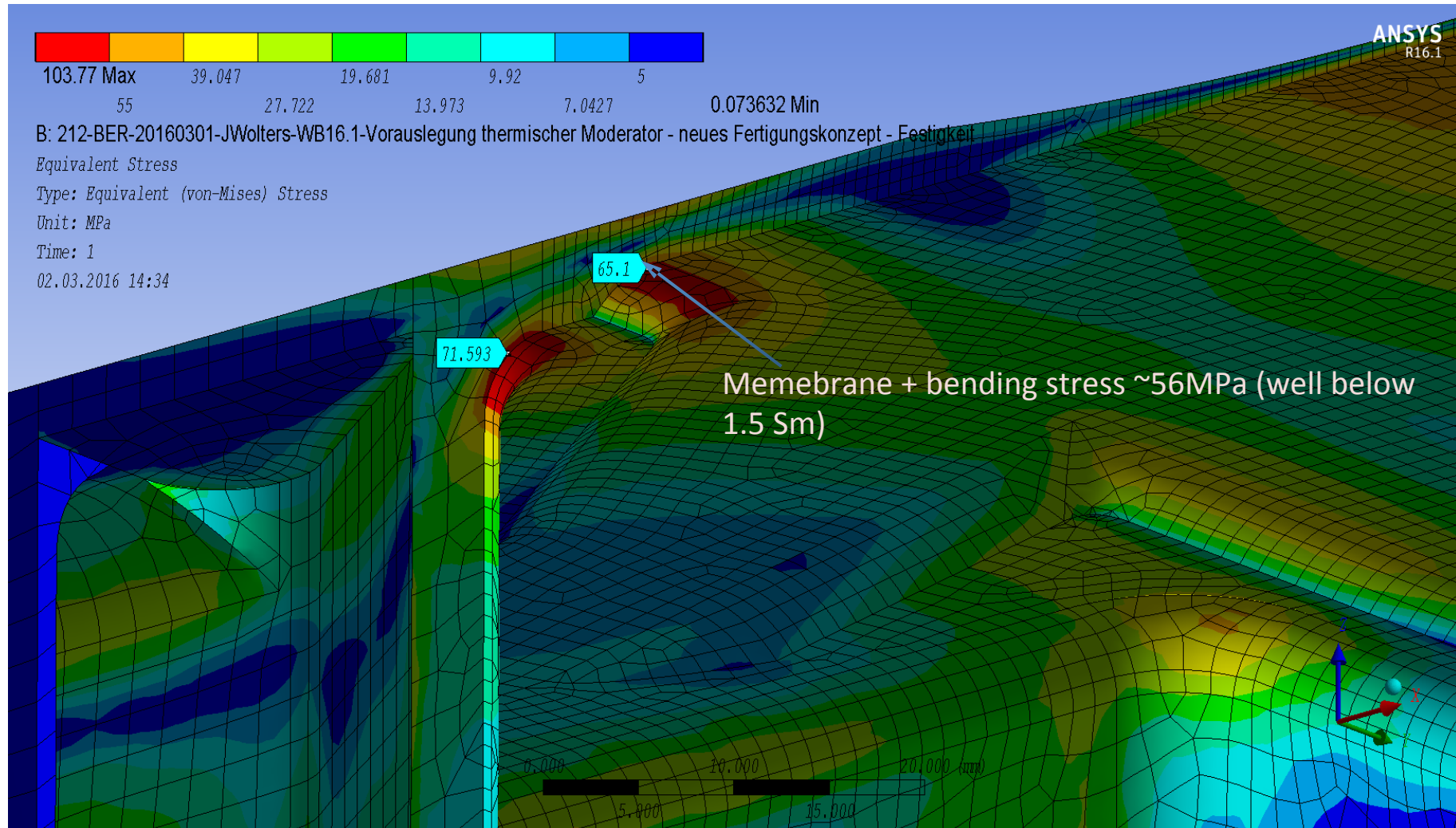
B: 212-BER-20160301-JWolters-WB16.1-Vorauslegung thermischer Moderator - neues Fertigungskonzept - Festigkeit  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
02.03.2016 14:10

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R16.1



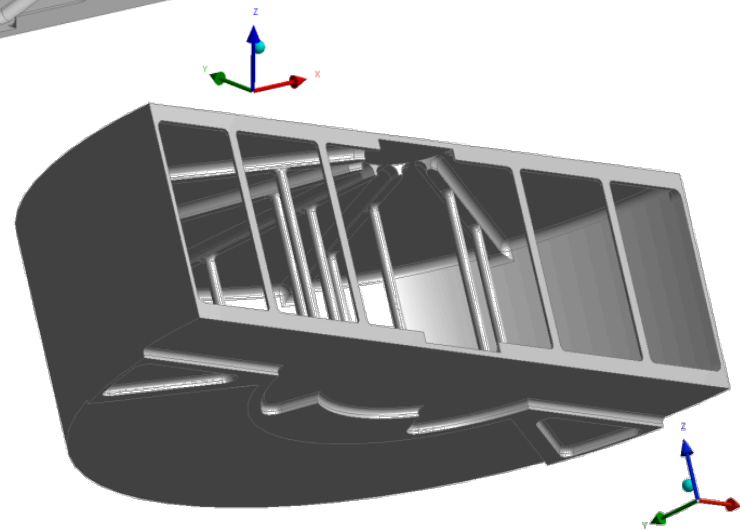
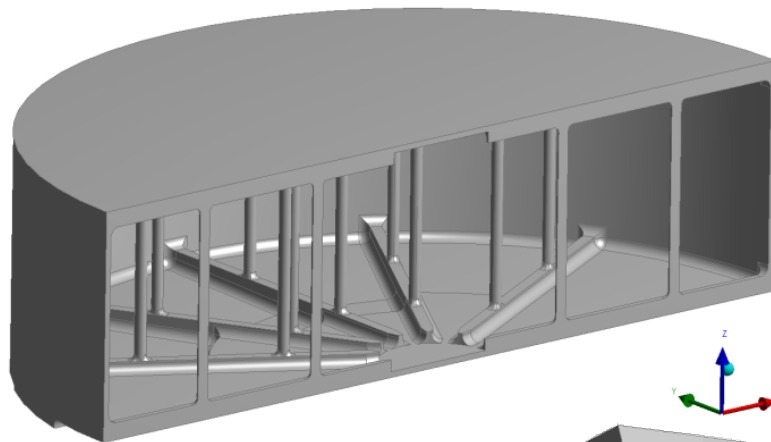
# Thermal moderator (TIK3.1)

## Mechanical layout (draft)



## Reflector vessel (TIK3.2)

Include change request from Lund:  
Vessel with water filled truncated cone shaped bottom and 5 mm water layer



### Status:

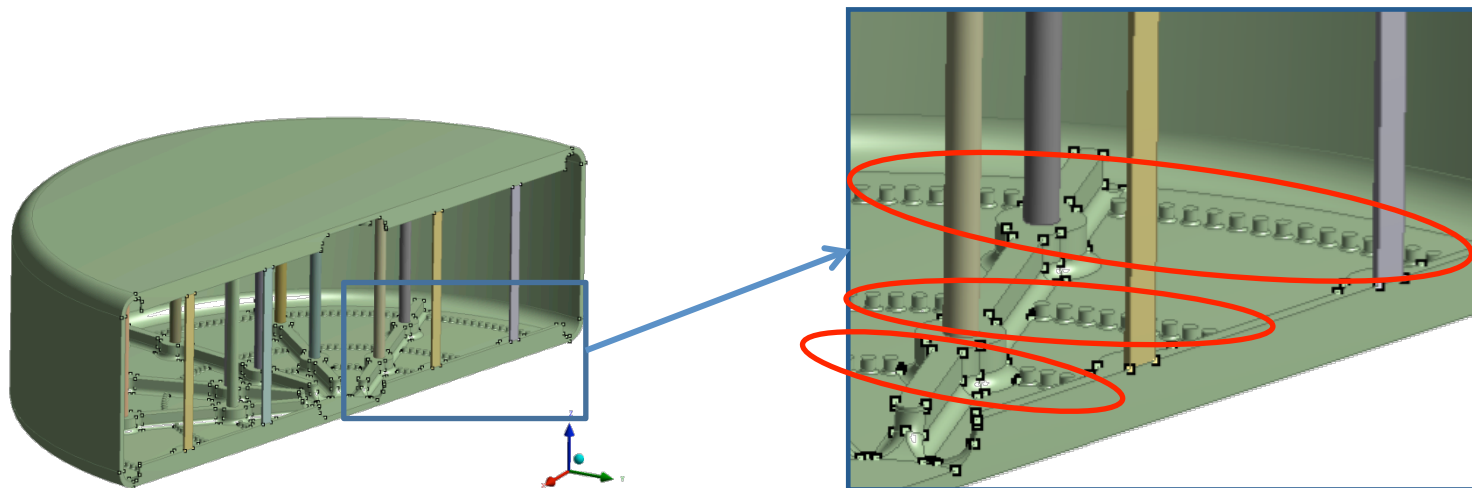
- ✓ no global critical stresses
- ✓ flow dynamics
- ✓ heat deposition

### To do:

- welding zone analysis
- full stress analysis with RCC-MRx

## Reflector vessel (TIK3.2)

- Vessel need provisions to prevent large eddys at the bottom:



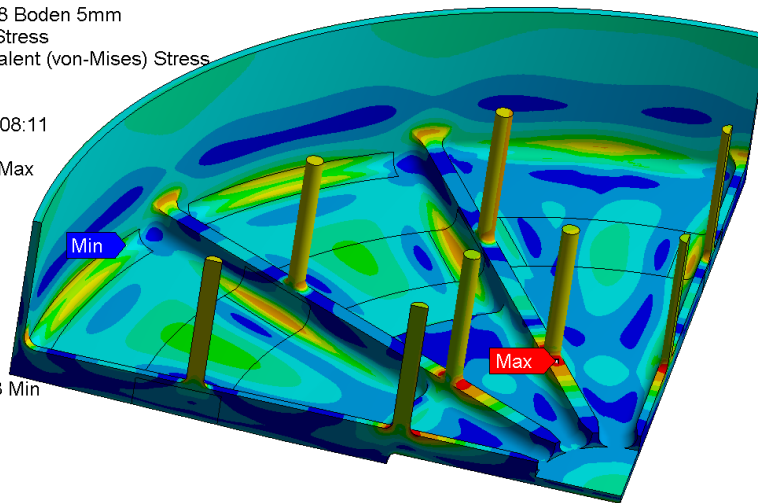
- Tension rods and reinforcement ribs are essential to keep deformations and stresses within an acceptable range.

# Reflector vessel (TIK3.2)

FEM results with 5 bar internal pressure

C: 20160218 Boden 5mm  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
22.02.2016 08:11

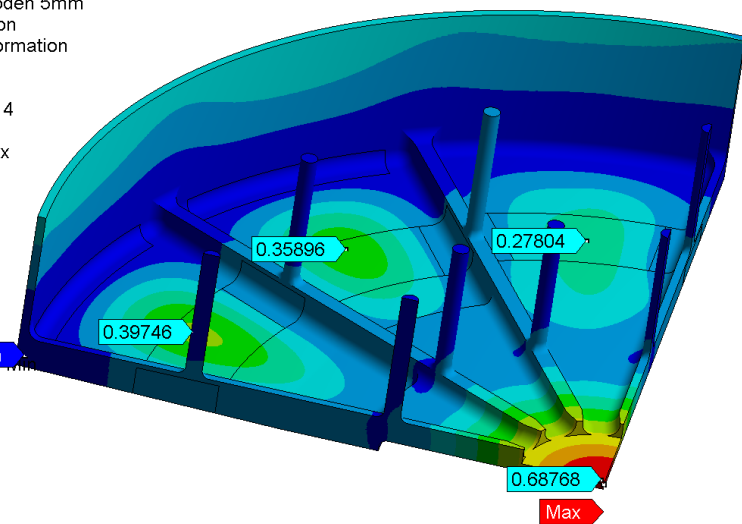
203.49 Max  
124  
84  
72.013  
60.027  
48.04  
36.054  
24.067  
12.08  
0.09363 Min



Equivalent Stress

C: 20160218 Boden 5mm  
Total Deformation  
Type: Total Deformation  
Unit: mm  
Time: 1  
22.02.2016 08:14

0.68871 Max  
0.61221  
0.53571  
0.45921  
0.38271  
0.30621  
0.22971  
0.1532  
0.076704  
0.000204 Min

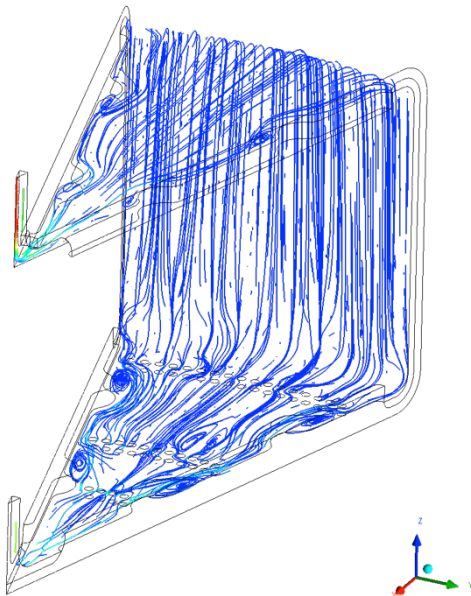


Deformation

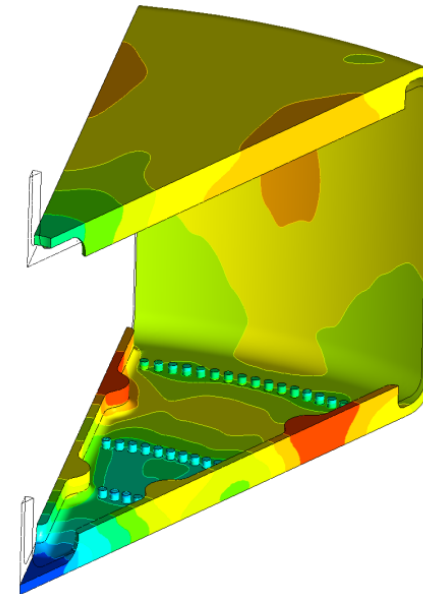
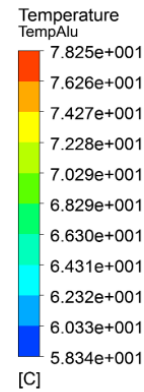
Stresses are O.K. regarding P-damage. Joining concept of tension rods needs further investigations.

# Reflector vessel (TIK3.2)

## CFD results



Streamlines

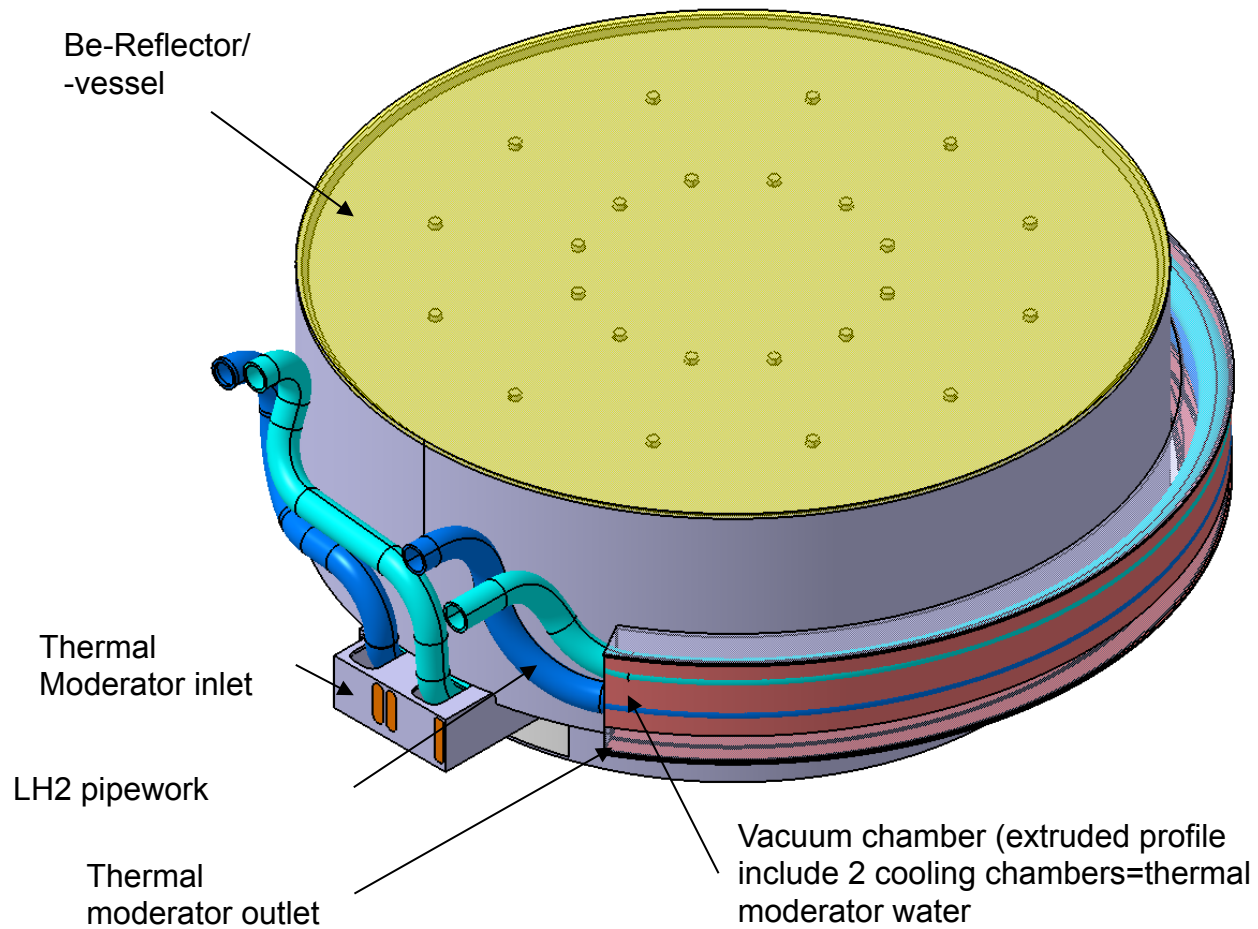


Temperature of vessel in °C

- Investigation of the cooling at the sector with the highest heat deposition.
- $T_{max} < 80 \text{ } ^\circ\text{C}$

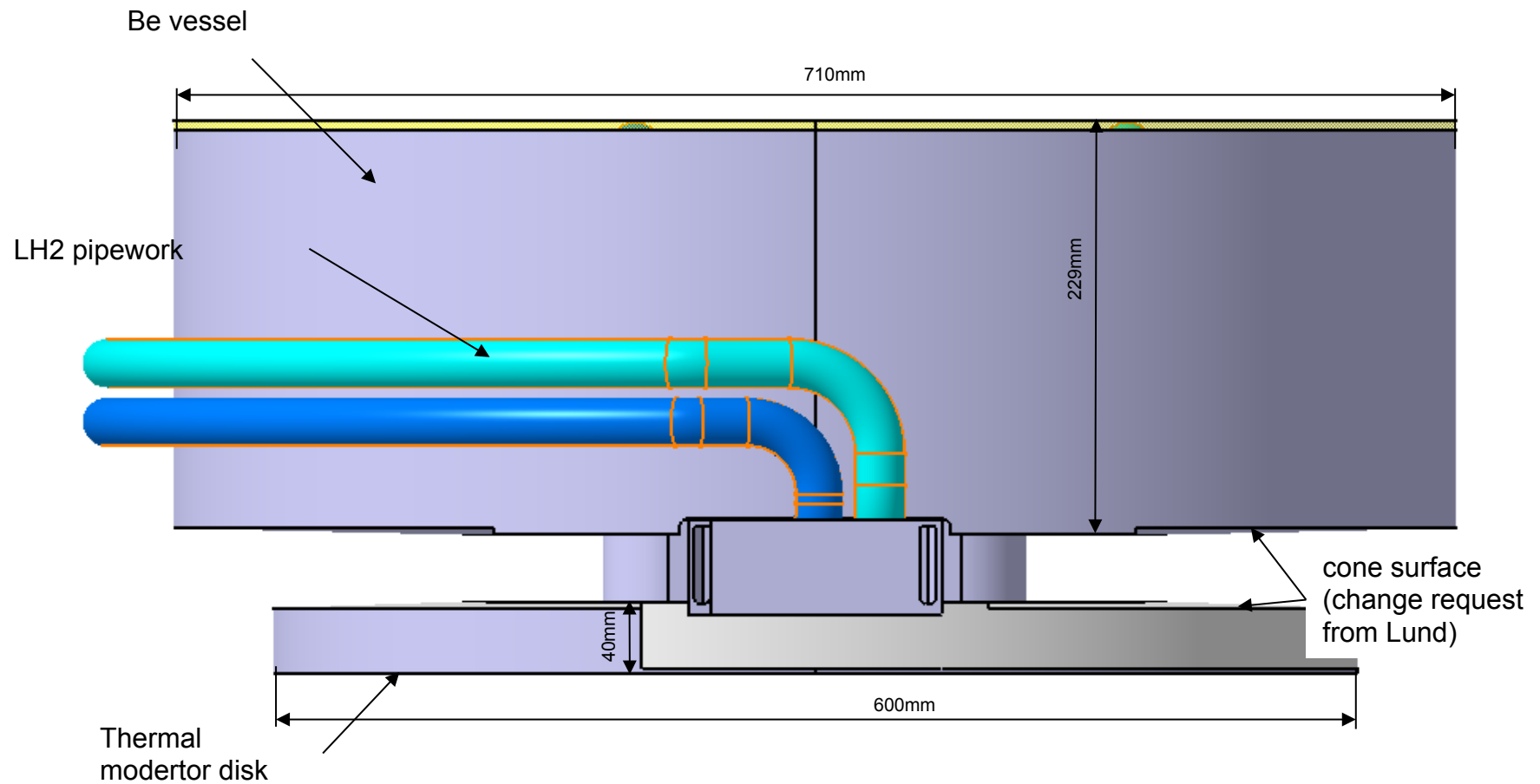


# Assembly moderator reflector unit (TIK3.1)

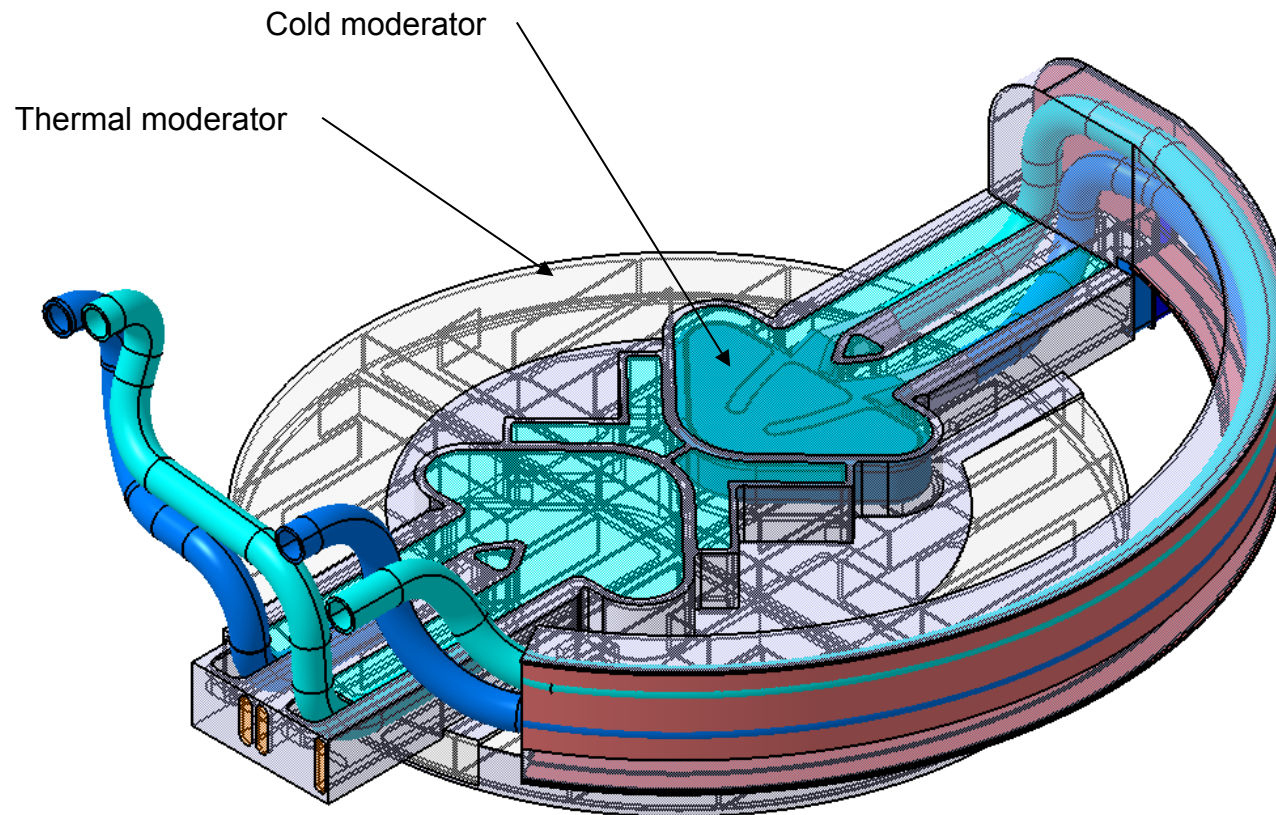




## Assembler moderator reflector unit (TIK3.1)



# Assembler moderator reflector unit (TIK3.1)



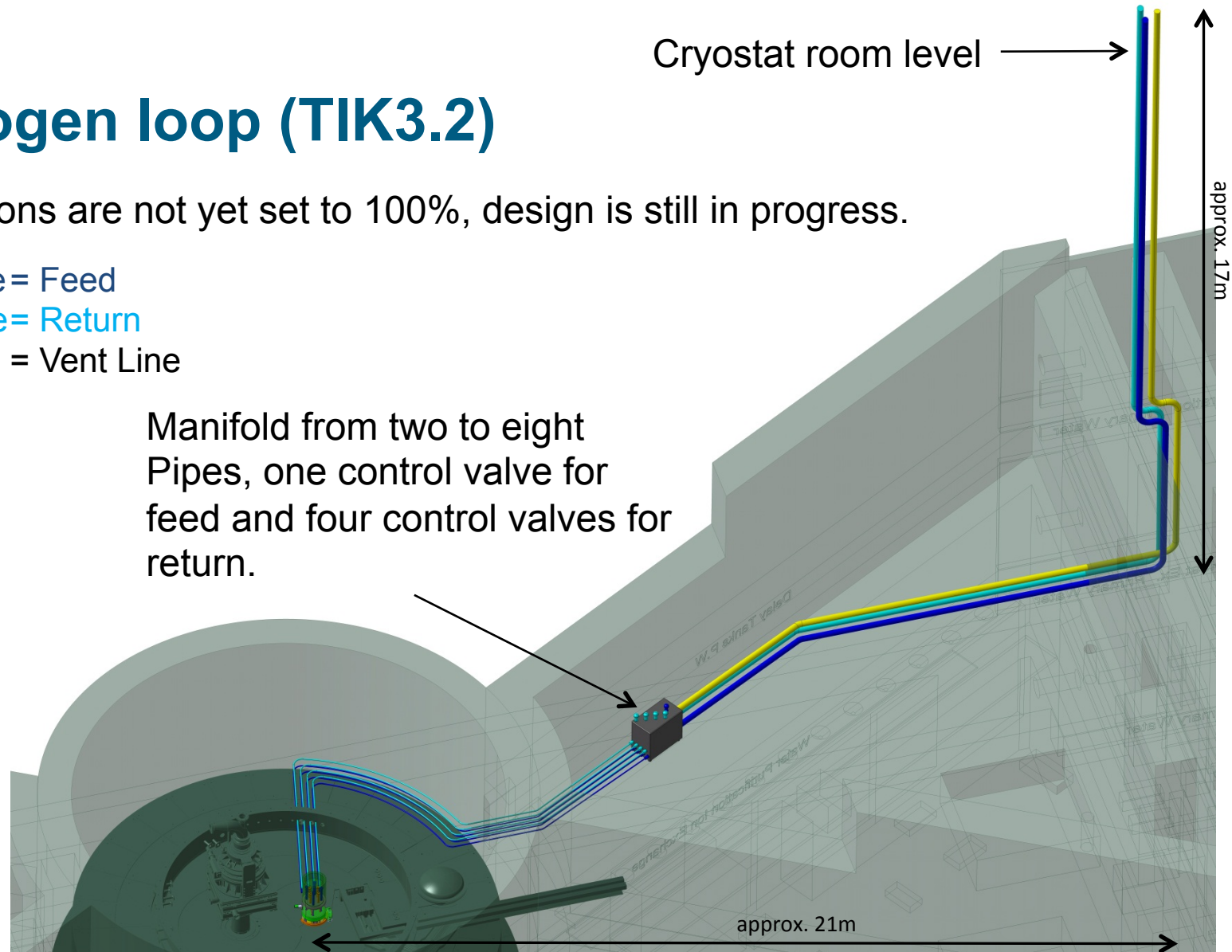
*view from reflector*

## Hydrogen loop (TIK3.2)

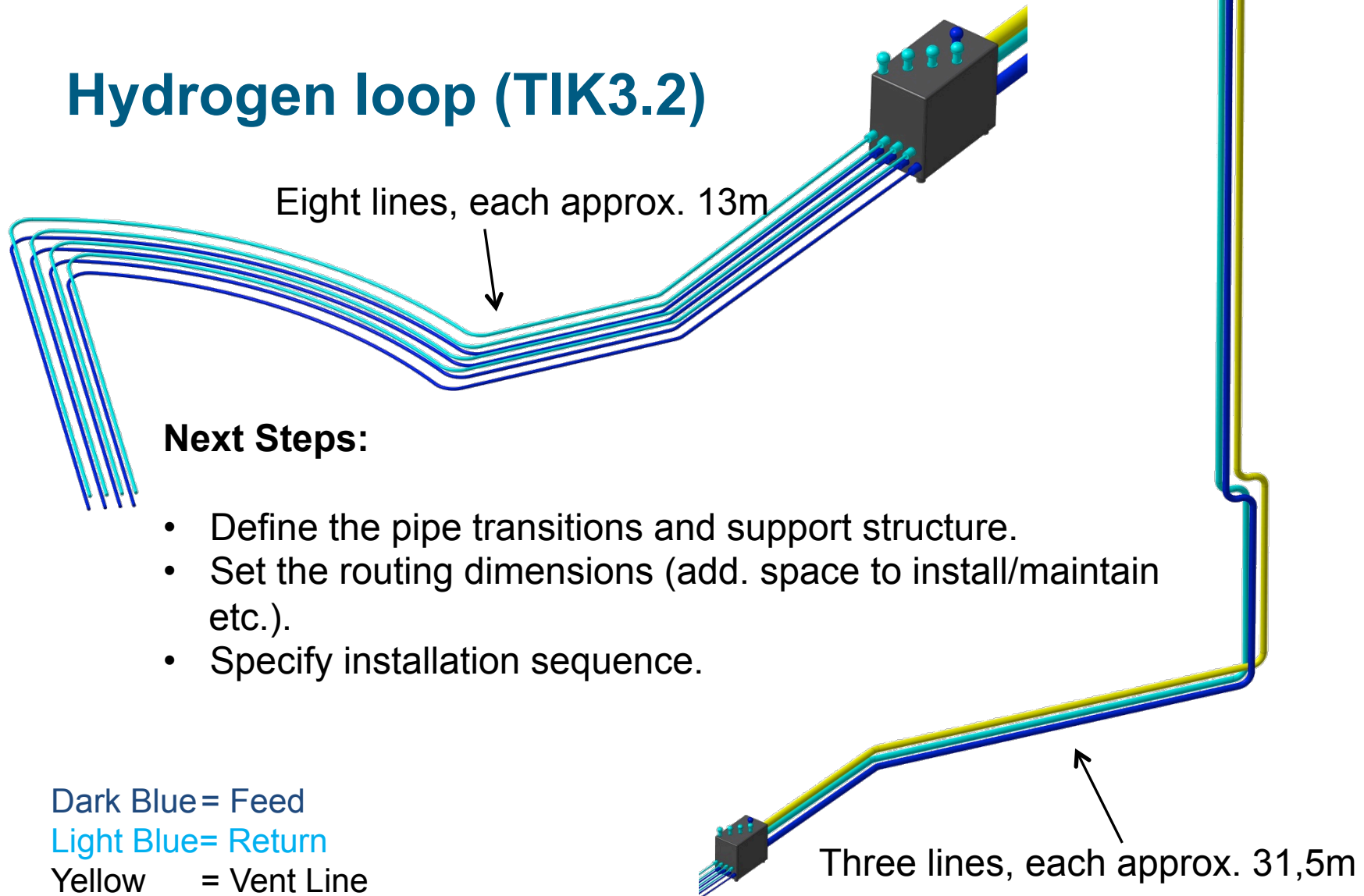
Dimensions are not yet set to 100%, design is still in progress.

Dark Blue = Feed  
Light Blue = Return  
Yellow = Vent Line

Manifold from two to eight  
Pipes, one control valve for  
feed and four control valves for  
return.

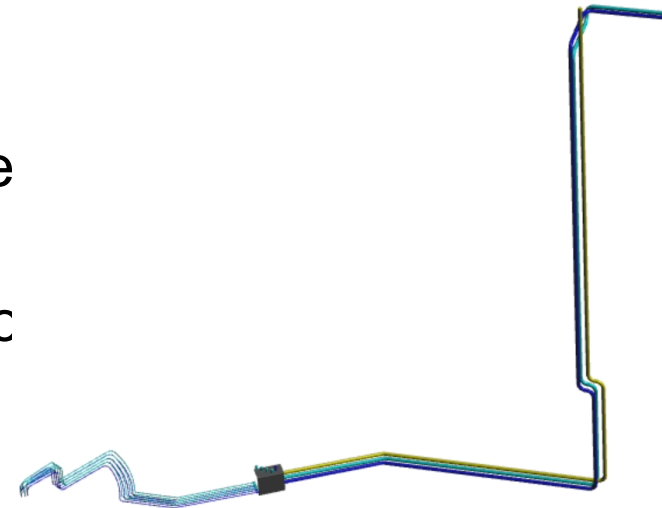


## Hydrogen loop (TIK3.2)

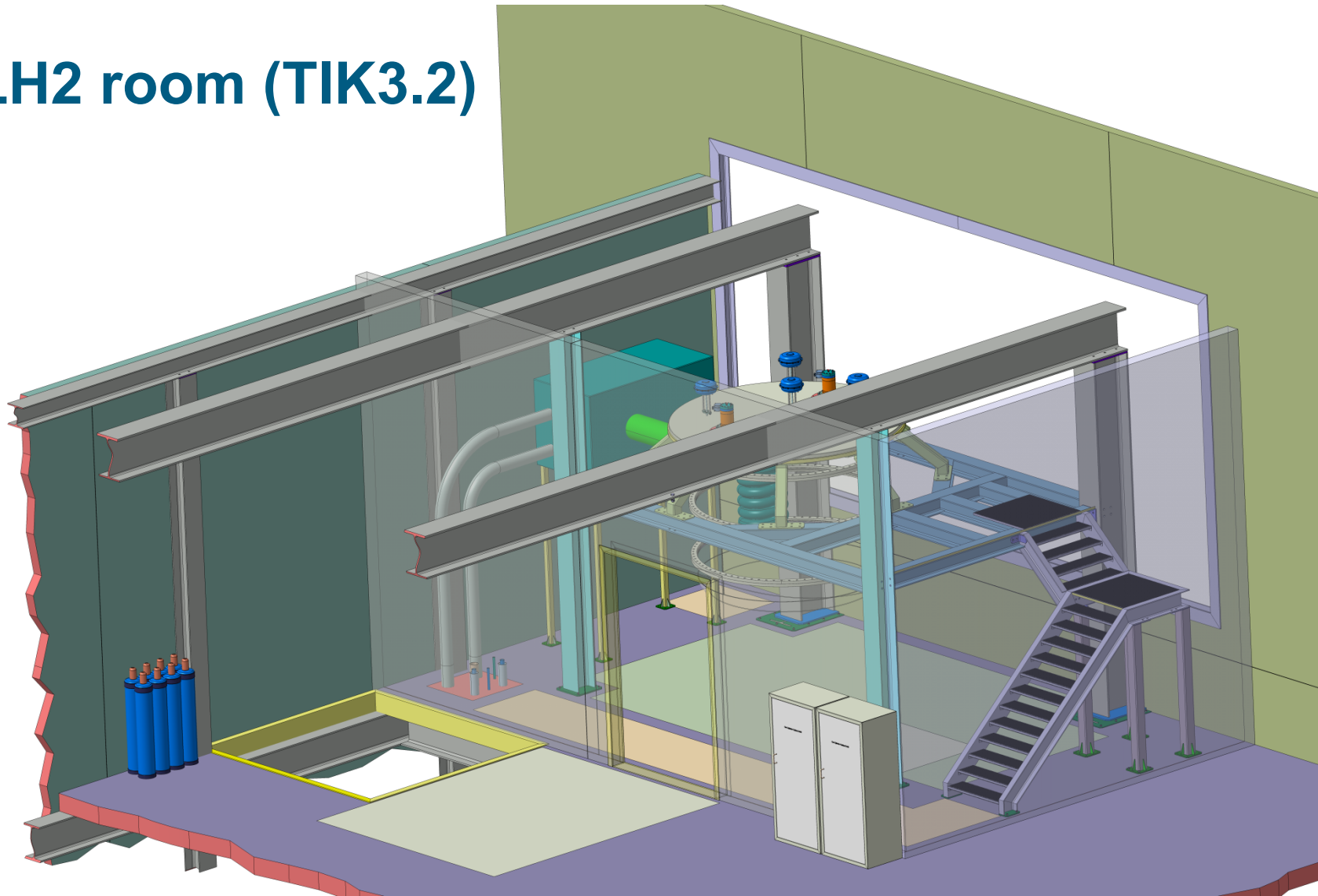


## Liquid Hydrogen Transfer lines from CMS room to Monolith

- Separate vacuum insulated feed and return line DN100/DN60
- Manifold box in triangle / A2T room splitting, controlling and uniting 4 parallel lines to the cold moderator
- Eight detachable (flexible) lines connect to the twister part
- Open tender (specification) planned for package: transfer lines, manifold box and individual lines
- Close cooperation among ESS CF and Cryogenics group for routing and installation



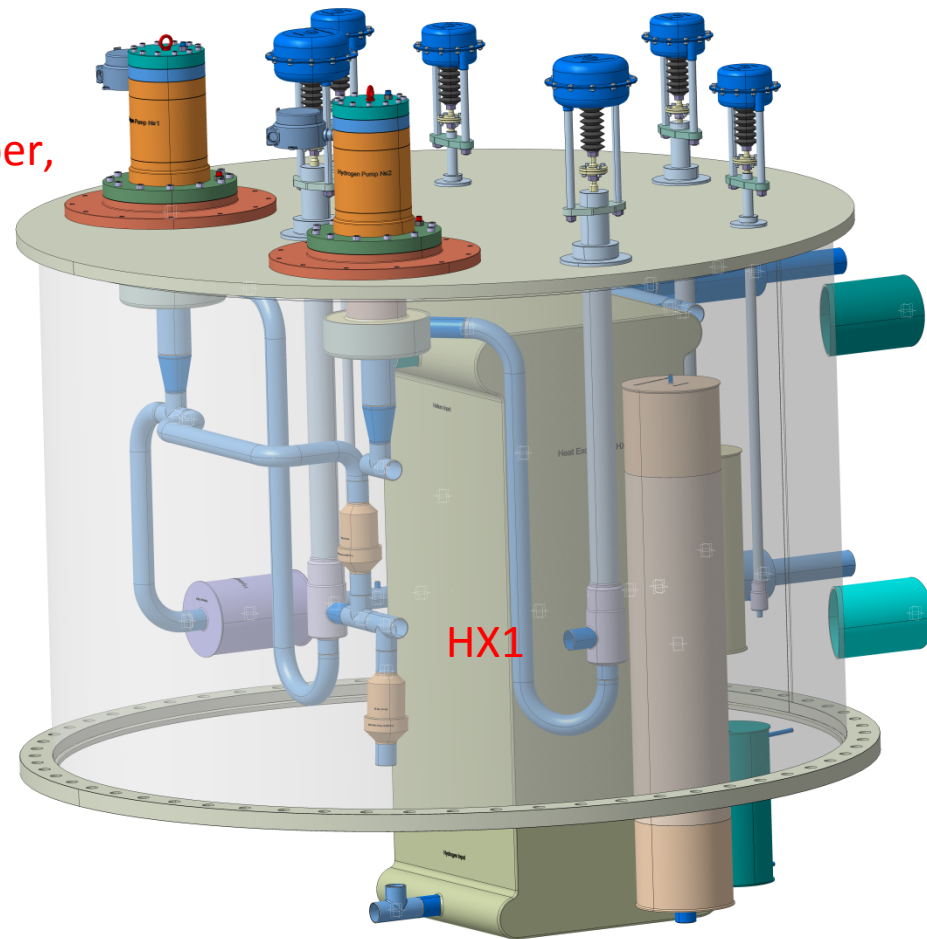
## LH2 room (TIK3.2)





# Cryostat (TIK3.2)

Interface: HX1 and o-p measurement  
final design must be ready before October,  
because of CDR, main dimensions /  
concept necessary as soon as possible

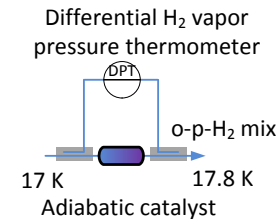
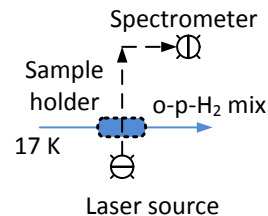
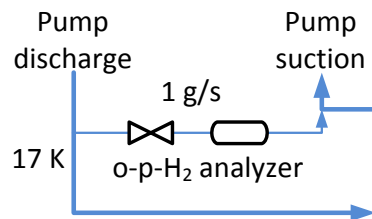




# Ortho-para-Hydrogen Contribution

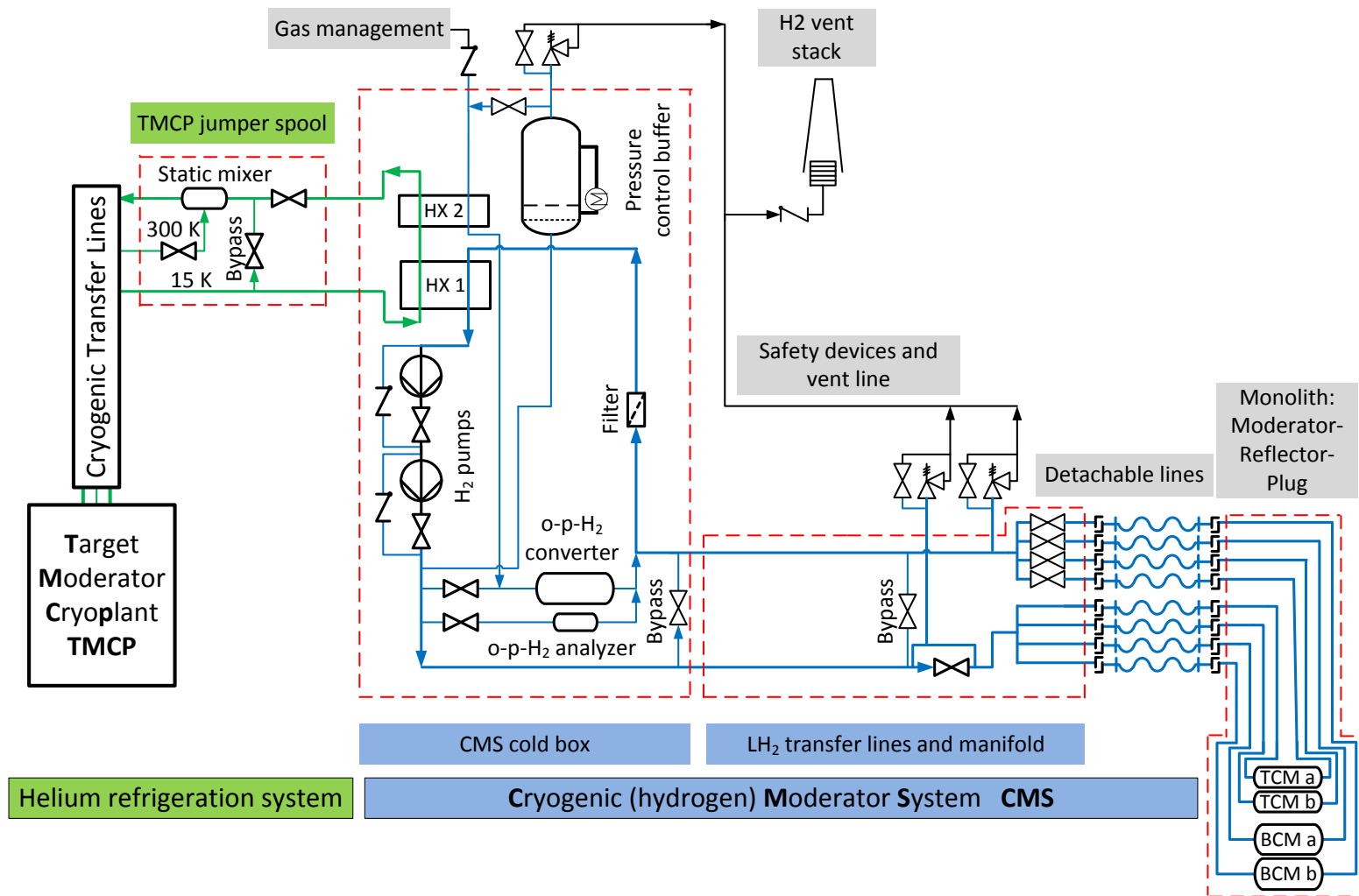
O-p-catalyst package outsourced to ESS materials group:  
 Rough estimates available – final spec. of catalyst and Raman detector still to be provided

Already agreed by all: o-p-H<sub>2</sub>-catalyst arranged in bypass  
 Eventually contribution of alternative o-p-H<sub>2</sub> detector based on temperature increase over adiabatic catalyst cell by TUD (tbd)



Challenge: In-situ o-p-H<sub>2</sub> monitoring (top); Solution: A) Raman spectroscopy (center) and B) temperature increase over catalyst (bottom).

# Final schematic configuration of the CMS



## Schematic configuration of the Cryogenic Moderator System

- Parallel coolant flow through four moderators
- Two (redundant) pumps in series with shared overall pressure head and circulating the same mass flow
- Active pressure control buffer (vertical temperature, density and hence compressibility distribution)
- o-p-H<sub>2</sub> converter and analyzer in bypass
- Helium refrigerator to re- and precool H<sub>2</sub>
- Three active control and spring loaded safety valve combinations (main on top of pressure control buffer)
- Helium gas inerted vent line guiding gas in case of an emergency release to the stack

## Warm-up of CMS

- No electric heater like J-Parc in ESS Cryogenic Moderator System (see PDR)
  - Static heat load including pumps (ca. 6 kW) would not be sufficient to realize 12 h warm-up duration
  - Metal mass is the driver for time to warm up to 300 K
  - Mass of HX1 not well known until now / rather long transfer lines
  - Proposed solution: Use TMCP and HX1 to introduce several more kW heat to the CMS and its cold mass
  - The TMCP and CTL has to be warm to cool down later on anyway
- > This has to be discussed close with the ESS cryogenics group

## Schedule performance / risks and issues

- **Structural support (Twister)** **delay by ? (early CDR / interfaces / long design process)**
- **Rotation Unit** **in time (interfaces)**
- **Cold Moderators** **in time**
- **Thermal Moderators** **in time (interface)**
- **Be-Reflectors** **in time (funding)**
- **Hydrogen System (CMS)** **in time (funding / interfaces)**

# Schedule performance / risks and issues

## Summary important not finally defined interfaces

- **Structural support (Twister)**
  - Remote handling
- **Rotation Unit**
  - Monolith vessel / airlock
- **Thermal moderator**
  - Irradiation module
- **Hydrogen System (CMS)**
  - Heat exchanger HX1 / o-p measurement system / o-p catalyst
- **From ESS... final system specification (PDR TIK3.1)!**, including load history / final material handbook / final vacuum handbook / final neurotic report (radiation damage / shielding / activation / heat deposition) which we can refer is necessary for the documentation of all nuclear components, around two months before each CDR

# Milestones

ID	Name	Planned Date	Current Forecast or Actual	Delay (W.Days)
A80110	Preliminary Design Moderator Reflector Plug	2015-03-26	2015-06-15	7
A38520	Preliminary Design Review of Cryogenic Moderator System (LH2)	2015-06-17	2015-06-16	0
A49360	CDR MR Handling System	2016-04-26	2016-04-26	ca. 25 ?
A42220	CDR Cold Moderator	2016-09-28	2016-09-28	0
A42880	CDR Thermal Moderator	2016-08-24	2016-08-24	0
A43330	CDR Reflectors	2016-07-10	2016-07-10	0
A39800	CDR Cryogenic Liquid Hydrogen System	2016-12-15	2016-12-15	0
A49440	Delivery MR Handling System	2018-03-31	2018-03-31	0
A42300	Delivery Cold Moderator	2018-03-31	2018-03-31	0
A42960	Delivery Thermal Moderators	2018-03-31	2018-03-31	0
A43410	Delivery Reflectors	2018-03-31	2018-03-31	0
A39810	Delivery Cryogenic Liquid Hydrogen System	2018-06-30	2018-06-30	0



## Near-term plans

- Prepare and perform CDR for rotation unit / Twister ? / Reflector
- Finalize detail design phase for all packages
- Order Beryllium and hydrogen Pumps
- Manufacturing test of the thermal moderator
- Finalize manufacturing tests of the cold moderator

## Concluding remarks

- The funding issues are the driver at the moment
- The interfaces create delays also, which we must handle promptly
- But in general the whole TIK3.1 and TIK3.2 packages go straight forward