LBNF CAD check

Abstract:
A crosscheck of the LBNF CAD model (ST1294927_01, August 2020) is done to verify if the changes described in document EDMS 2194738 have been implemented: https://edms.cern.ch/document/2194738/

Prepared by:	***Verified by:***	***Approved by:***
Jaakko Esala Christophe Bault	Andrea Catinaccio	Marzio Nessi Dimitar Mladenov
Date: 26 August 2020	Date : 27 August 2020.	Date : Click here to enter a date.

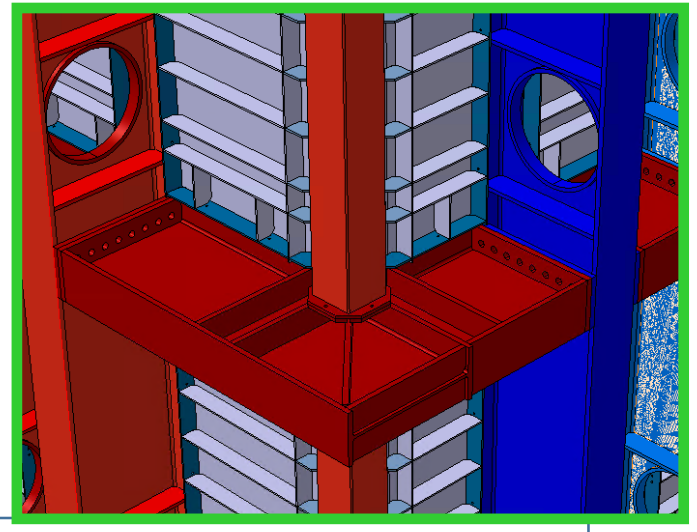
Introduction

- The LBNF CAD model ST1294927_01 (Version from August 2020) shared by Neutrino team is checked to see if changes described in document ”Changes to the Cryostat structure since design review 21-22 August 2017” are implemented. (https://edms.cern.ch/document/2194738/)

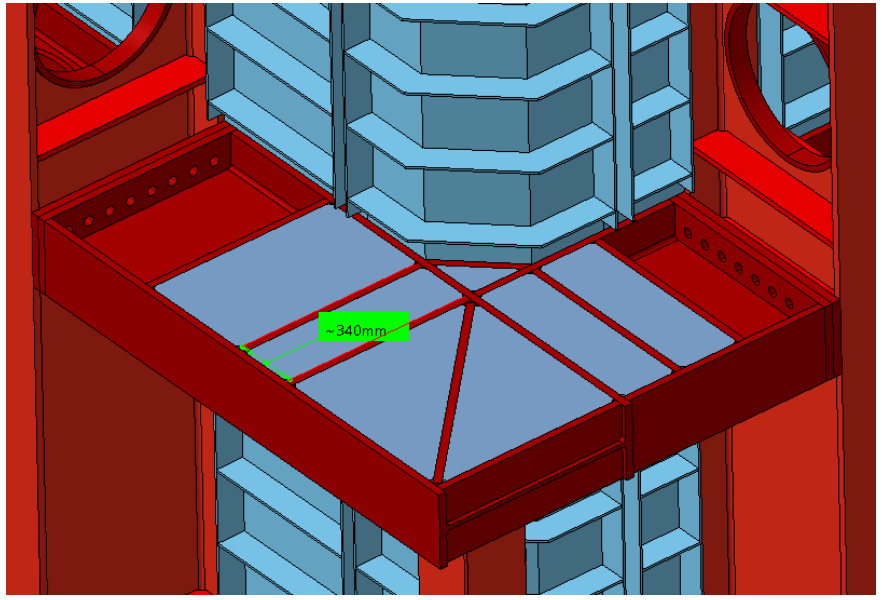
- The structure of this document follows the document ”Changes to the Cryostat structure since design review 21-22 August 2017” (https://edms.cern.ch/document/2194738/)

- Points requiring action are summarized and listed at the end.

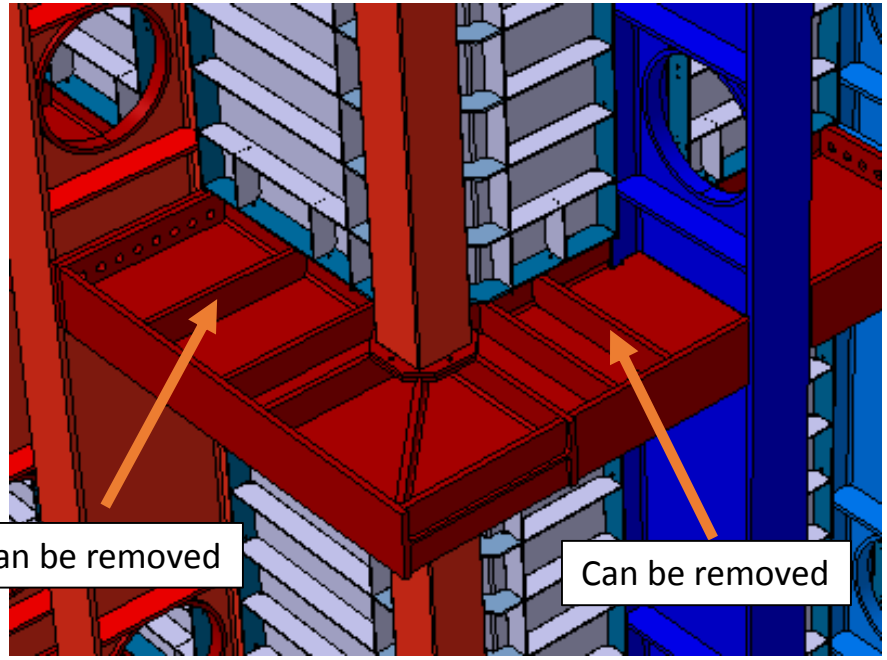
1. Corner haunch connection



- Reinforcement plates removed from the corner → **OK!**
- Extra stiffeners have been left after removing they plates → **Extra stiffeners may be removed**

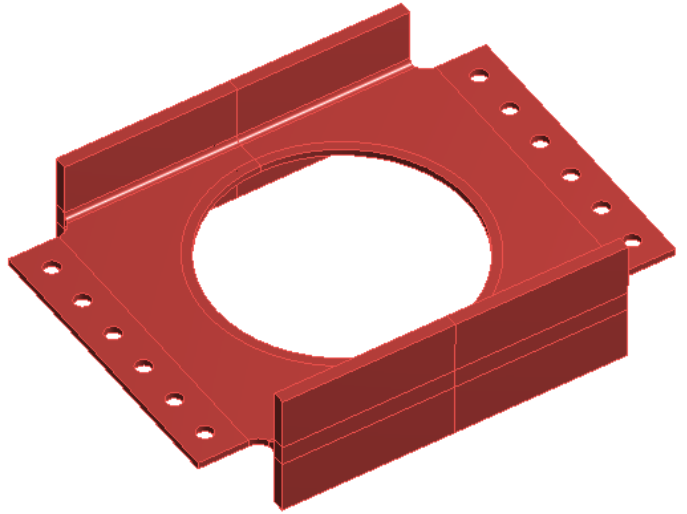


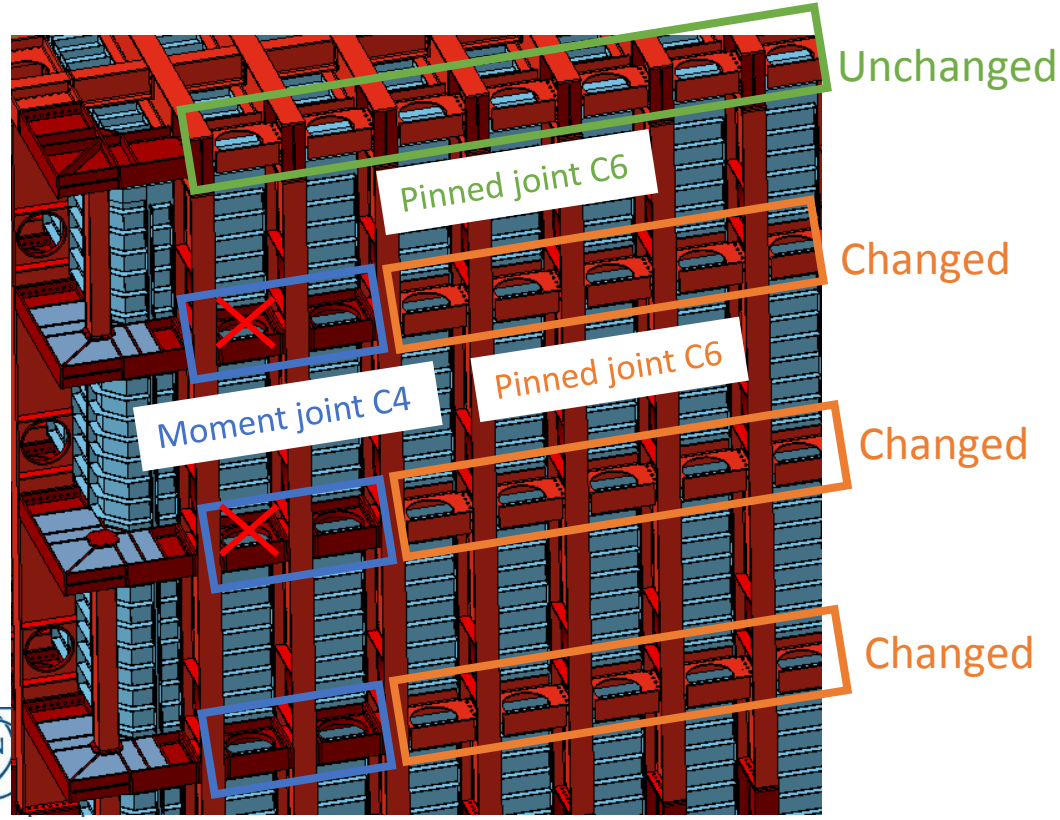
New Model – ST1294927_01 – 20.8.2020



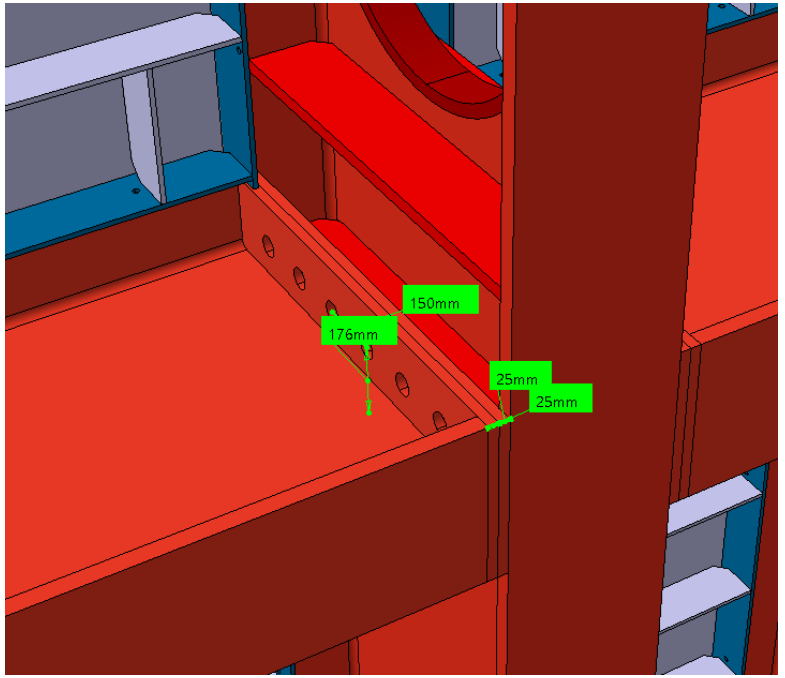
2. Change of long wall belts

- Long wall belts have been changed from lap-joints to end-plated connections → **OK!**
- Dimensions of the connection have been checked → **OK!**



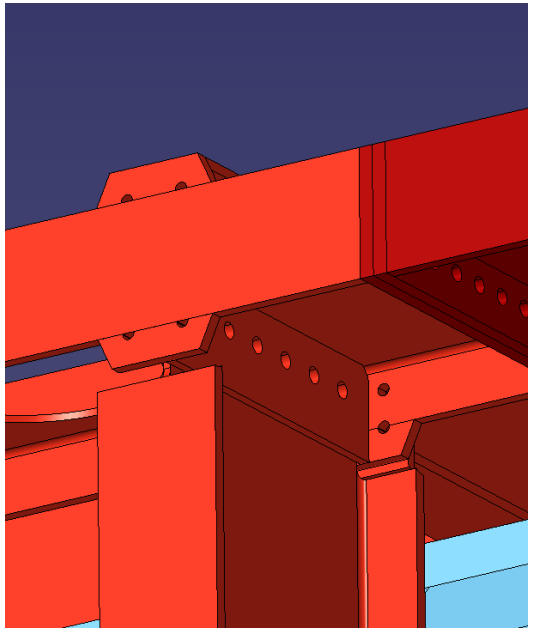


New Model – ST1294927_01 – 20.8.2020

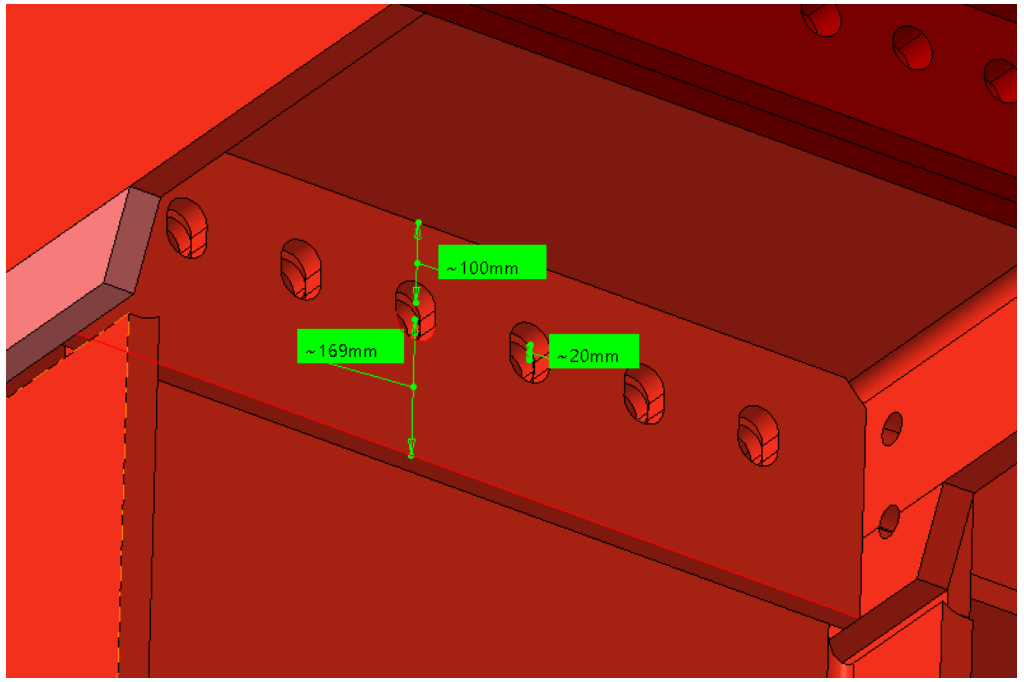


3. Short wall roof

- The lap joint on short wall roof has be changed with slotted holes → **OK!**
- Slotted holes are on fin plate side → **OK!**
- Dimensions have been checked → **OK!**



New Model – ST1294927_01 – 20.8.2020

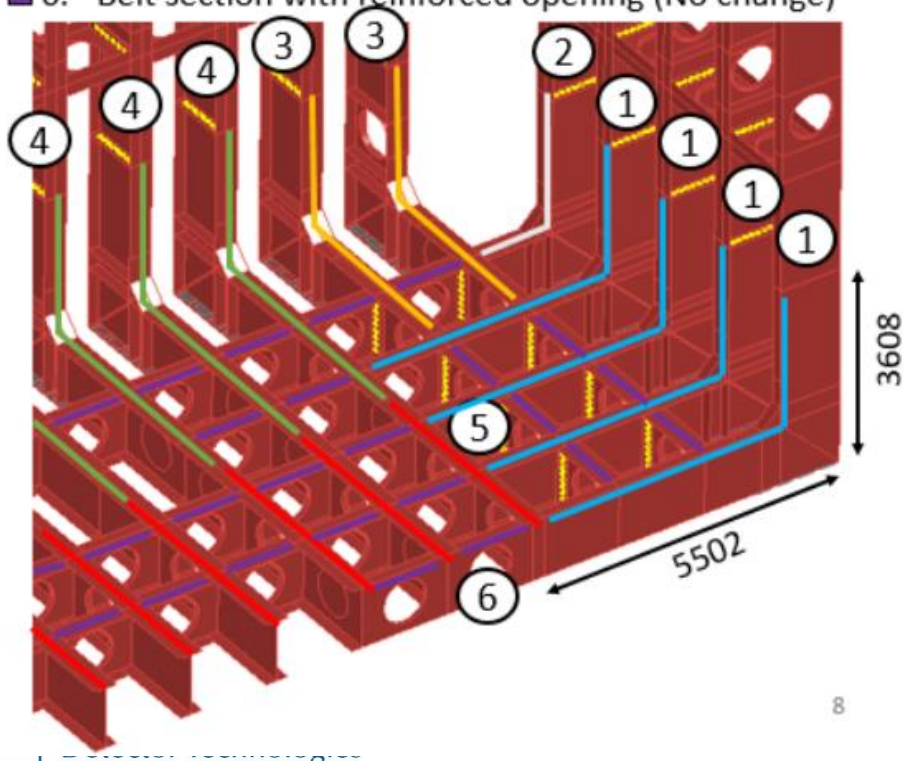


4. Changes to the floor

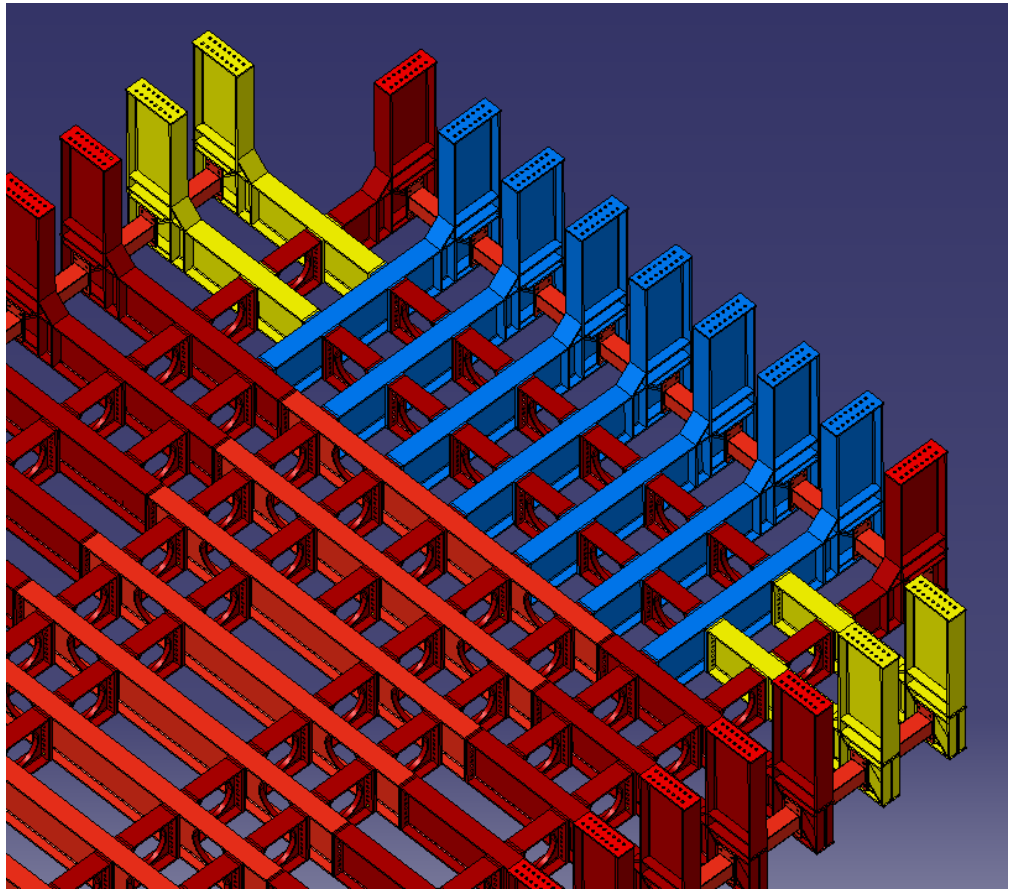
- Corner pieces on the short wall floor have been changed → **OK!**

Beam types

1. Corner beam 3608×**5502** (height×length) **(New)**
2. Corner beam 3608×2299 (height×length) (No change)
3. Corner beam 3608×4452 (height×length) **(New)**
4. Corner beam 3608×**5495** (height×length) (No change)
5. Central beam section (No change)
6. Belt section with reinforced opening (No change)



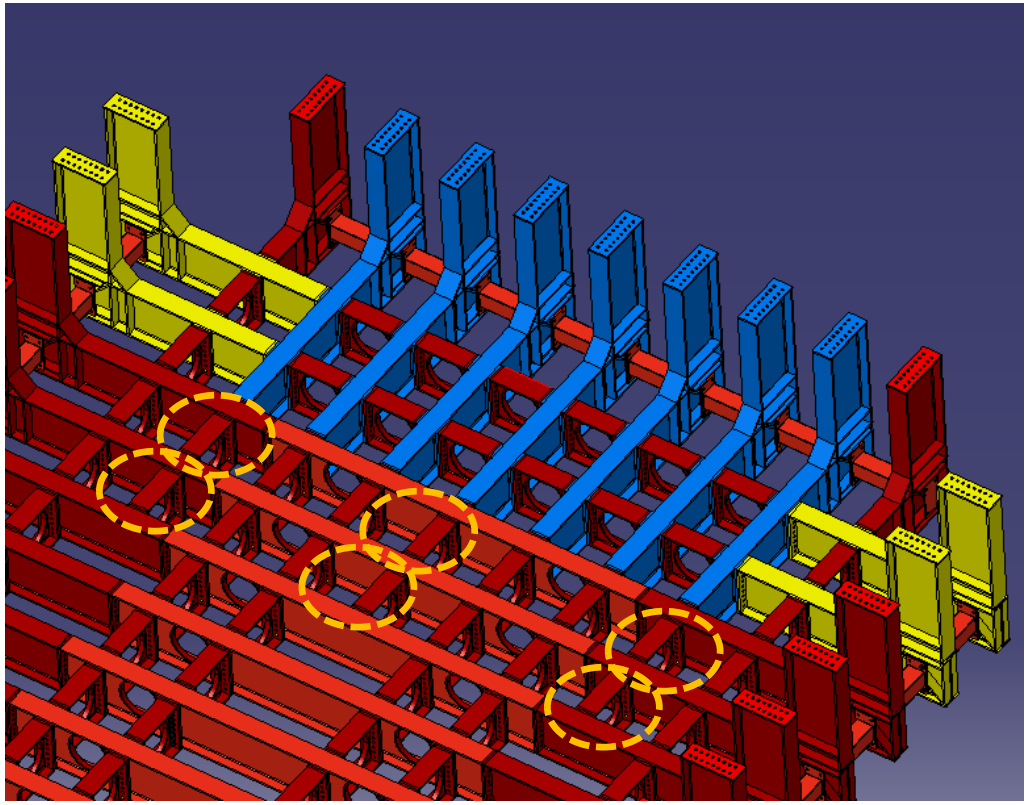
New Model – ST1294927_01 – 20.8.2020



4. Changes to the floor

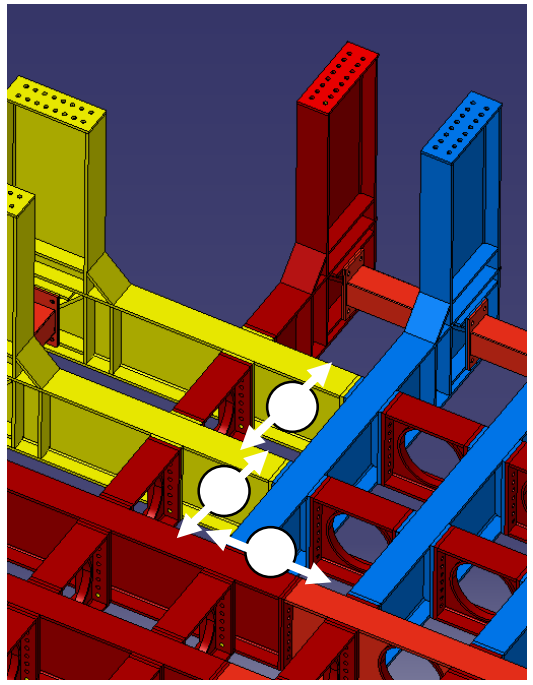
- Two extra belt sections added on the floor on some beams → **OK!**

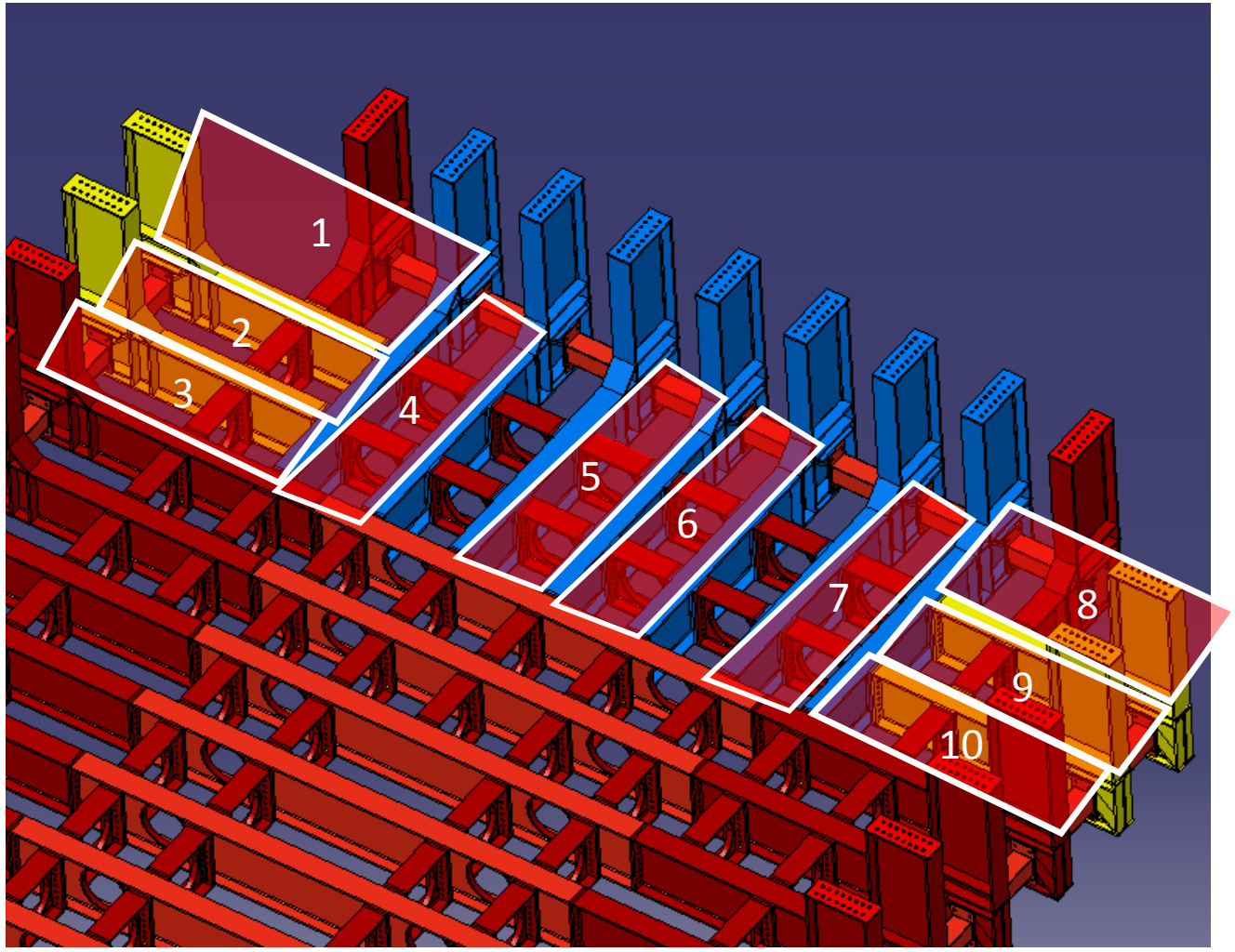
New Model – ST1294927_01 – 20.8.2020

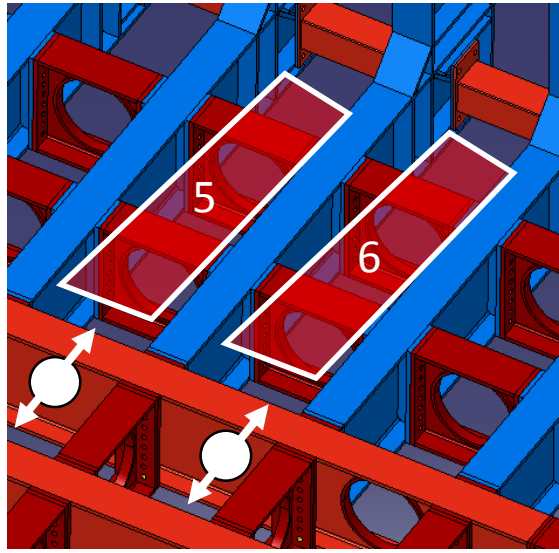


4. Changes to the floor

- The following sections are not accessible from the central floor through openings → **Not a structural issue. If access is needed, it should be placed in the locations shown below (white circles). Openings in these locations were calculated in EDMS 2308165.**

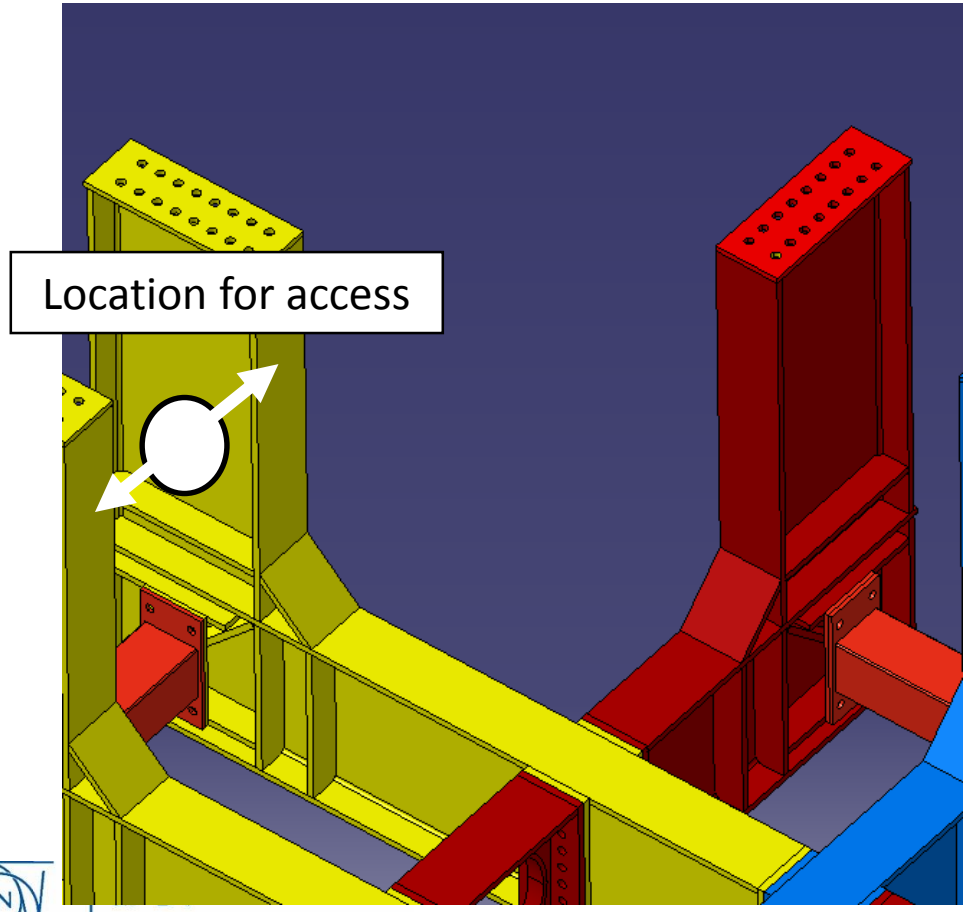




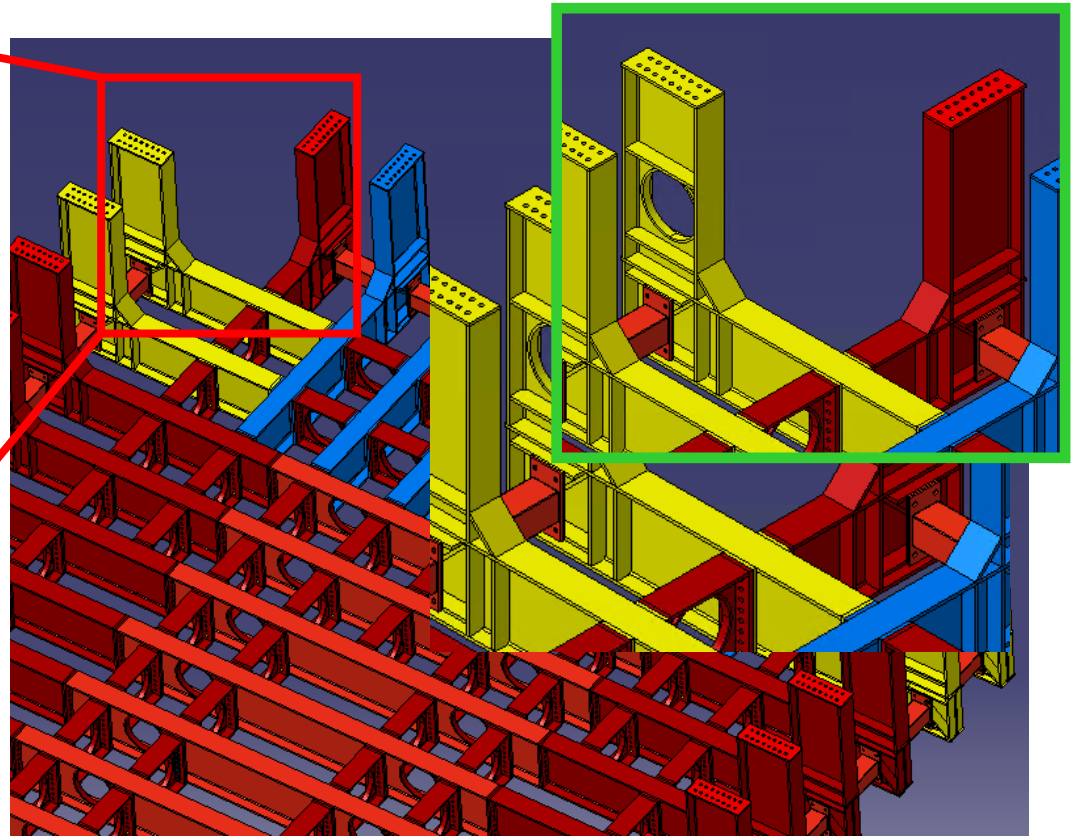


4. Changes to the floor

- Similarly the corners of the cryostat are not accessible → **Access should be placed in the vertical portion of the yellow beam, in case it is needed. (Openings in this location was calculated in EDMS 2308165.)**

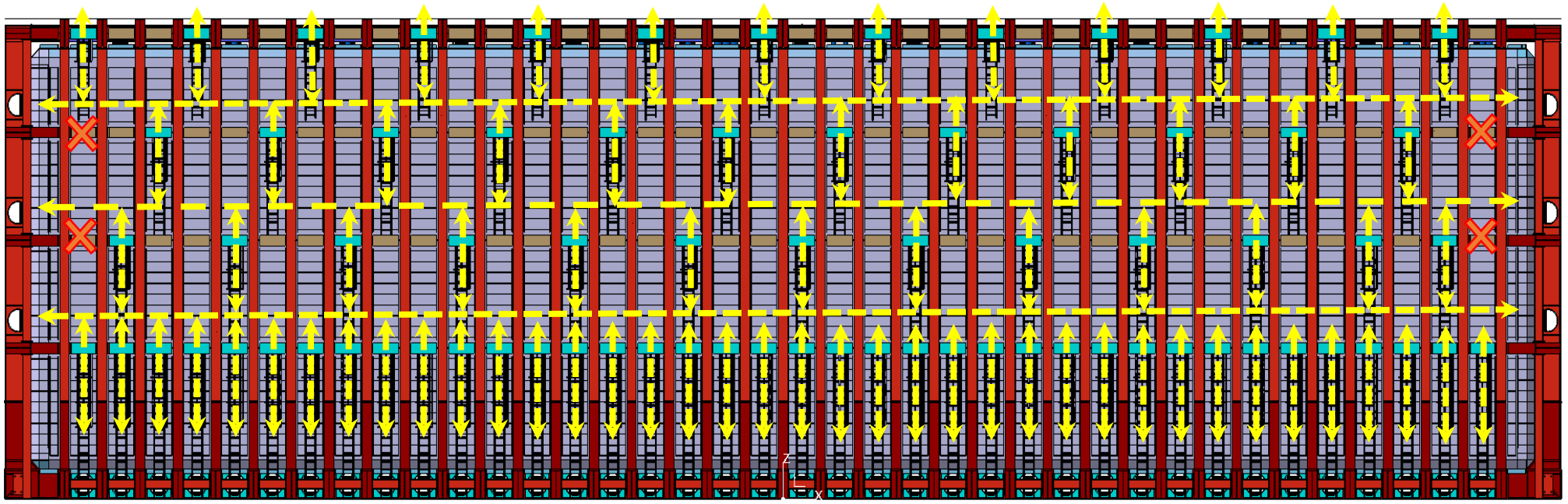


New Model – ST1294927_01 – 20.8.2020



5. Pattern of access holes on the walls

- The pattern of access holes on the Short and Long walls is checked → **OK!**
- Critical areas marked are avoided → **OK!**
- Access holes are reinforced in correct positions (C4 moment connection). The rest of the connections are unreinforced as specified → **OK!**



Horizontal beam with access hole: Diam 800mm

Horizontal beam without access hole

No opening allowed

Tunnel access

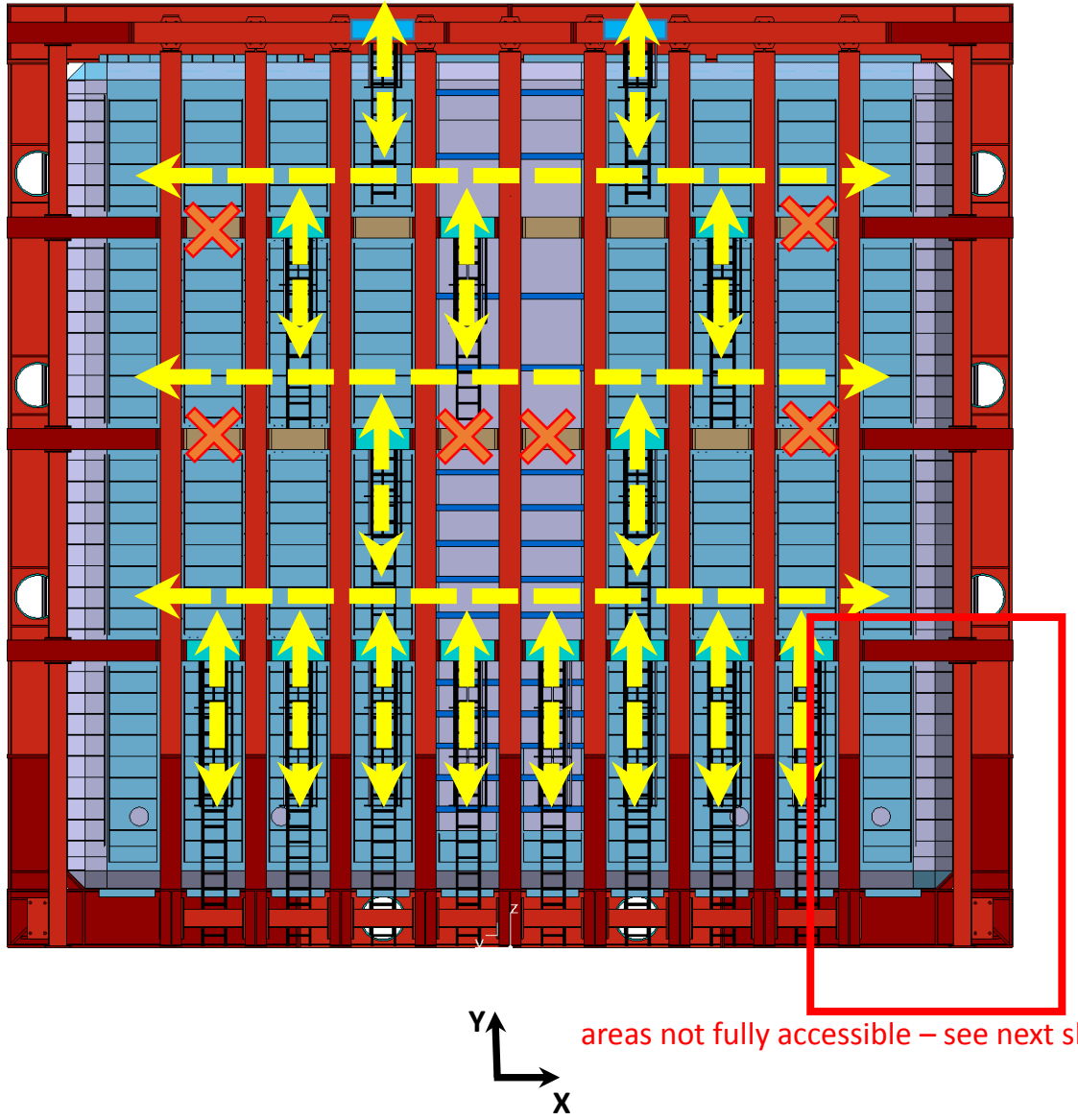
5. Pattern of access holes on the walls

- The pattern of access holes on the Short and Long walls is checked → **OK!**
- Critical areas marked are avoided → **OK!**
- Access holes are reinforced in correct positions (C4 moment connection). The rest of the connections are unreinforced as specified → **OK!**

Horizontal beam with access hole: Diam 800mm

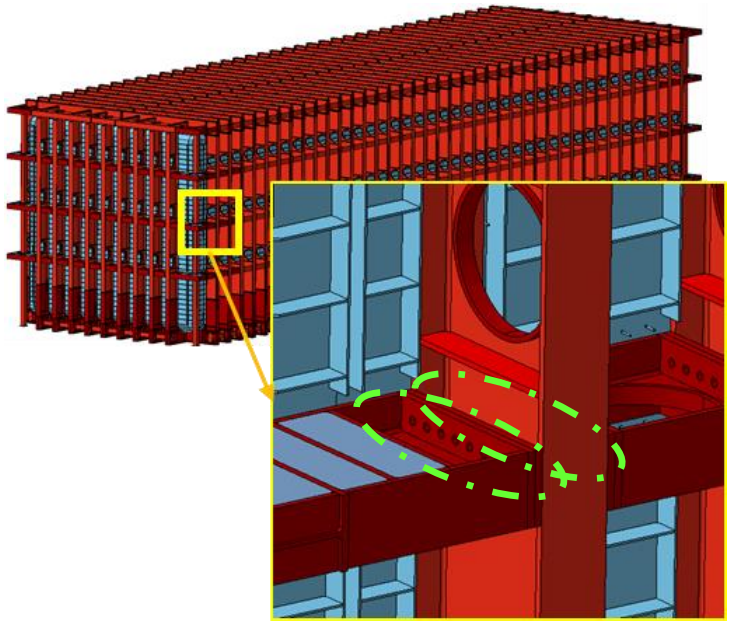
Horizontal beam without access hole

No opening allowed

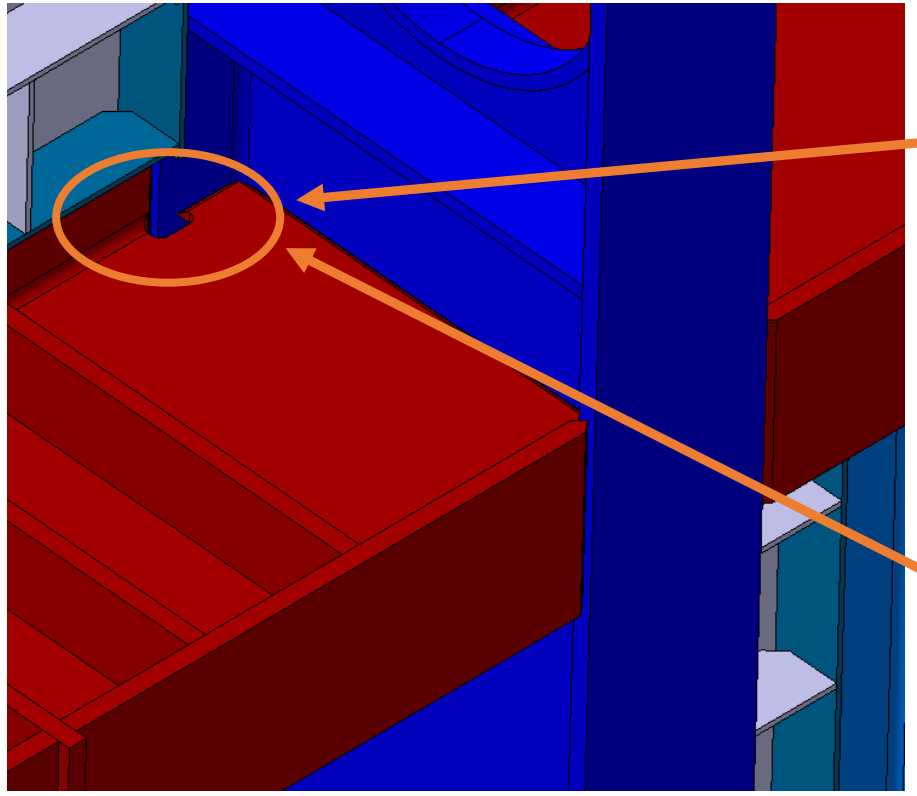


6. Welded connections – Belt 2 corner

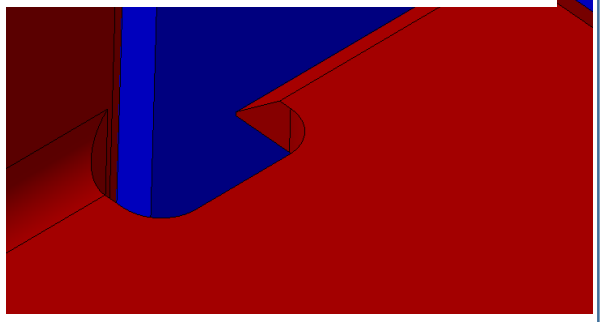
- Welded connections are included on the belt 2 corners in the correct positions. 8 welded connections in total → **OK!**
- Weld chamfers are on the wrong side on two corners → **Check that the orientation of chamfers is correct**



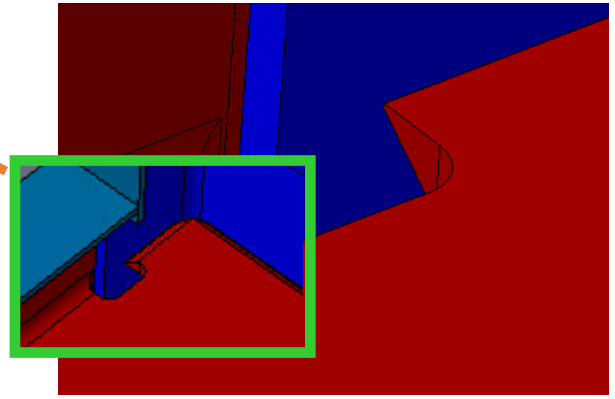
New Model – ST1294927_01 – 20.8.2020



Chamfer towards top (in 2 corners)

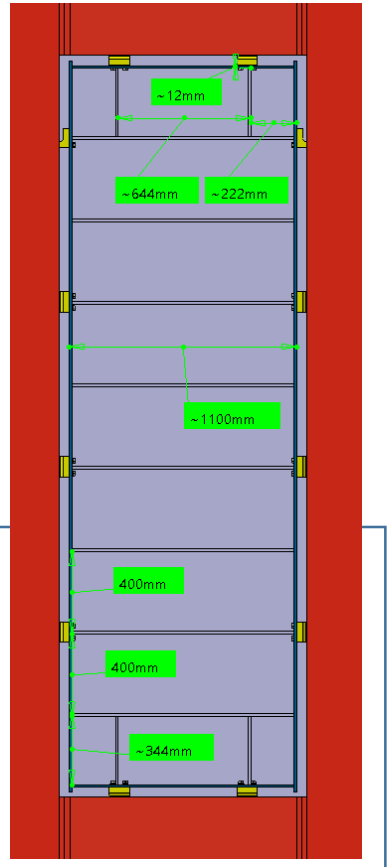


Chamfer towards bottom (in 2 corners)



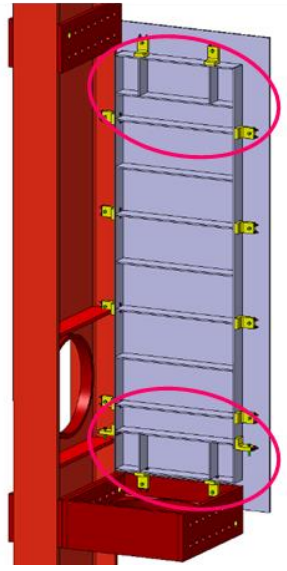
7.a) Warm membrane: wall plates

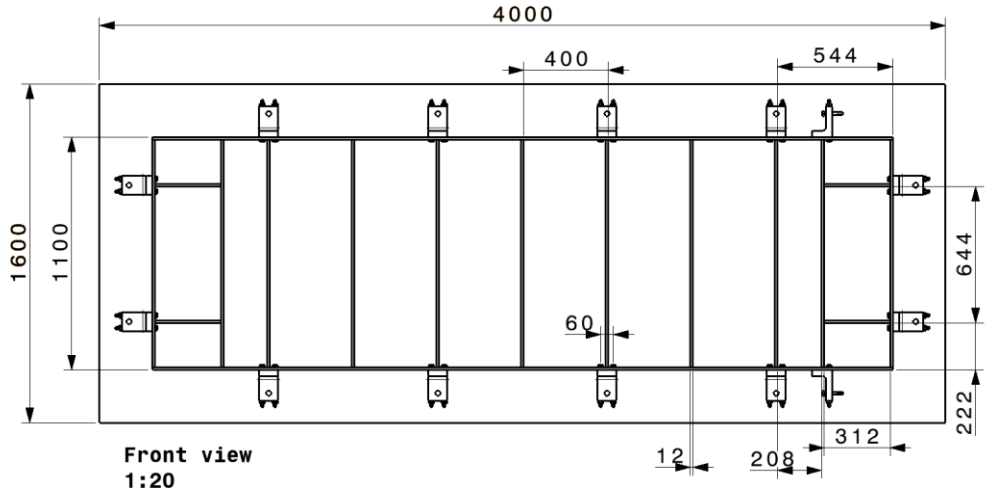
- One less rib is used on the wall plates → Should be ok OK, as the 400 mm rib spacing is respected. Originally the extra rib was added to have a more even distribution of clamps. <u>This exact configuration of ribs has not been checked by calculation.</u>
- Vertical clamps are on the top instead of the bottom → <u>This configuration is not checked by calculations, but is not expected to present a problem</u>
- One less row of clamps is used → Not expected to be problem on the wall plates, which are far away from membrane corners
- Distance between rib and frame is 49 mm → **OK!**



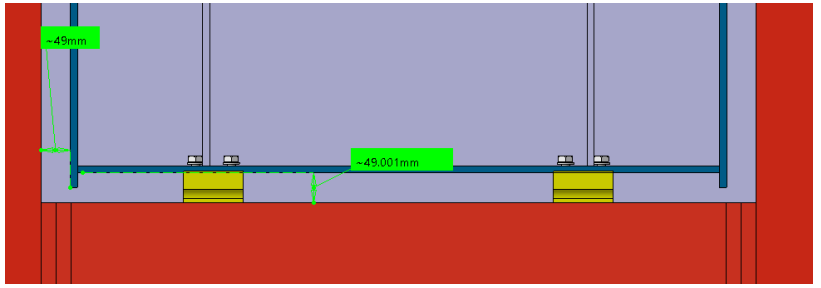
Wall plate concept. January 2020

New configuration





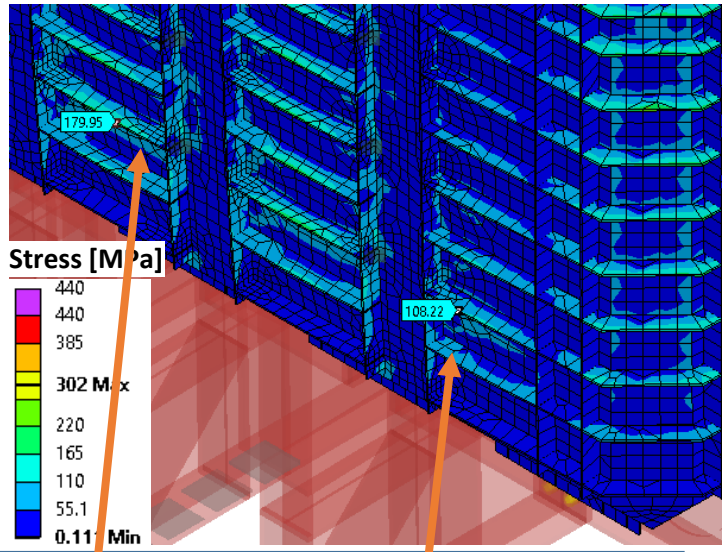
New Model ST1294927_01 20.8.2020



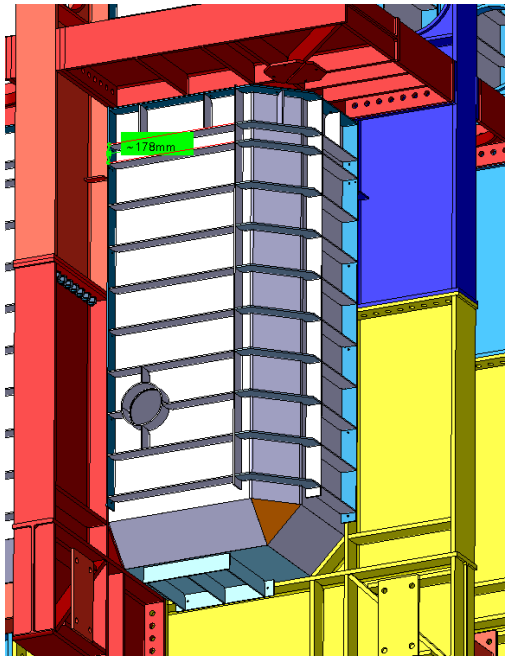
7.a) Warm membrane: wall plates

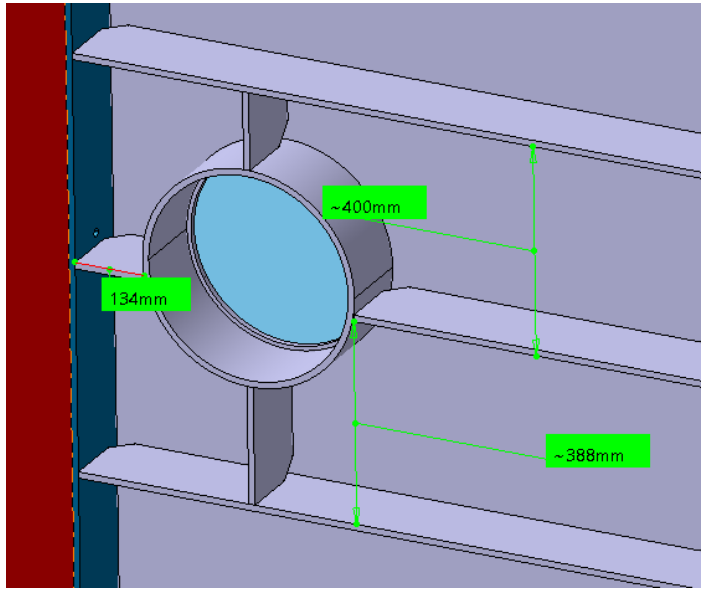
- Any local changes to the ribs respects the maximum rib pitch of 400 mm → **OK!**
- Local changes in ribs are <u>not checked by calculations.</u> Significant stresses are present on the ribs (Max ~180 MPa) → **It is recommended to check the strength and stiffness of the local changes.**
- **It is also recommended to consider the effects of membrane deformations on the feed-through.**

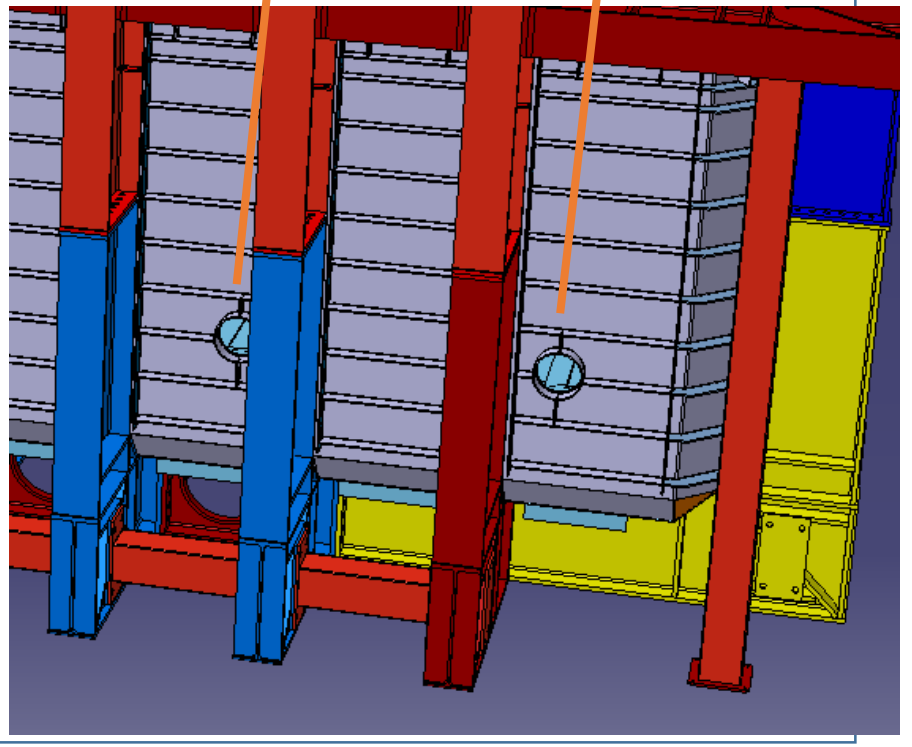
FEA Model (EDMS 2308165)



New Model – ST1294927_01 – 20.8.2020





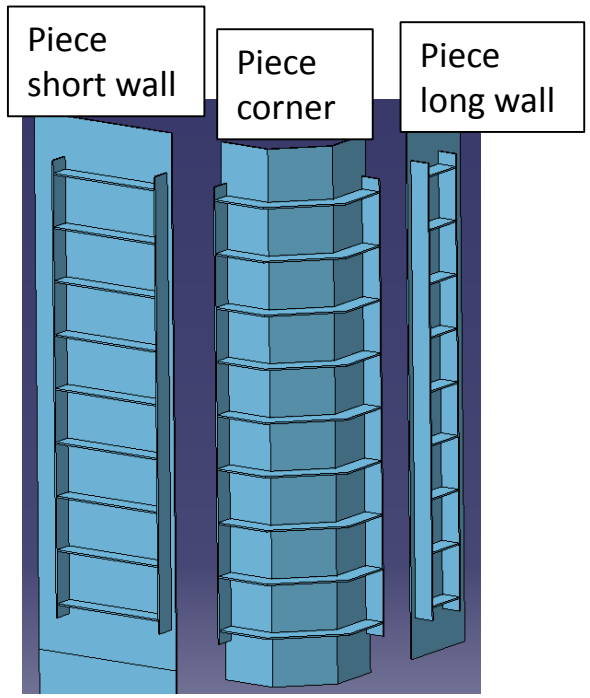


7.b) Warm membrane: wall corners

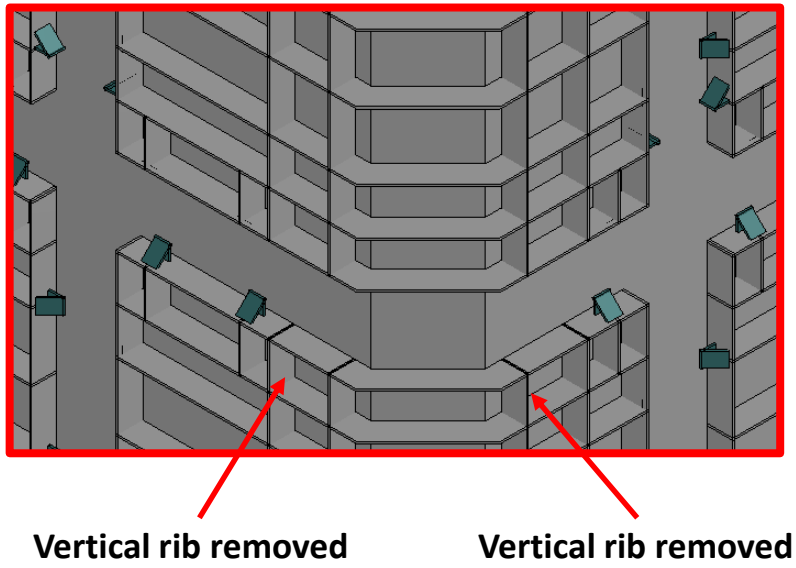
- The wall corner is now manufacture now in one piece, instead of welding from three pieces → **OK!**
- The dimensions are close to what was specified → **OK!**
- Plates across corner were changed to 15 mm thick → **OK!**
- The new model has one less vertical rib, but this was checked to be OK. See Annex in EDMS 2308158. → **OK!**

Remember to remove clamps close to the membrane corners after vacuum load case!

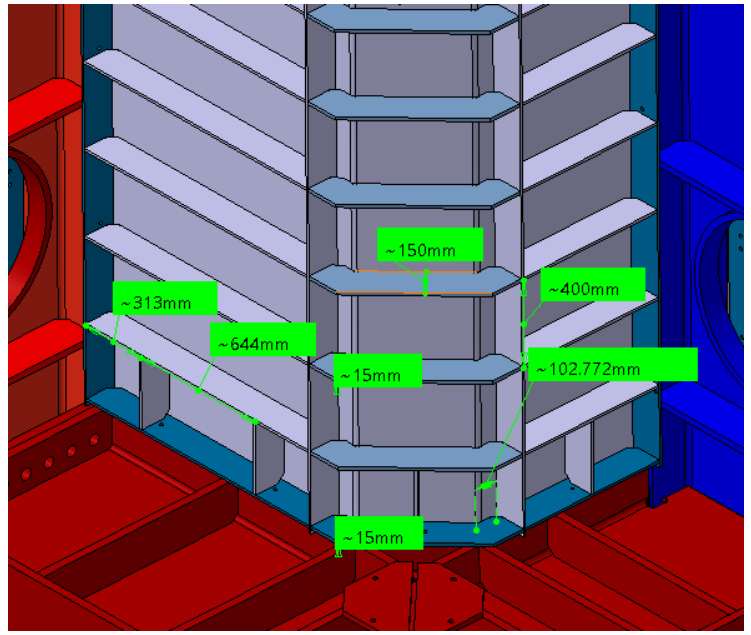
Old CAD model



New concept



New Model – ST1294927_01 – 20.8.2020

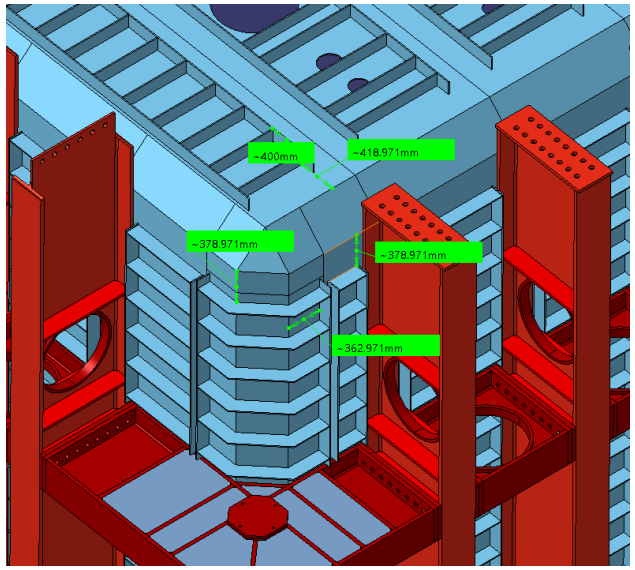


7.c) Warm membrane: Floor and Roof corners

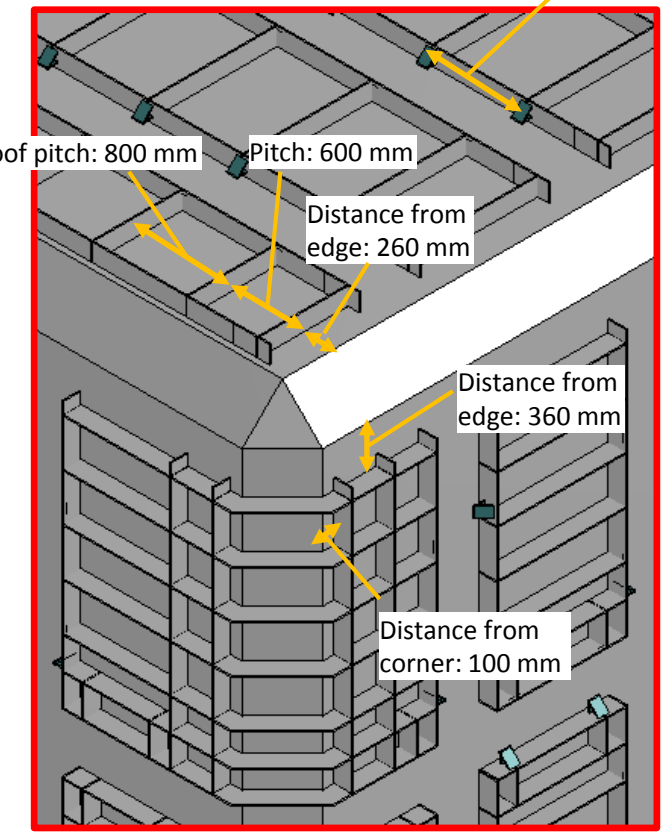
Remember to remove clamps close to the membrane corners after vacuum load case

- The maximum pitch of 800 mm is respected → **OK!**
- The spacing of the roof ribs seems OK. Distances of the first rib from the edge are respected → **OK**
- Distance between the 1st and 2nd rib is shorter (600 mm specified vs. 365 mm in the model) → **OK! No critical loads in the clamps in this location in operation**

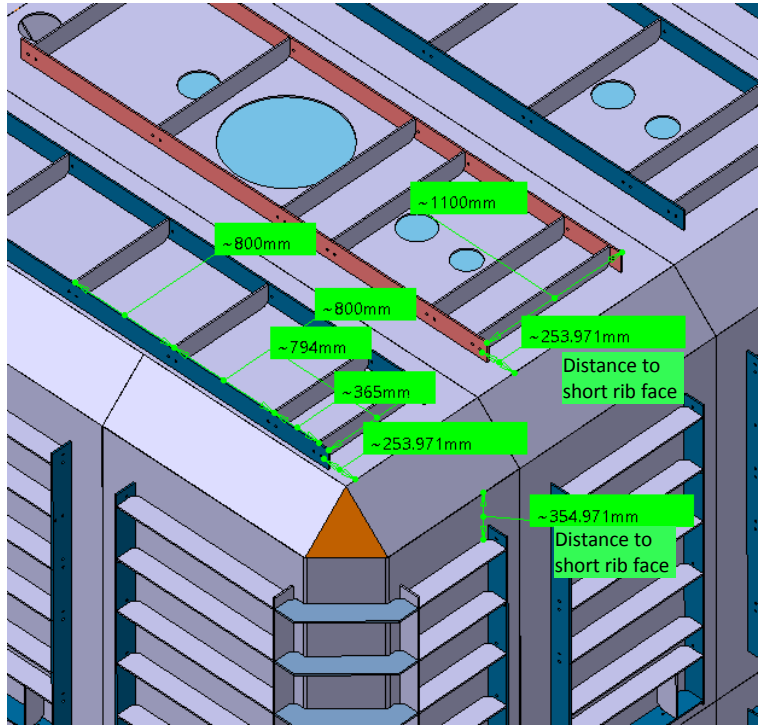
Old CAD model



New concept

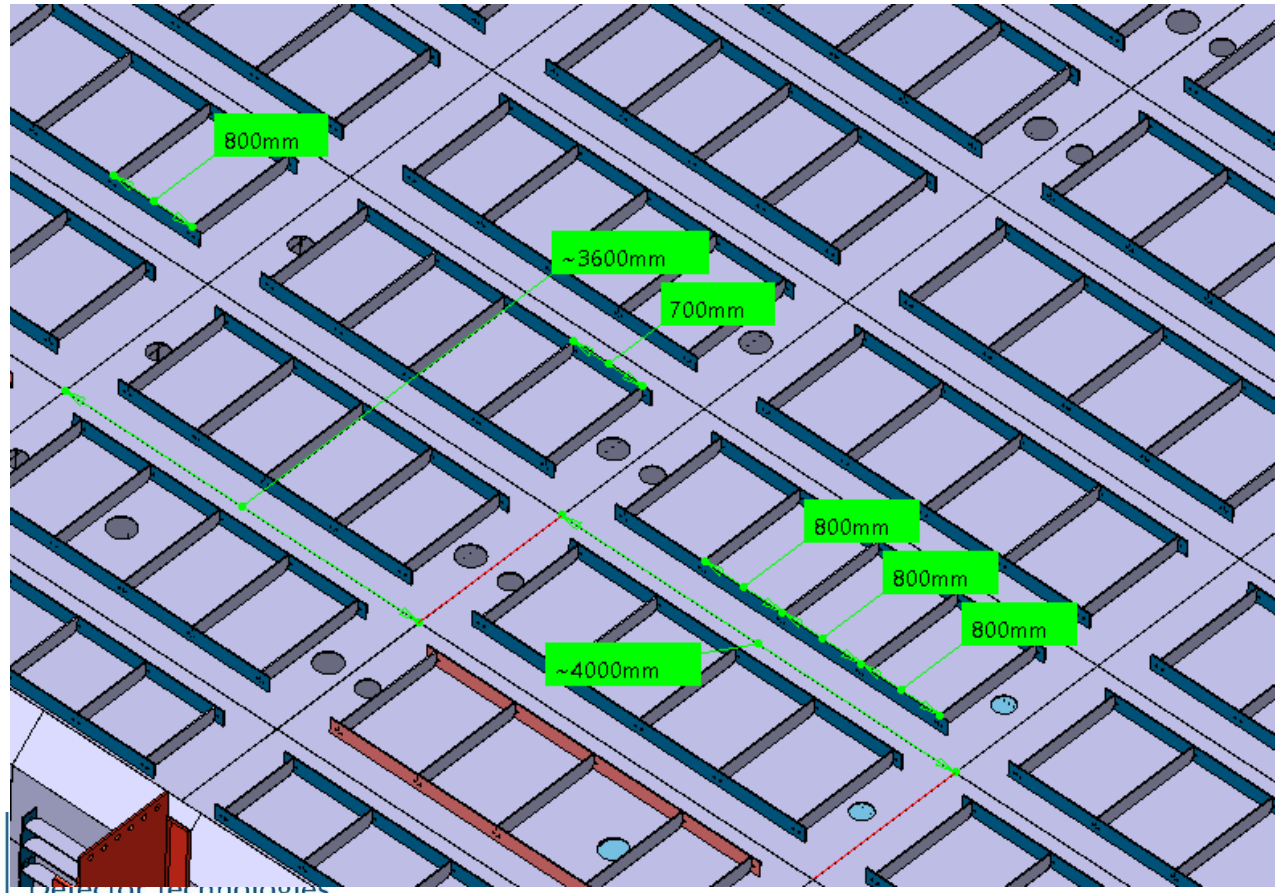


New Model – ST1294927_01 – 20.8.2020

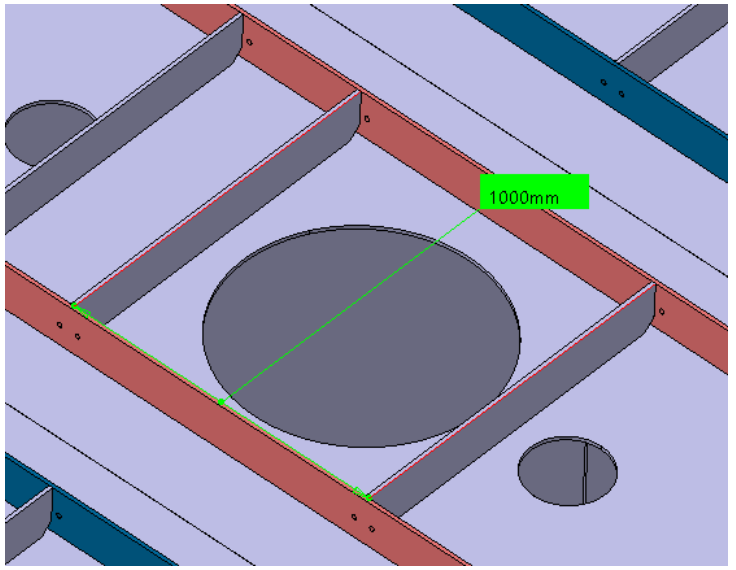


7.c) Warm membrane: Floor and Roof corners

- NOTE! The roof plates and ribs are not fully symmetric, and some local changes have to be made for feedthroughs.
- Local changes have not been checked by calculation, but no areas with obvious problems are spotted. The loads on the roof ribs are generally low.
- If some problematic areas are spotted, **local reinforcement shall be considered.**
- Generally the pitch of 800 mm is respected → **OK!**



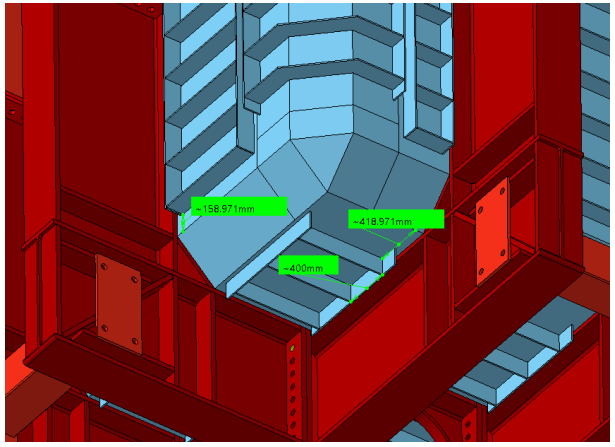
Locally 1000 mm pitch for a feed-through.
Maximum pitch was calculated as 1000 mm in EDMS 1865792
→ OK!



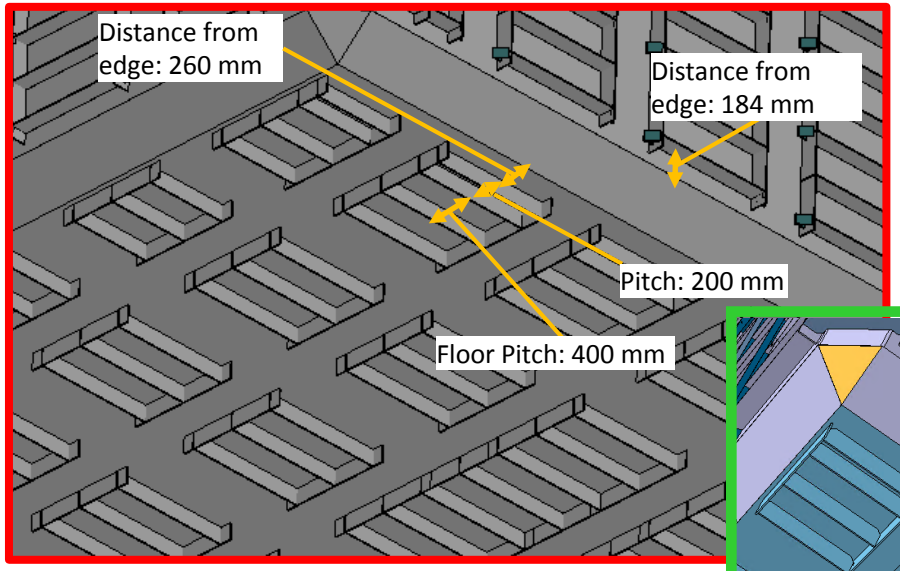
7.c) Warm membrane: Floor and Roof corners

- Extra ribs have not been placed close to the membrane corners → **To be added according to calculation. See new concept below.**
- Holes for clamps for the insulation negative gauge pressure have been added to the correct positions → OK!

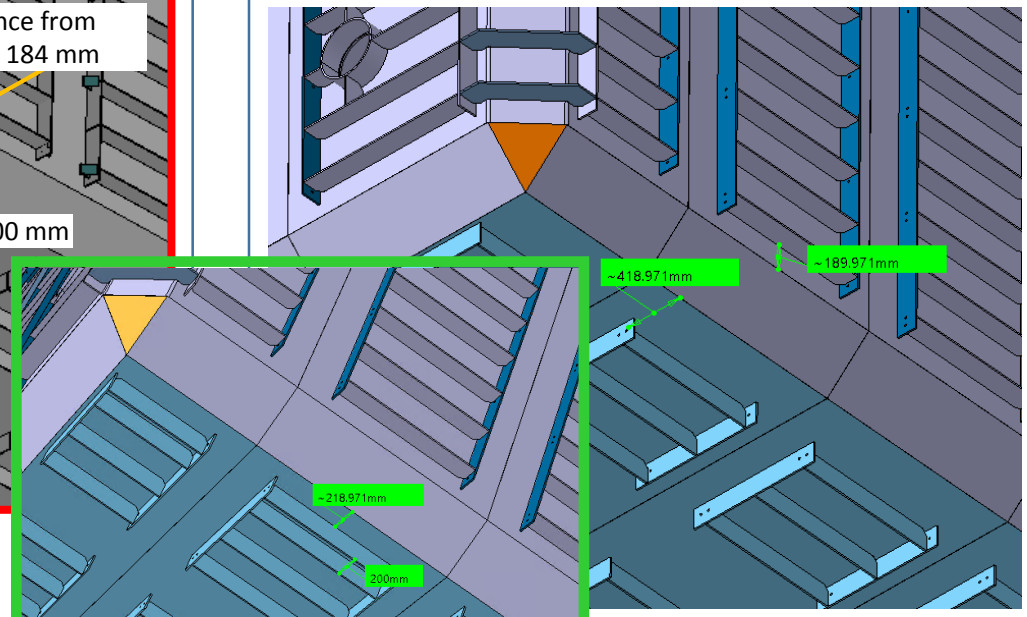
Old CAD model



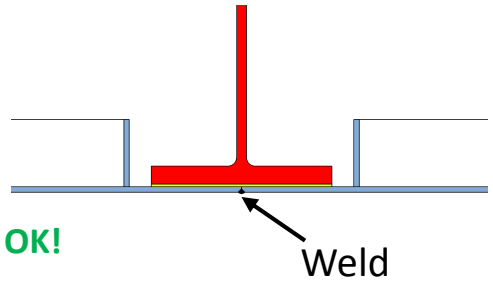
New concept



New Model – ST1294927_01 – 20.8.2020

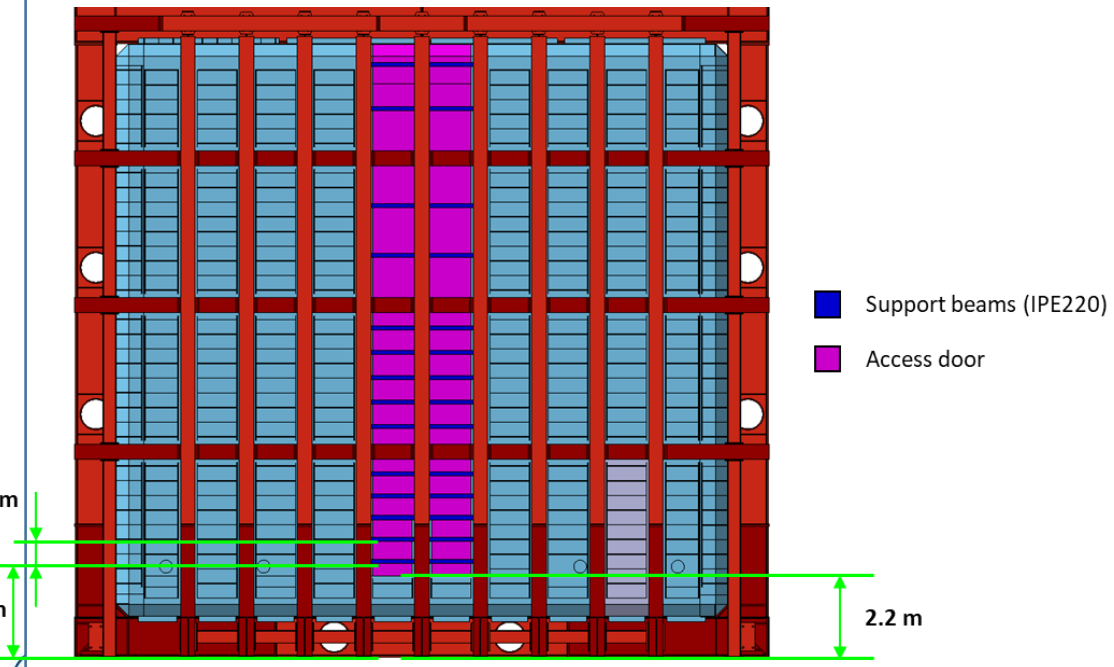


7.d) Warm membrane door

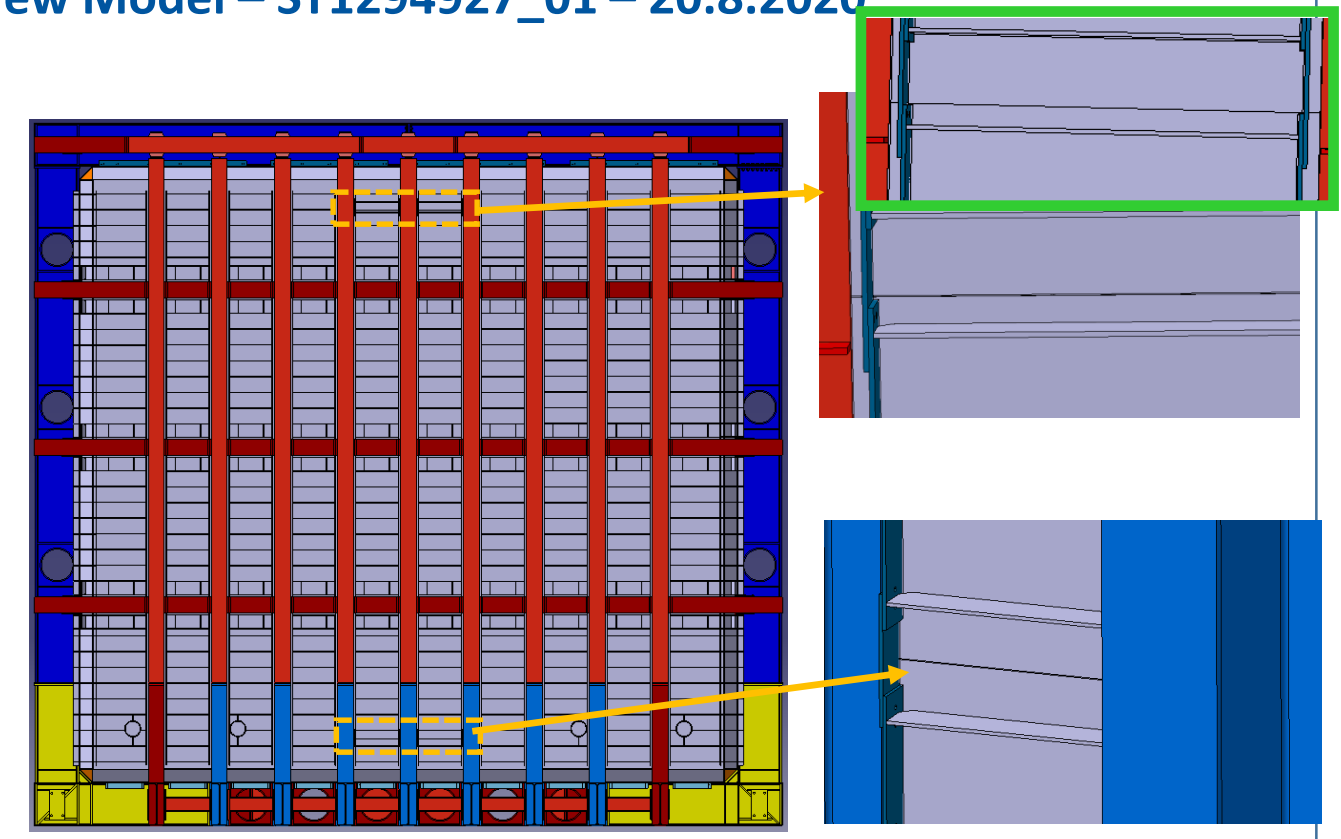


- The membrane door concept with IPE220 beams has been replaced with a standard welded door like the wall plates → **OK!**
- Weld of the door is not offset from the I-beam centerline, although the possibility was discussed?
- Some gaps or misalignment seems to be present → **Check alignment/dimensions of door plates in the CAD Model**

Old CAD model



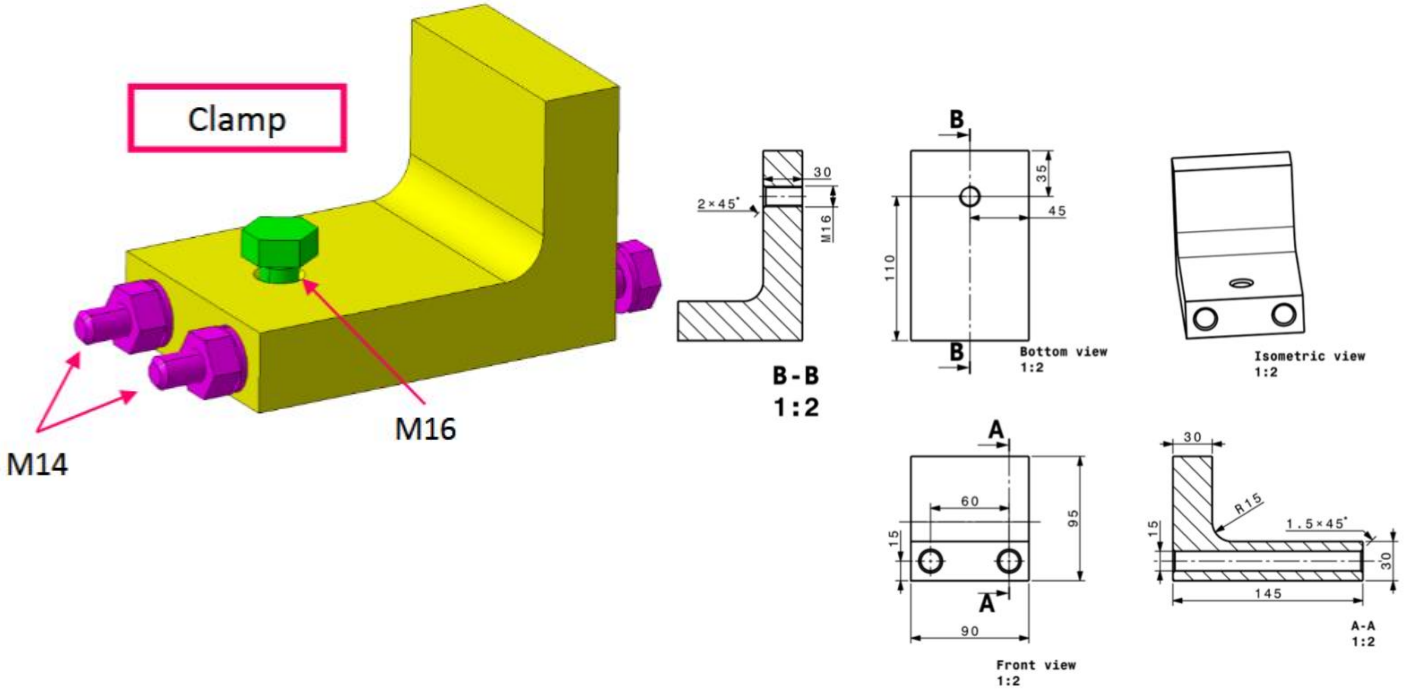
New Model – ST1294927_01 – 20.8.2020



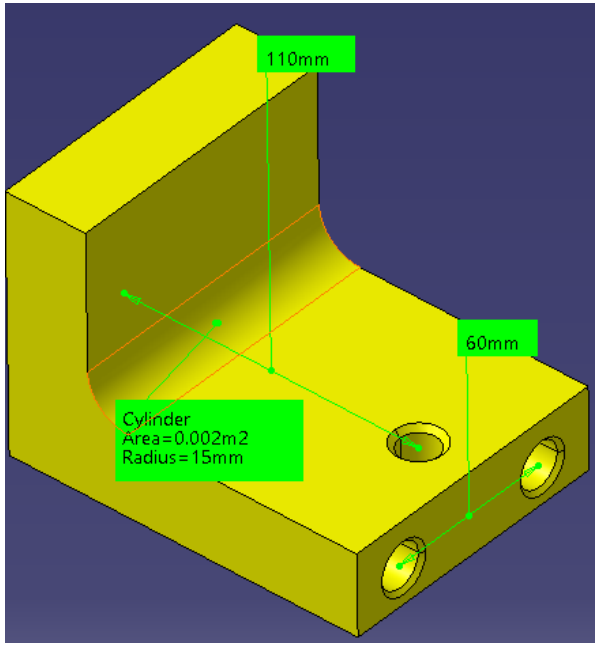
8. Warm Membrane Clamps

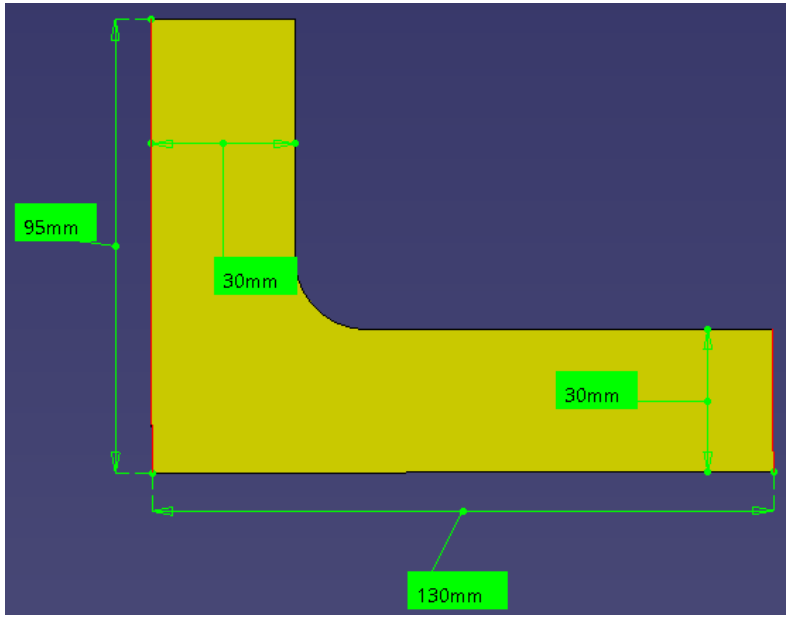
- Functional dimensions of the clamps are similar to the initial concept.
- The total length of clamp is reduced from 145 mm to 130 mm. Distance from bolt hole center to edge is 20 mm, which is still **OK**!
  (for example EC3 requires minimum $1.2 \times D_{bolt}$ from hole center to edge for end-plates).

Clamp concept. January 2020

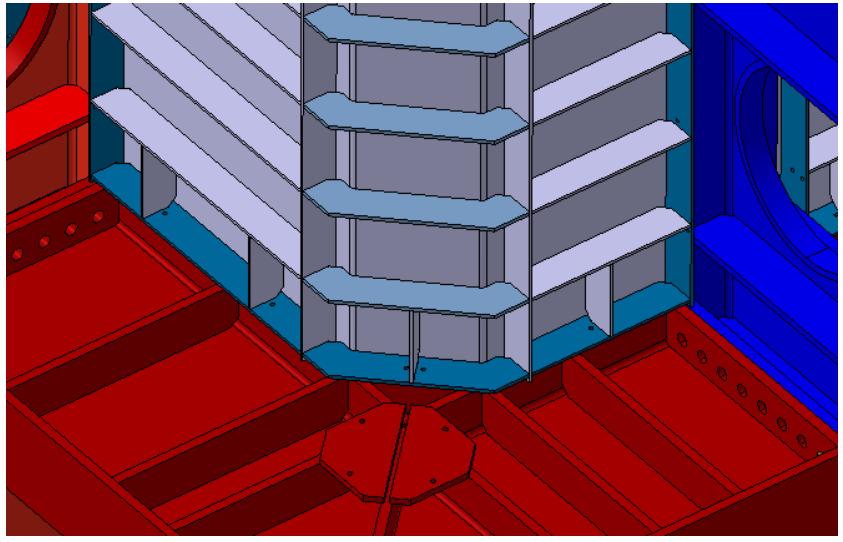


New Model ST1294927_01 20.8.2020

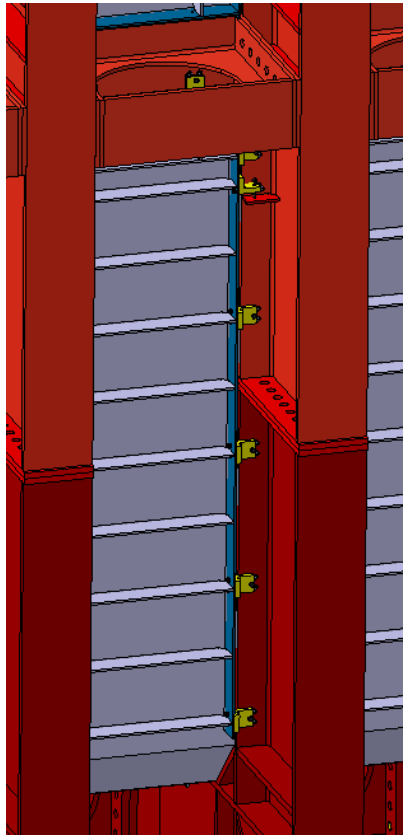




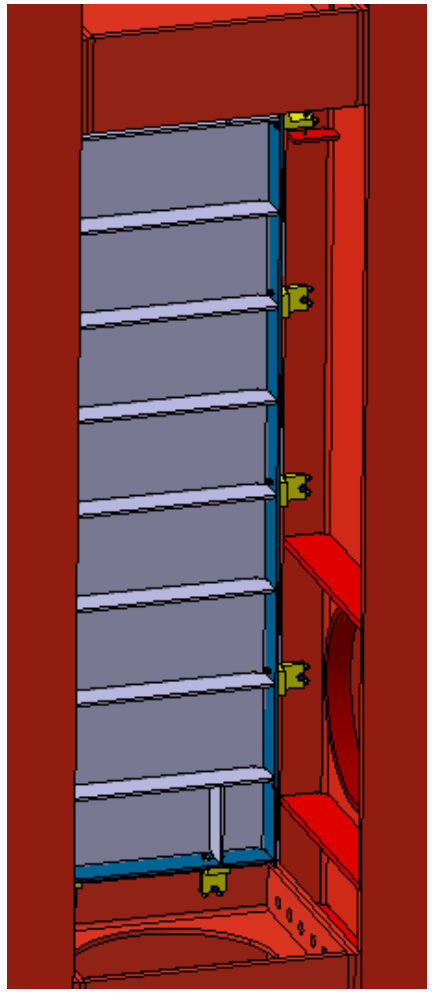
8. Warm Membrane Clamps



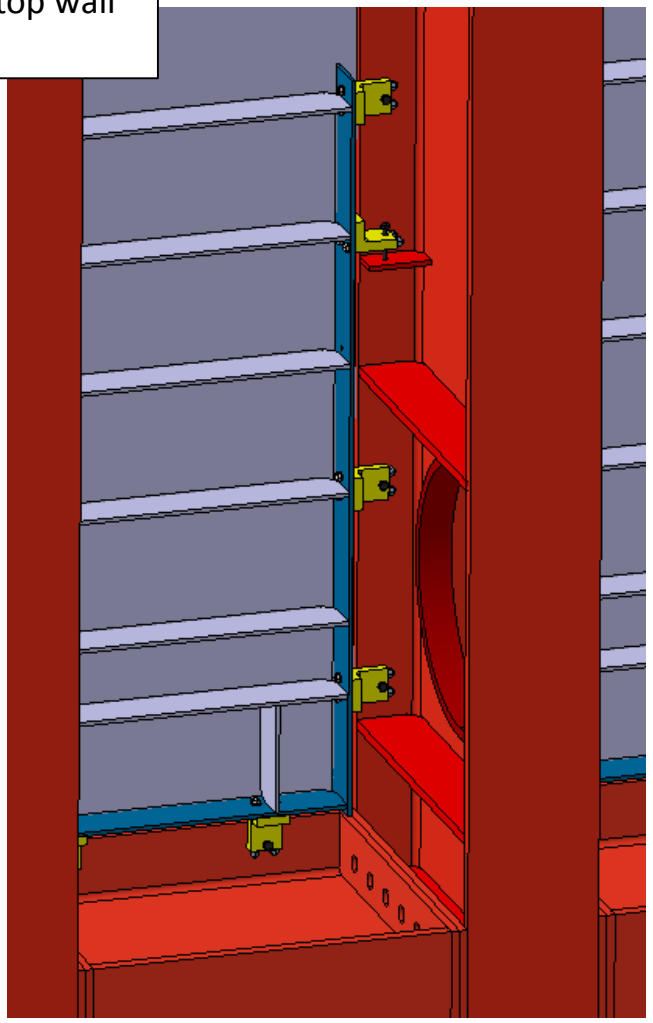
Clamps on bottom wall plate



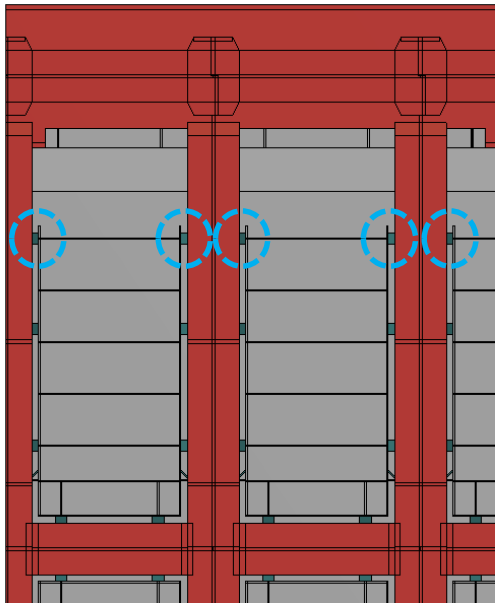
Clamps on standard central wall plate



Clamps on top wall plate

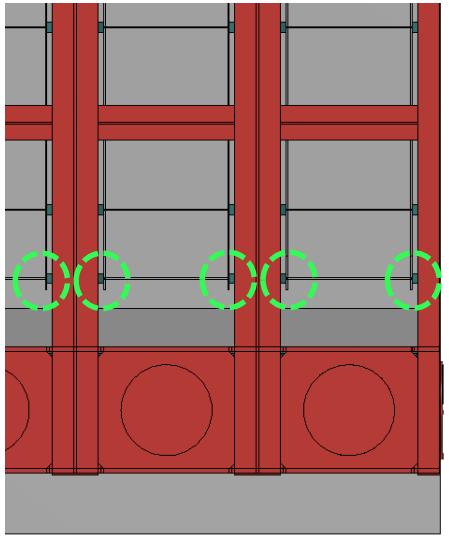


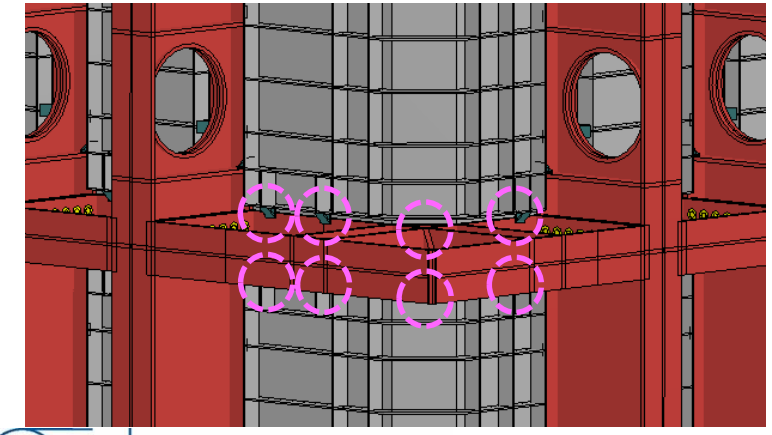
Reminder: Clamps used in vacuum case to be released for operation

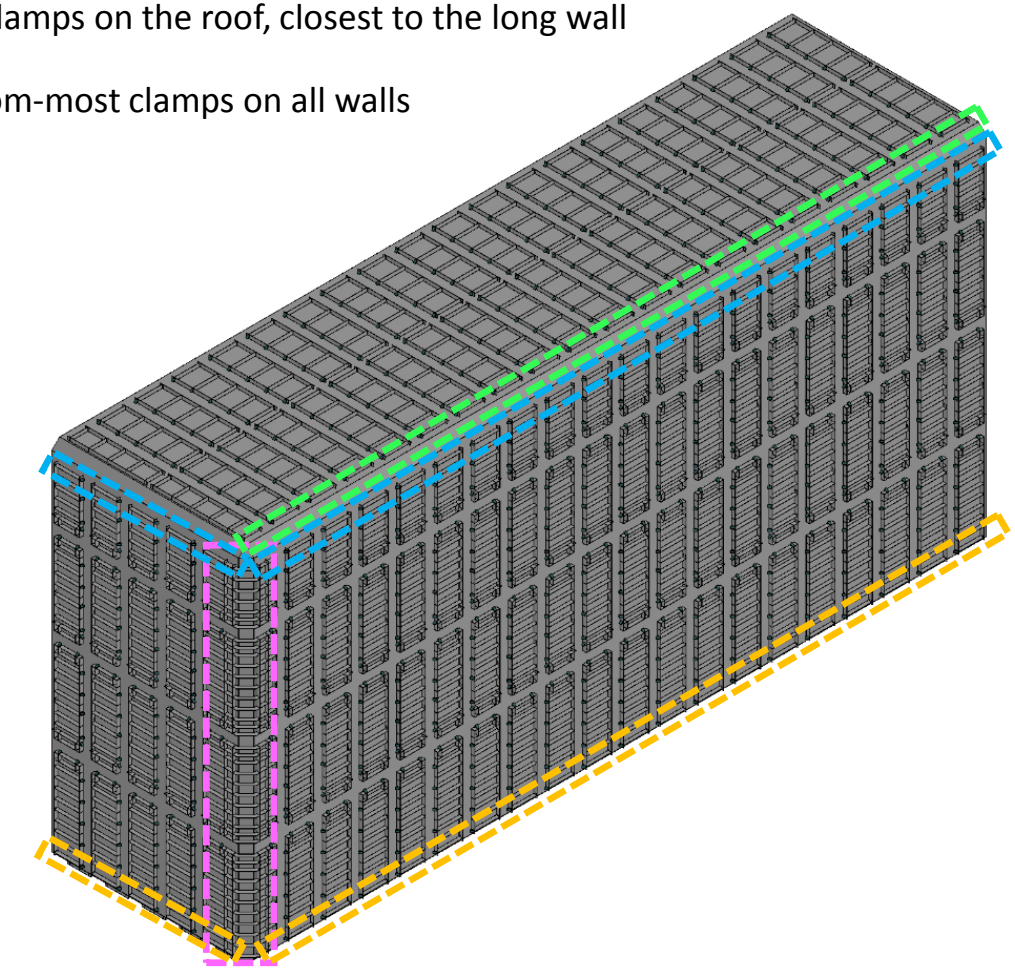


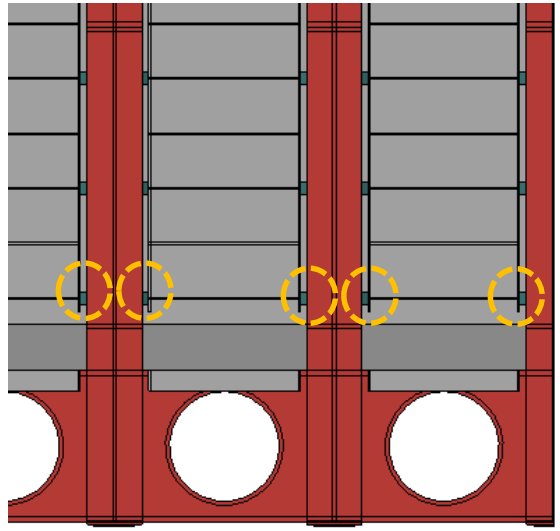
The following clamps should be released after insulation cavity vacuum testing

1. Topmost clamps on all walls
2. All clamps on the wall corners
3. All clamps on the roof, closest to the long wall
4. Bottom-most clamps on all walls

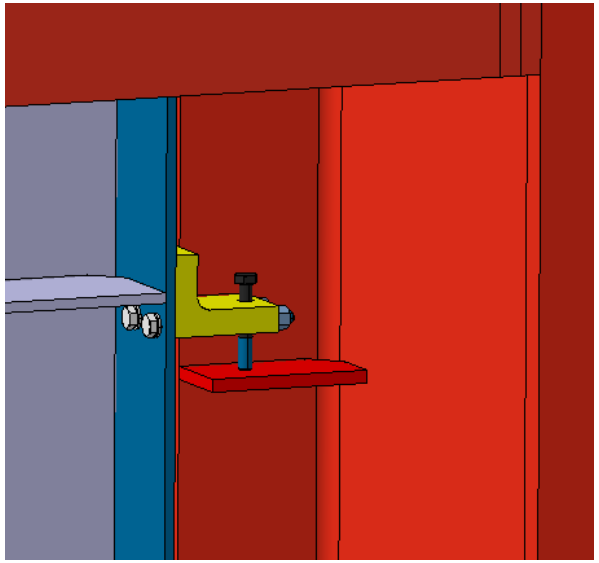




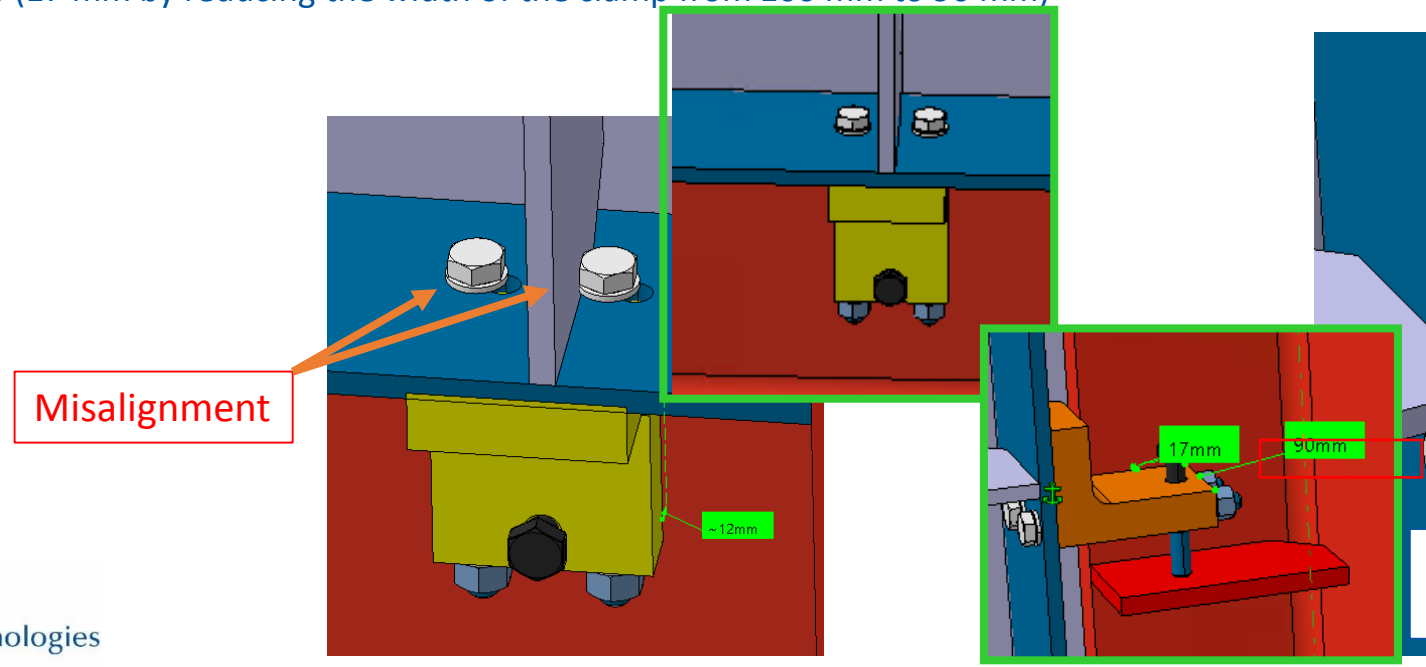




8. Warm Membrane Clamps



- The holes for all the clamps seems to be present, in the correct position, but not all clamps are populated in the model → **OK!**
- Some clamps are not correctly aligned with the holes → **Check alignment**
- The vertical clamps are supported on small welded plates instead of stiffeners of the beams as assumed in previously analyzed → Conceptually **OK!**
- There is a gap of 50 mm between the vertical clamps and the supporting plates. The plates can be pre-aligned in the shop to account for the dimension tolerances of the beams → Therefore the gap between the clamp and the plate could therefore be reduced for example from 50 mm to 30 mm
- There is only 7 mm gap only between flange of the beam and clamp. It is recommended to preserve a larger gap (17 mm by reducing the width of the clamp from 100 mm to 90 mm)



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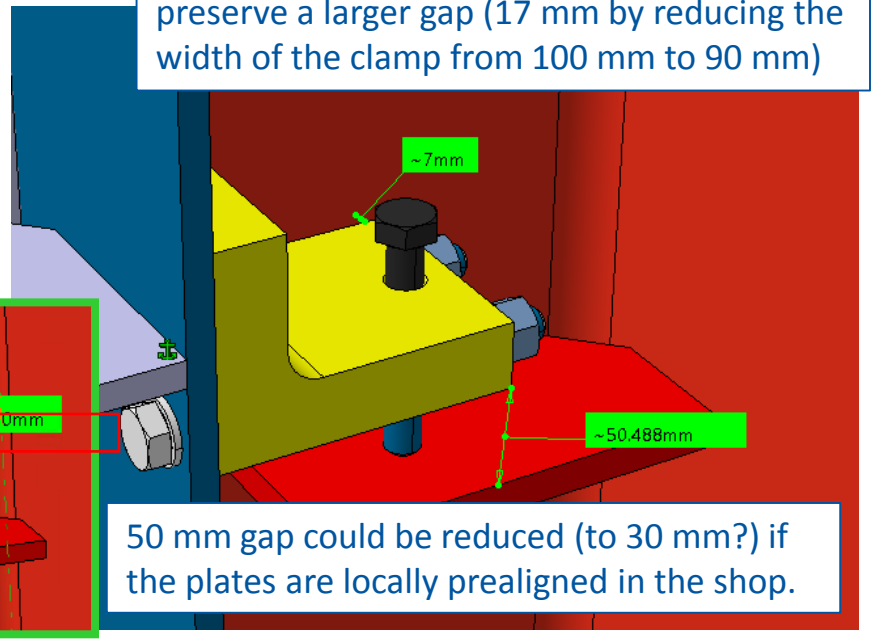
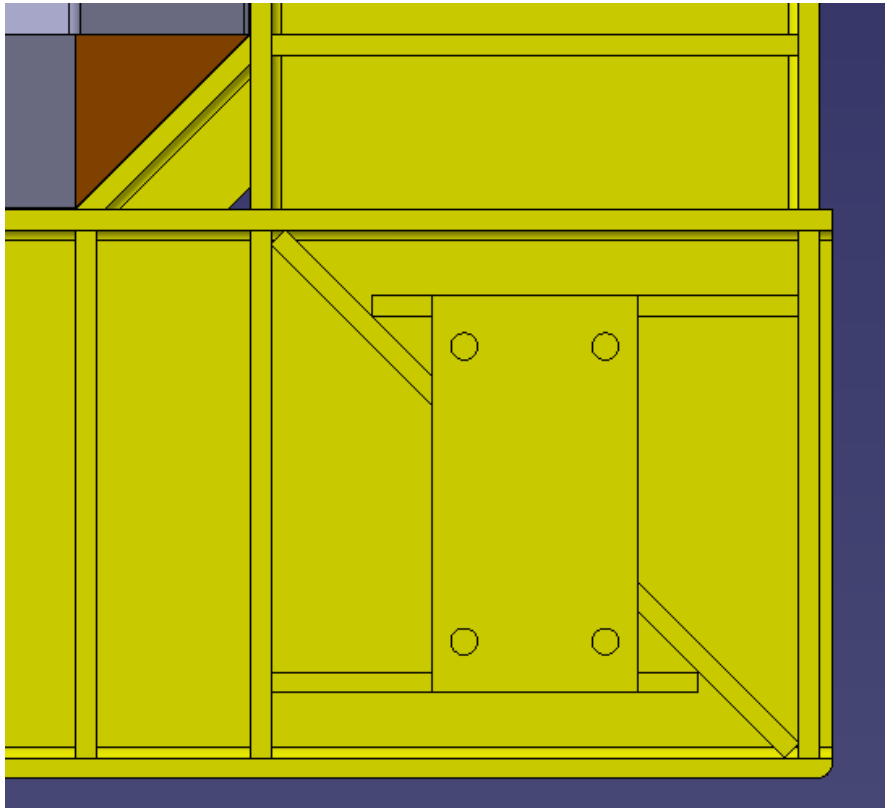


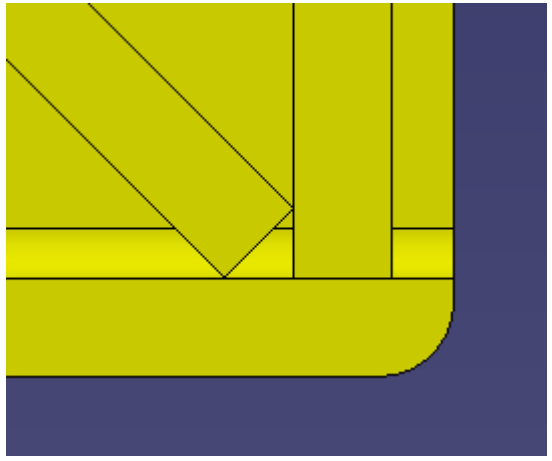
50 mm gap could be reduced (to 30 mm?) if the plates are locally prealigned in the shop.

9. Floor corners and bearing pads

- Bearing pads are not included in the model and therefore not checked.
- Corners of the bottom haunch connections are rounded → **OK!**

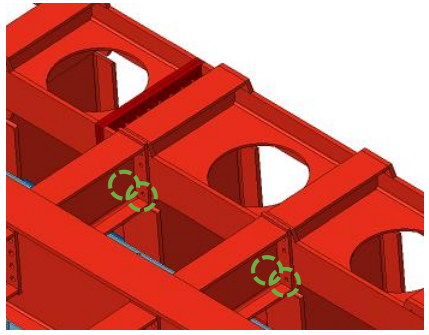
New Model – ST1294927_01 – 20.8.2020

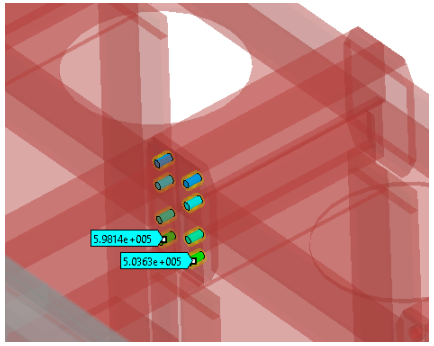




10. Notes on the bolts (not included inthe model)

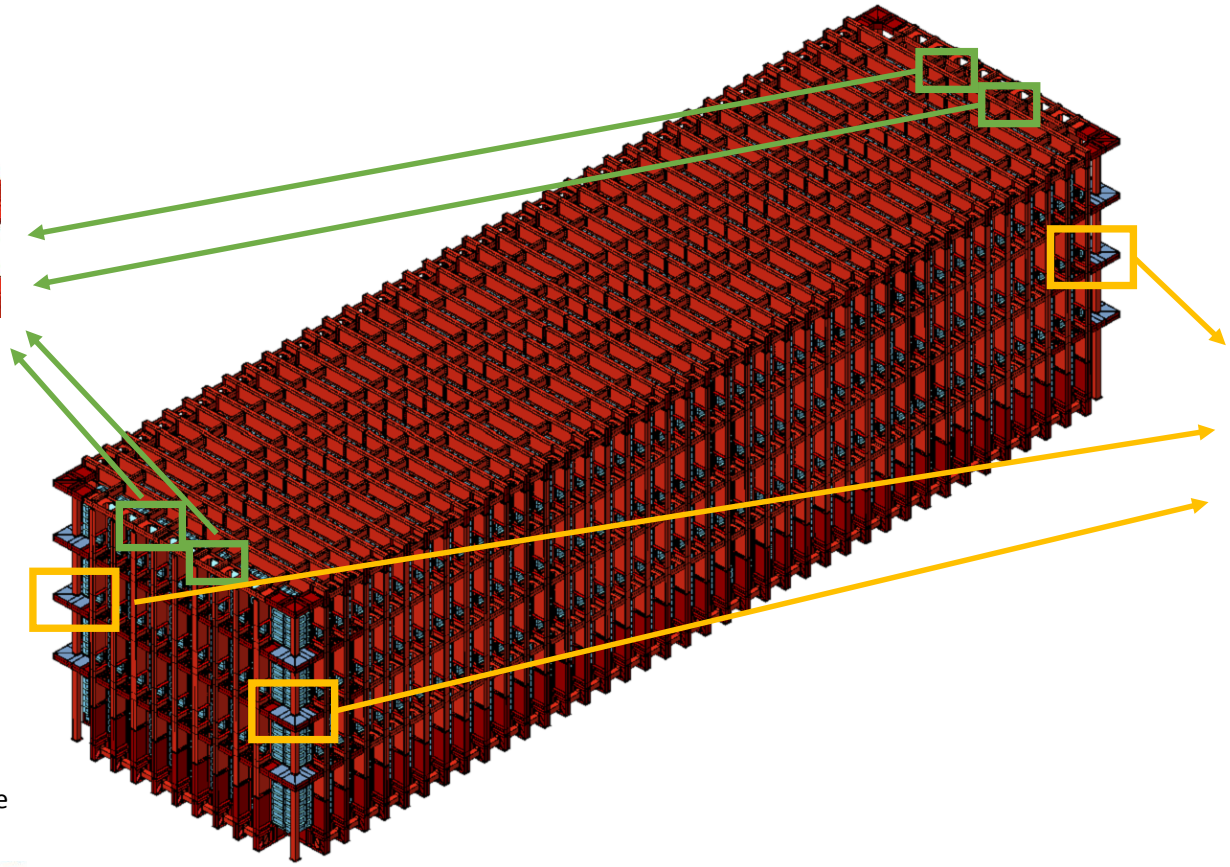
- If the elongation of the bolts M48 are not improved, double nuts on first bolt row of connections on short wall are recommended. Bolts on the inside row, both sides of the frame
  - 2 bolts per connection × 2 connections per corner × 4 corner = total 16 bolts with double nut
- Bolts M36 have not been tested. If their behavior is in question, some connections C5 on the short wall roof may also use double nuts, in the lower bolt rows of the connection.
  - 2 bolts per connections × 4 connections per wall × 2 walls = total 16 bolts with double nut





From Global model EDMS 2308158

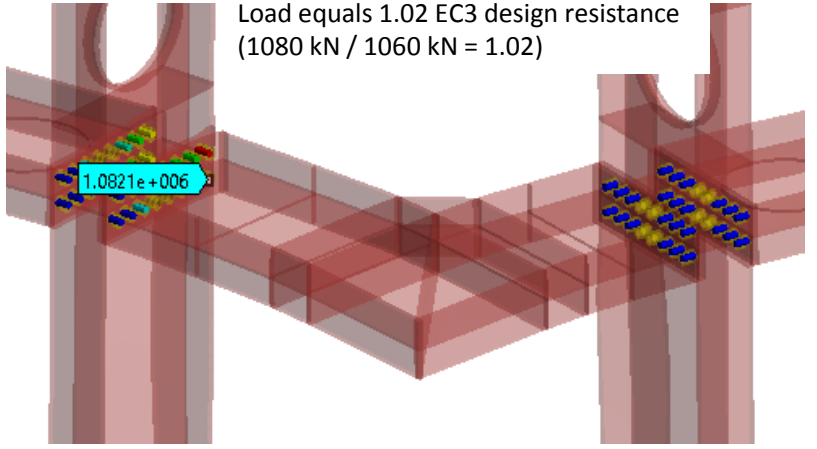
Max. load reached = 598 kN
Load equals 1.02 EC3 design resistance
(598 kN / 588 kN = 1.02)

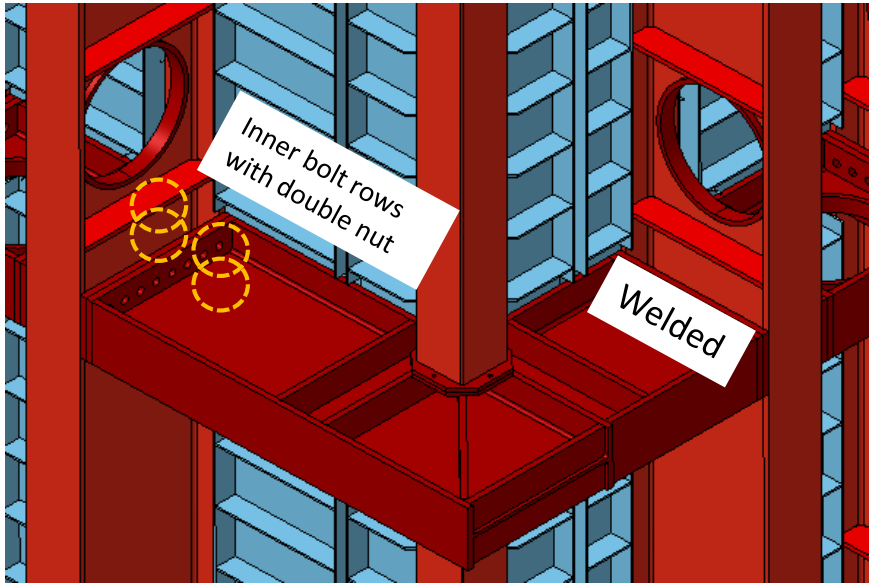


From Global model EDMS 2308158

Max. load reached = 1080 kN

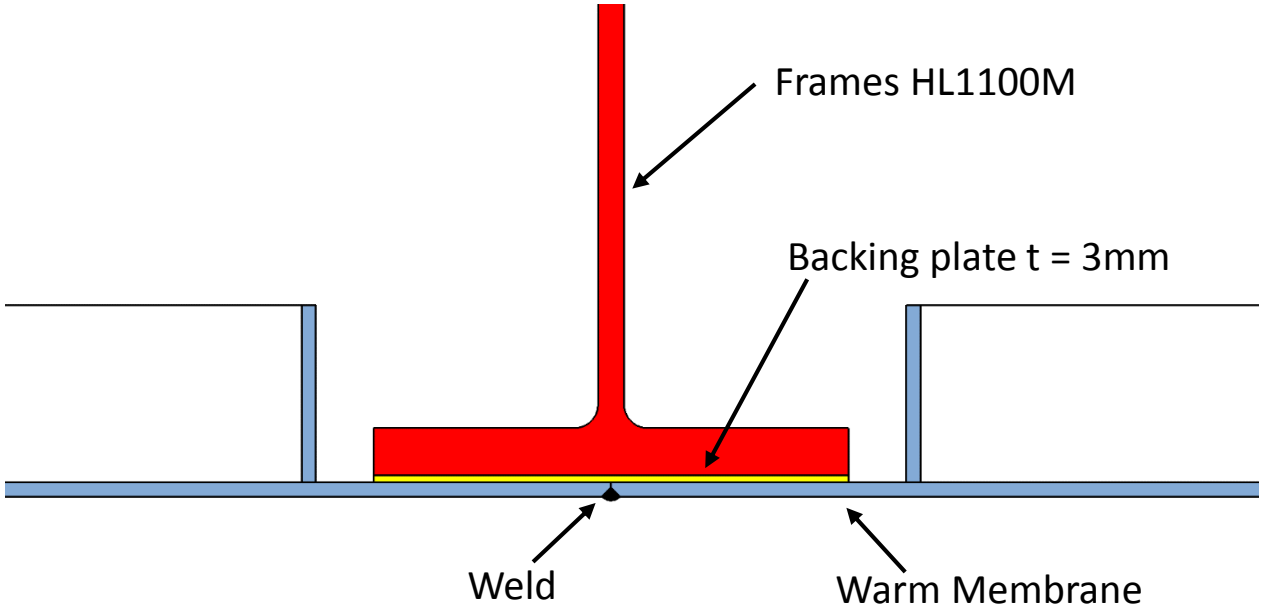
Load equals 1.02 EC3 design resistance
(1080 kN / 1060 kN = 1.02)





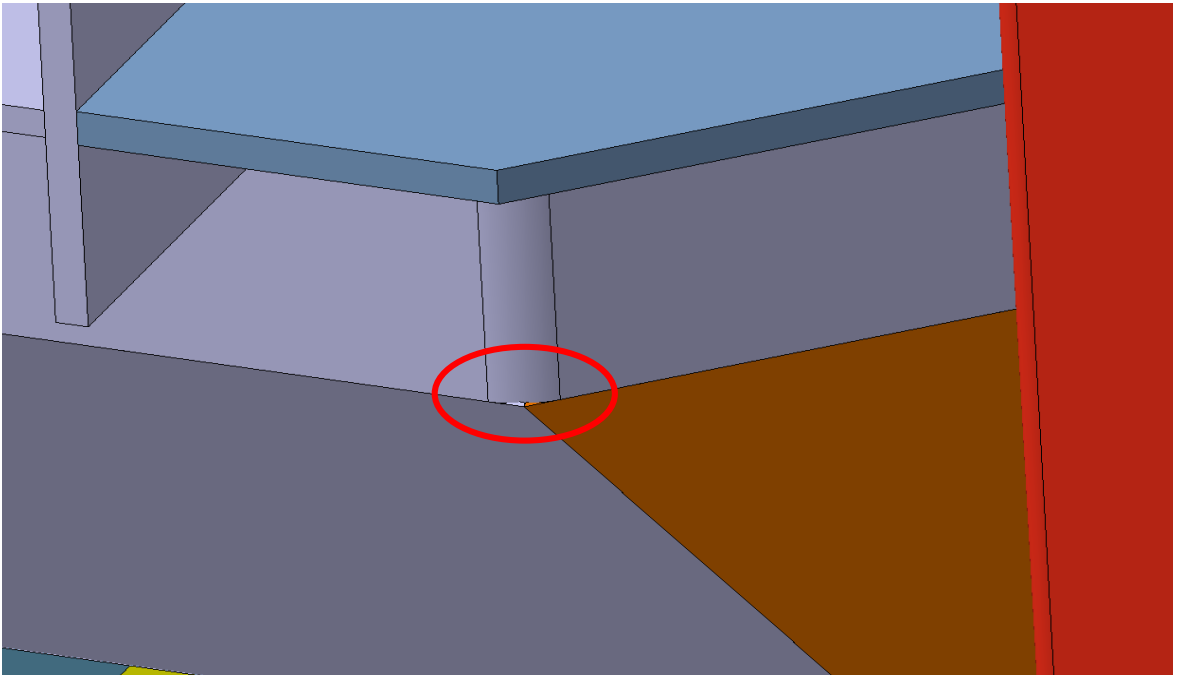
11. Backing plate

- A backing plate is introduced between the HL1100M frames and the warm membrane for welding purposes, and to avoid fusing the frame to the membrane during welding.
- A gap for 3 mm thick gap for the backing plate is left between the frame and the membrane.
  It is recommended to do a welding test to see if the thickness is sufficient.

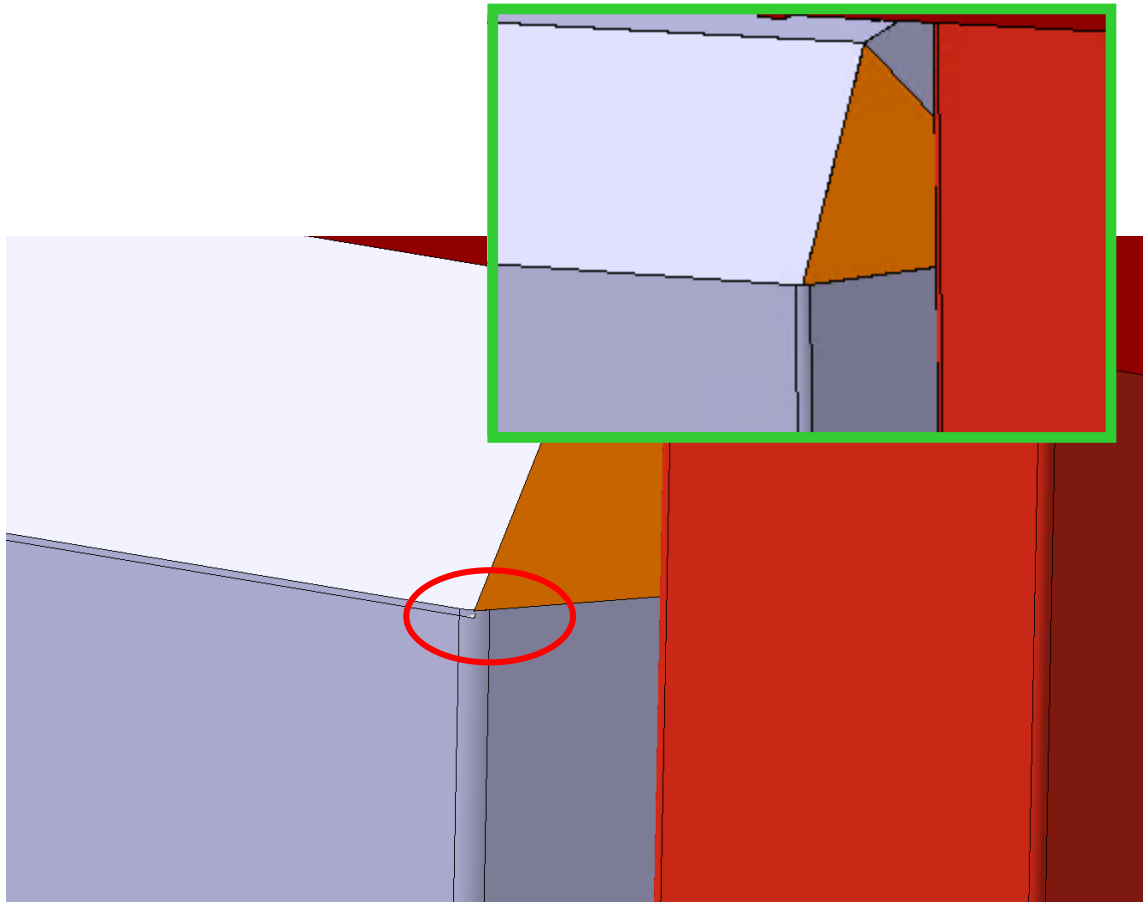


12. EP/DT Vs Neutrino team CAD model: comparison by Christophe

1. Warm membrane: connection in corners (side/side/top or side/side/bottom) → to be reworked



Bottom



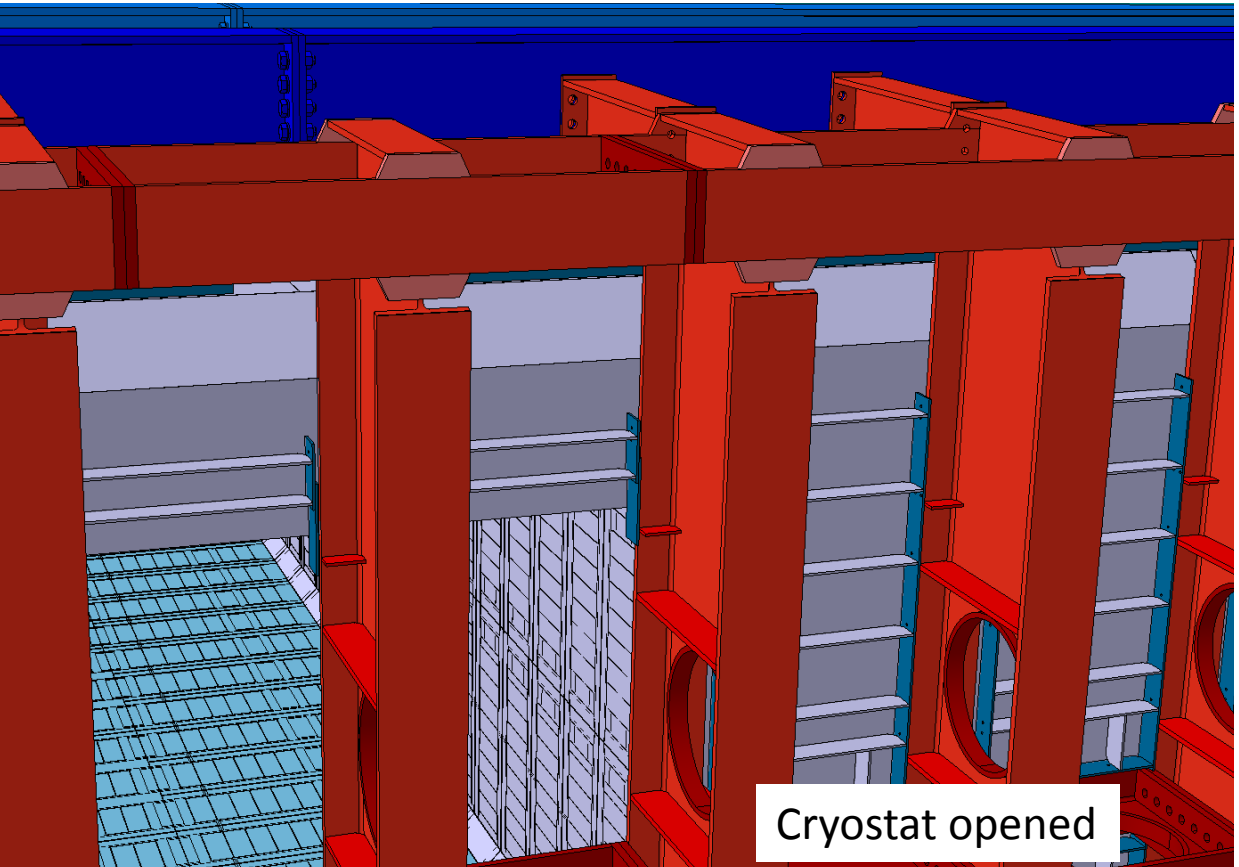
Top

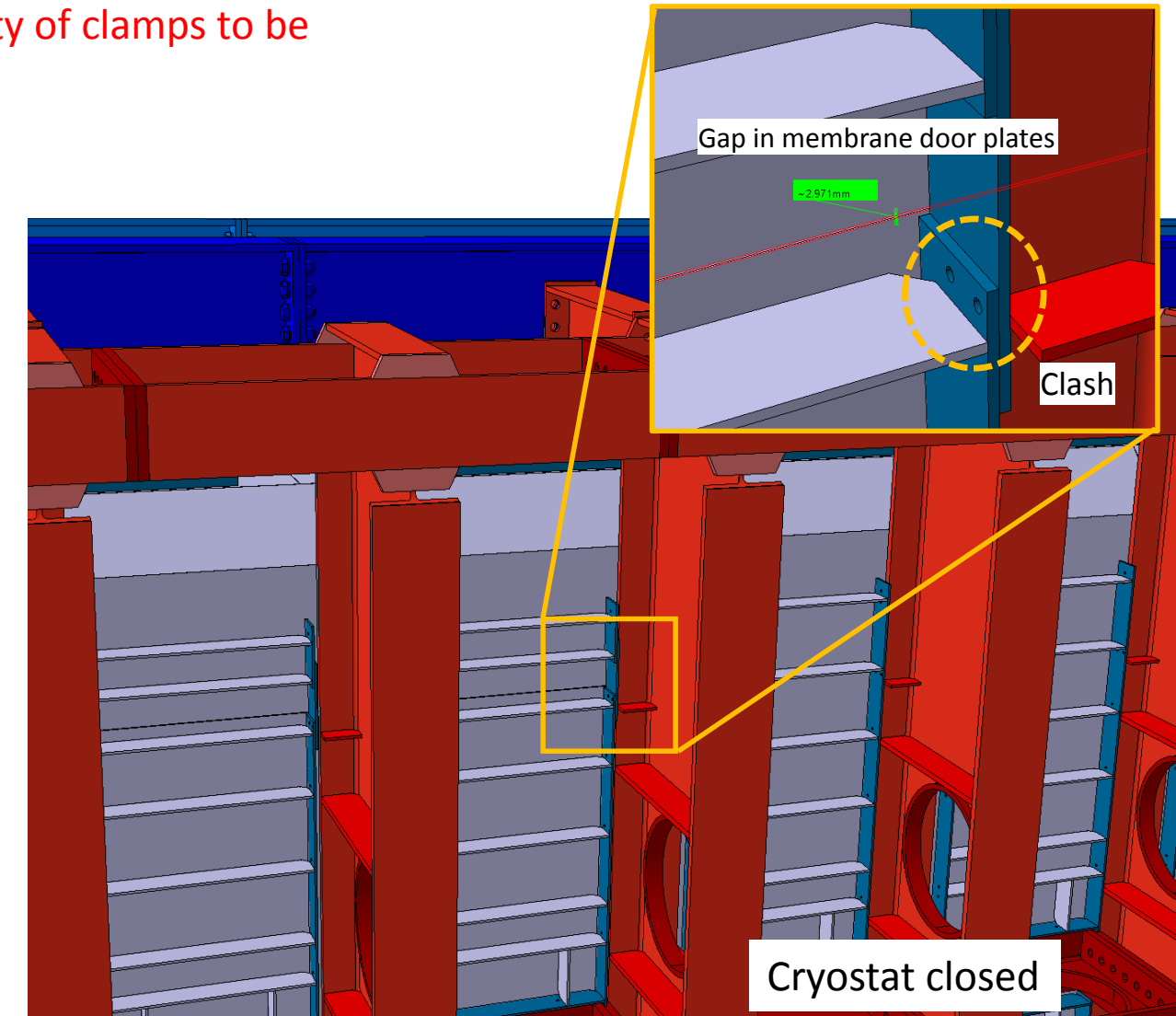
12. EP/DT Vs Neutrino team CAD model: comparison by Christophe

2. Door for detector insertion, IPE replaced by ribbed plates:

- Clamps (for vertical support and others): Position and quantity of clamps to be adjusted for the membrane door.

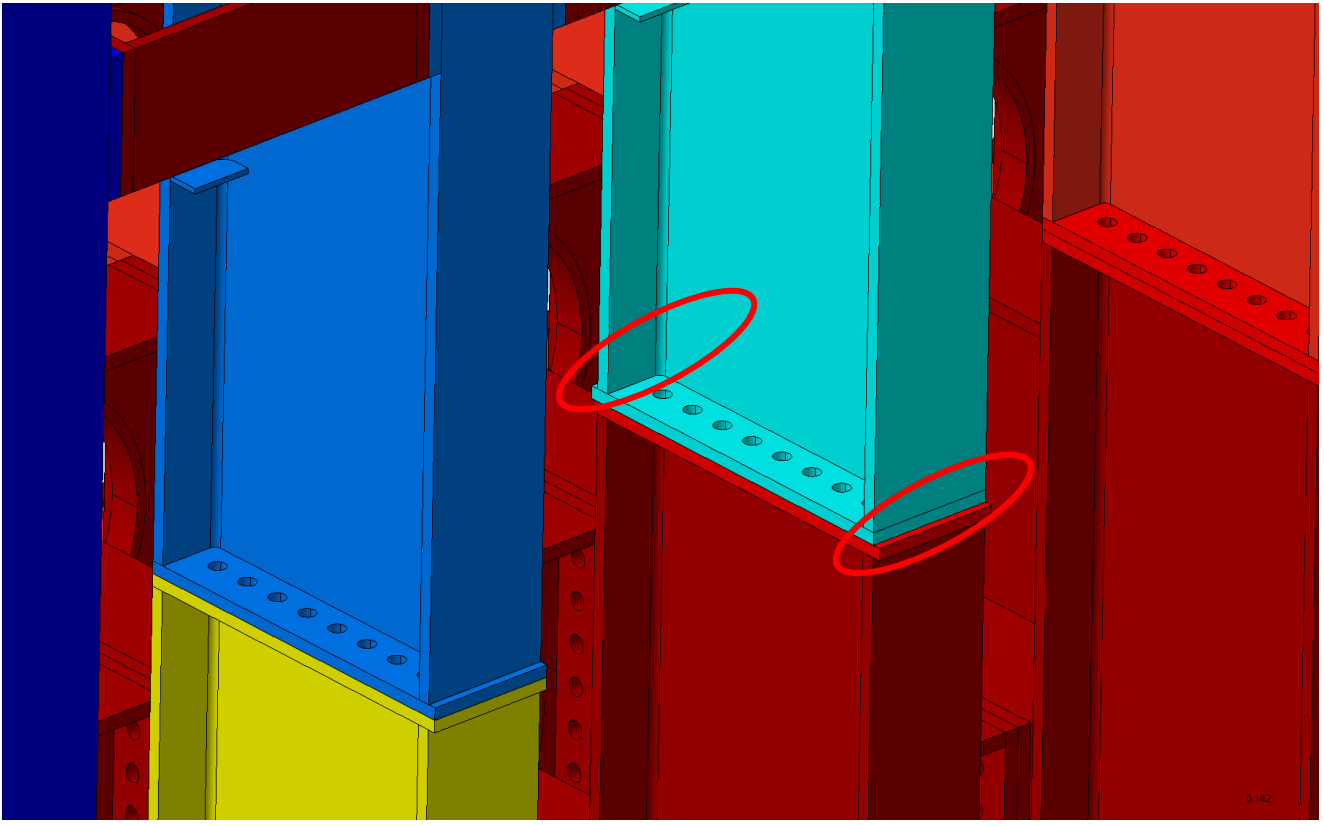
- Misalignment of membrane door plates to be checked

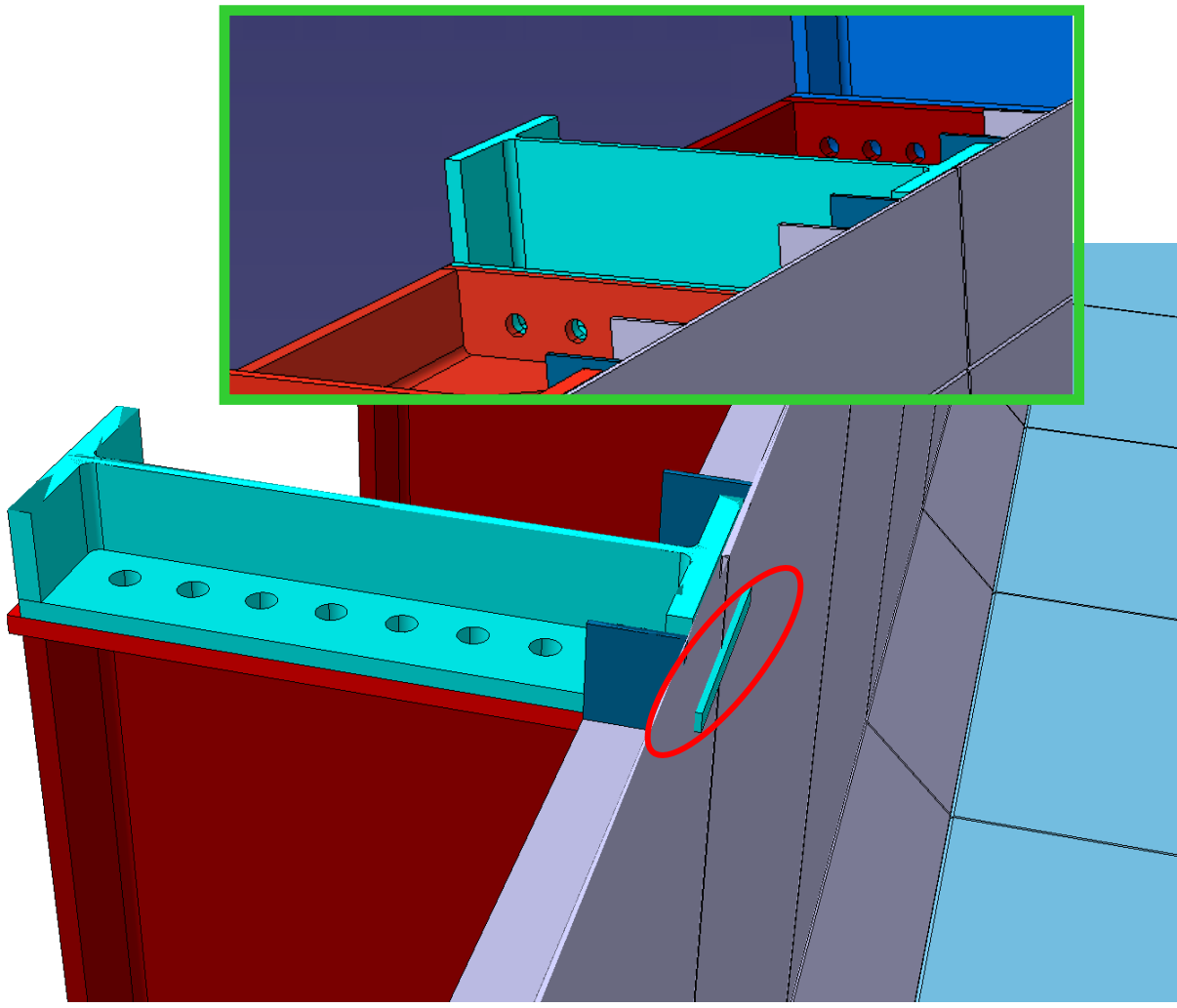




12. EP/DT Vs Neutrino team CAD model: comparison by Christophe

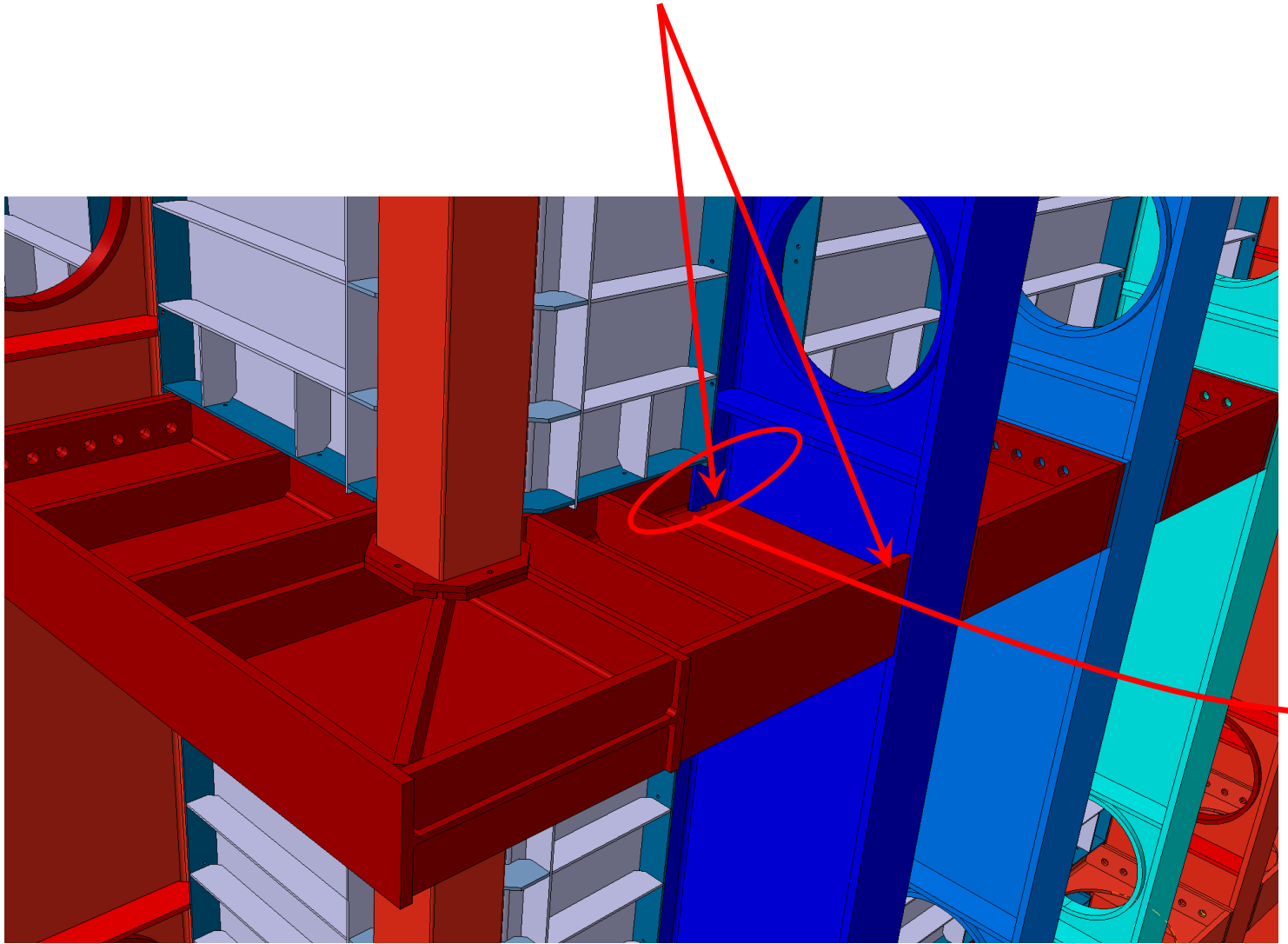
3. 3rd vertical beam of long walls (x4): To be 180° rotated

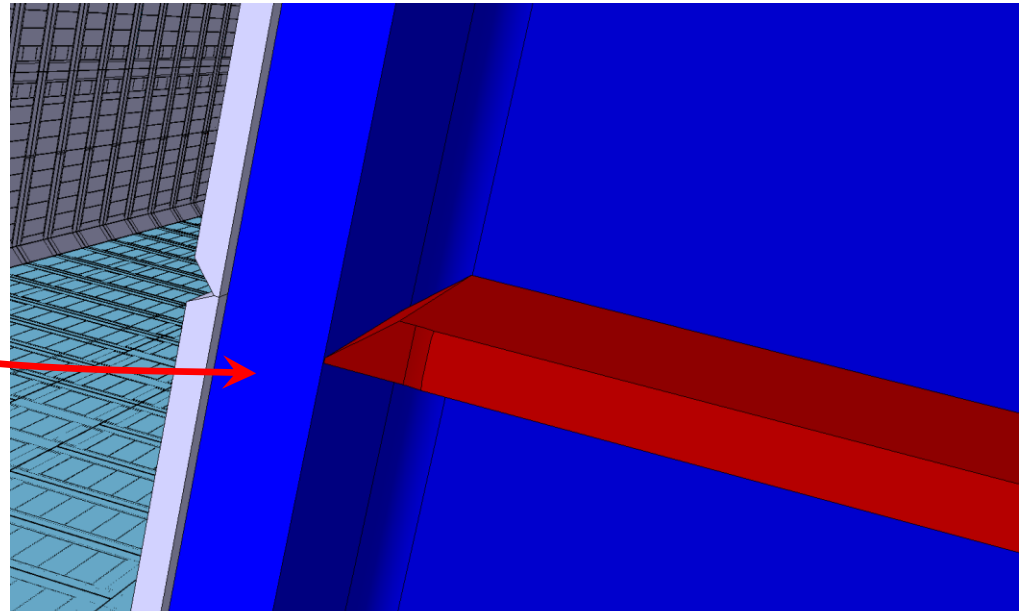




12. EP/DT Vs Neutrino team CAD model: comparison by Christophe

Note: No clash, but also no gap between blue vertical beam and red corner beam in chamfer region. Probably needs in situ adjustment





Summary

- Points requiring action are listed in the table below. See the relevant section number for more details.

Section	Actions
1	• Extra stiffeners next to the corner belt haunch connection may be removed
4	• Several sections of floor are not accessible through openings. If access is needed, they should be added to the specified locations.
6	• Chamfers for welds is on the wrong side in some corner connections. Check the orientation.
7a	• It is recommended to check the strength and stiffness from the local changes to the warm membrane (specifically the openings for feed-throughs close to the bottom of the membrane wall) • It is also recommended to consider the effects of membrane deformations on the feed-throughs
7c	• Extra rib to be added on the membrane floor corner/chamfer according to calculation.
7d	• Alignment of membrane door in the CAD model to be checked. Some misalignment spotted.
8	• Remember to release clamps close to the membrane corners after vacuum case. Mark in assembly drawings for execution. • Check alignment of some clamps in the CAD model. • In the vertical clamps, the gap of 50 mm between the clamp and the support plate may be reduced if the plates are pre-aligned in the shop. • Only 7 mm gap is present between the vertical clamps and the beam flanges. It is recommended to increase this gap.
11	• 3 mm gap is included between the frames and the membrane for a weld backing plate. It is recommended to test if this thickness is sufficient.
12	• Some problems with the CAD models should be checked (see the relevant section)