MuCool Absorber Review meeting

FermiLab, Chicago

21 – 22 February 2003

Window Design & Alternative MICE Absorber arrangement by Oxford

by

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The Window Design

A brief summary of the work done so far:

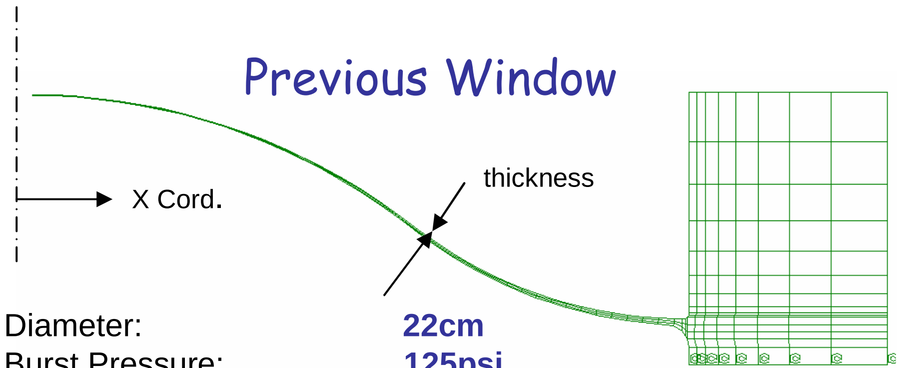
The current window design has gone through a number of revisions and optimisations aiming at minimising its thickness without compromising its safety.

In the first revision, the change from a torispherical shape to a bellow shape offered a thickness reduction of some 45% in the crown region at the expenses of the materials in the concave region at the junction between the Window and the flange.

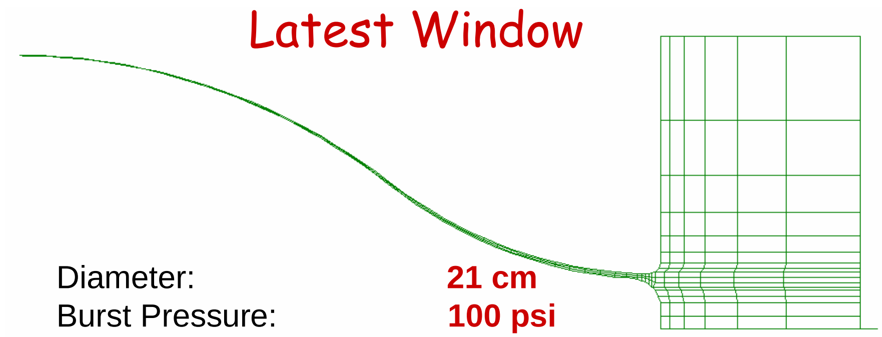
Our second revision was to gradually trim the extra material in the concave region. This resulted in an overall thinner and slightly more flexible window which can sustain nearly 5, instead of 4 times the design pressure by re-distributing the strain energy more evenly throughout the window.

The highest stress in these two models always occurs at the centre of the window.

The latest revision trims the window further to reduce its pressure rating from 5 down to 4 times the design pressure. This was done successfully and the highest stress point has now shifted from the window centre to the window to flange joint.



Diameter: **22cm**
Burst Pressure: **125psi**
Location of highest stress: **at the centre**

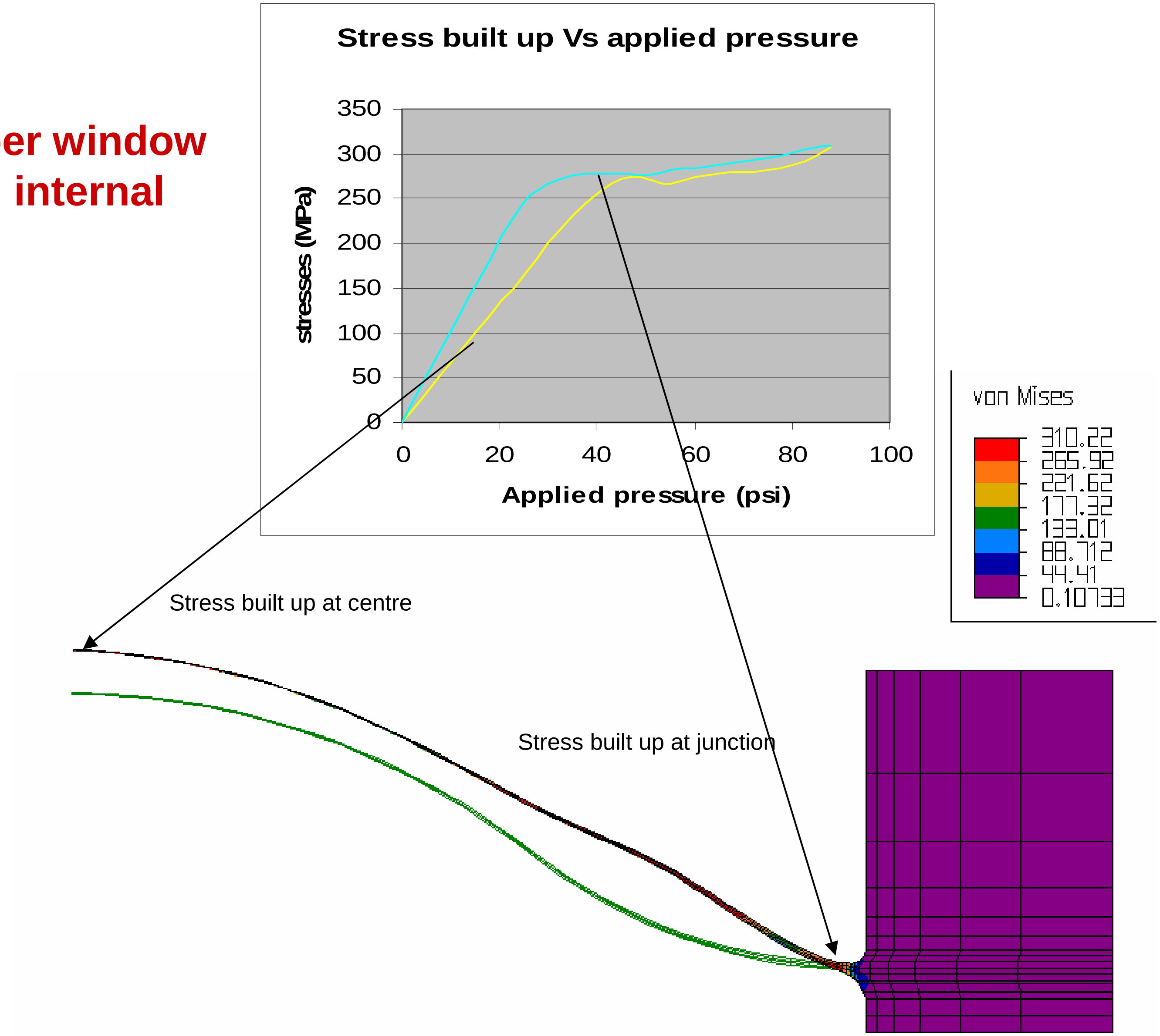


Diameter: **21 cm**
Burst Pressure: **100 psi**
Location of highest stress: **at the junction**

	Previous Window (as presented at the Berkeley meeting)	**Latest Window (21cm diameter)**
X Cord.	**Thickness**	**Thickness**
0	**0.132**	0.105
10	**0.14**	0.113
20	**0.163**	0.138
30	**0.203**	0.180
40	**0.260**	0.241
50	**0.337**	0.324
60	**0.437**	0.433
70	**0.536**	0.529
80	**0.633**	0.626
85	**0.681**	0.674
90	**0.730**	0.722
95	**0.778**	0.77
100	**0.826**	0.818
105	**0.874**	

The 21 cm Absorber window under incremental internal pressure

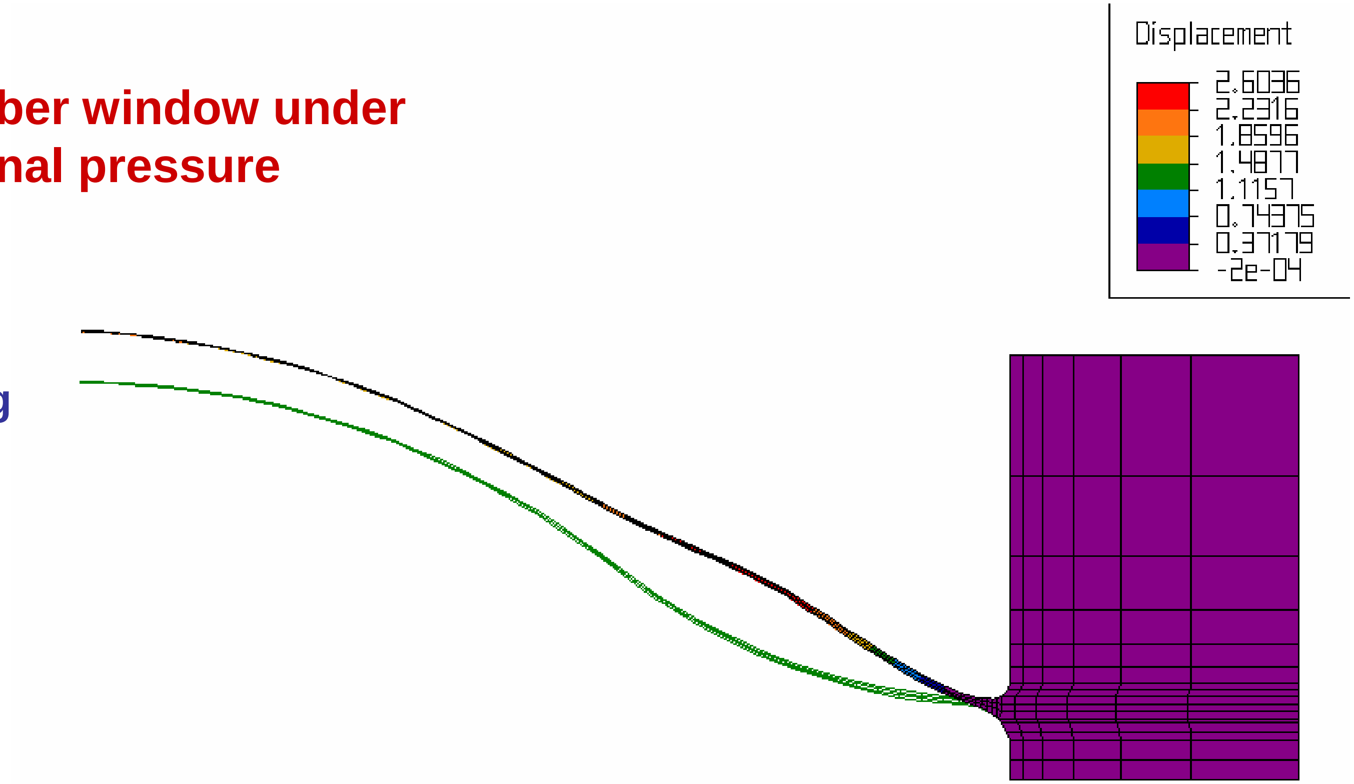
Note that the maximum stress occurs at the junction rather than at the centre of the window



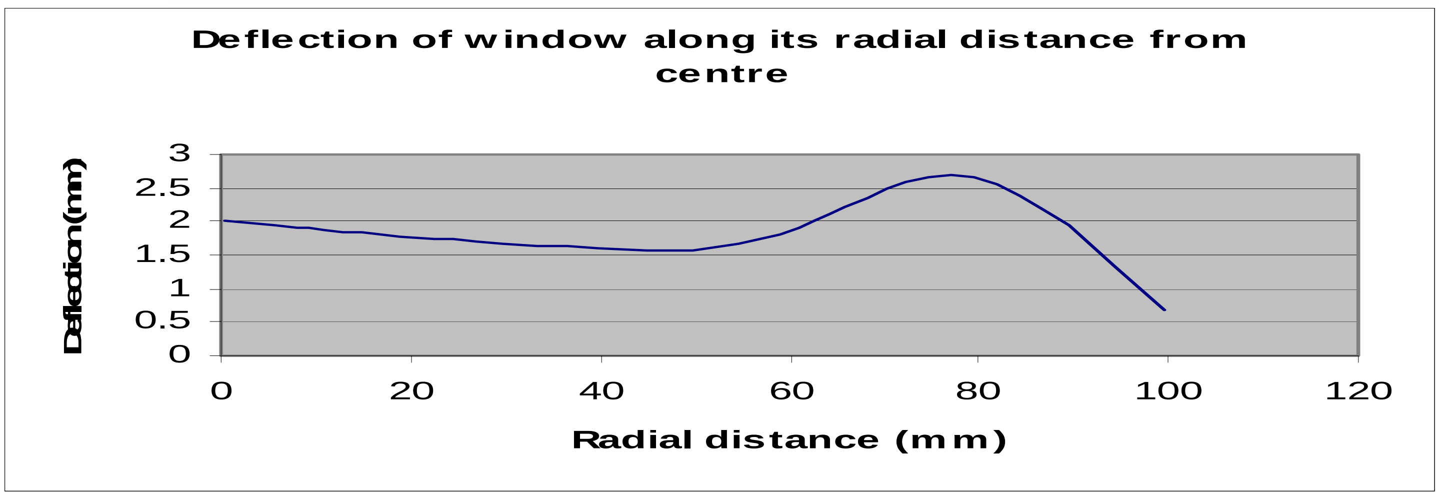
Max. stress detected at junction when applied pressure reaches 102 psi

The 21 cm Absorber window under incremental internal pressure

Note that the concave part of the window is being stretched, taking up the bulk of the strain energy during the pressurisation of the window



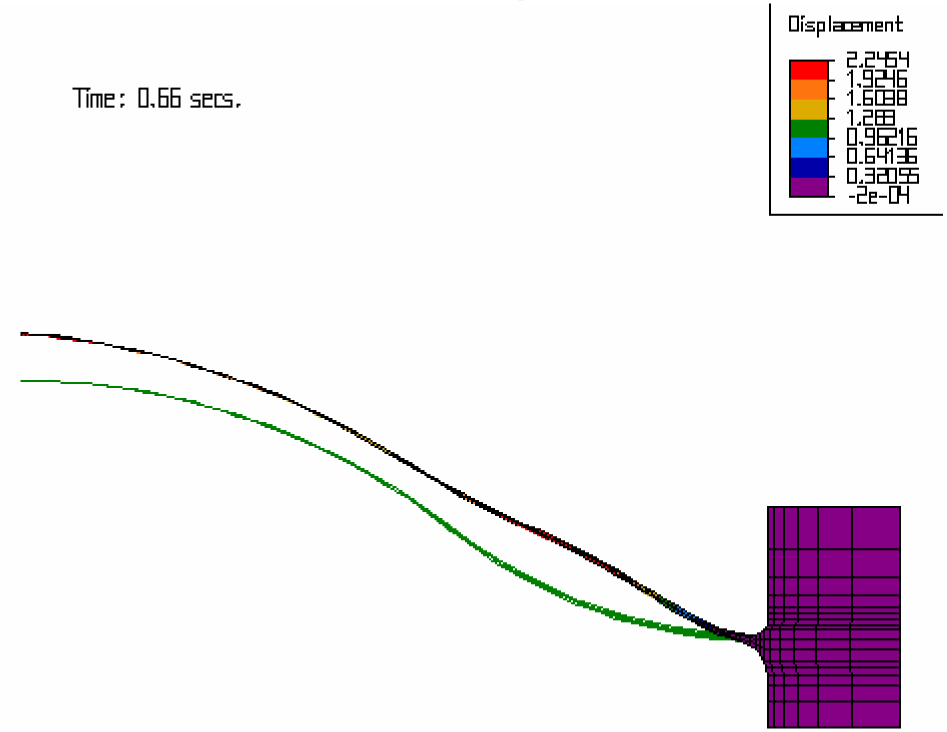
Max. disp. at window centre when internal pressure reaches 102 psi



Radial dist from centre (mm)	Previous window thickness (mm)	Latest window thickness (mm)
0	0.128	0.121
10	0.132	0.126
20	0.147	0.142
30	0.173	0.167
40	0.208	0.203
50	0.255	0.25
60	0.313	0.31
70	0.384	0.381
80	0.469	0.467
90	0.569	0.569
100	0.674	0.679
110	0.771	0.777
120	0.868	0.874
130	0.965	0.97
140	1.061	1.067
150	1.158	1.163
160	1.254	1.259

34 cm Vacuum Window

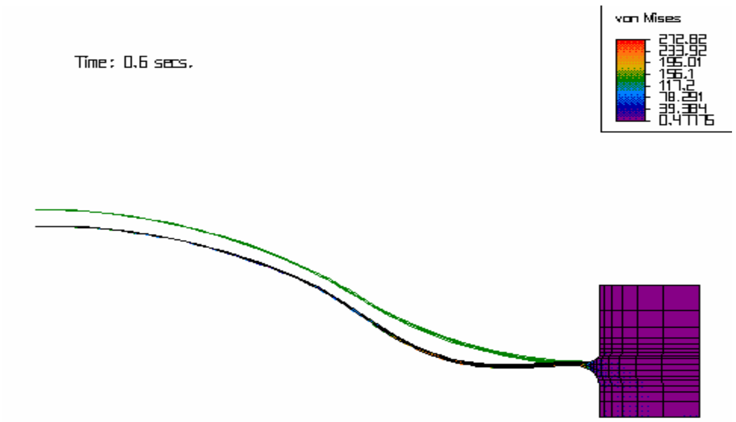
Incremental internal pressure



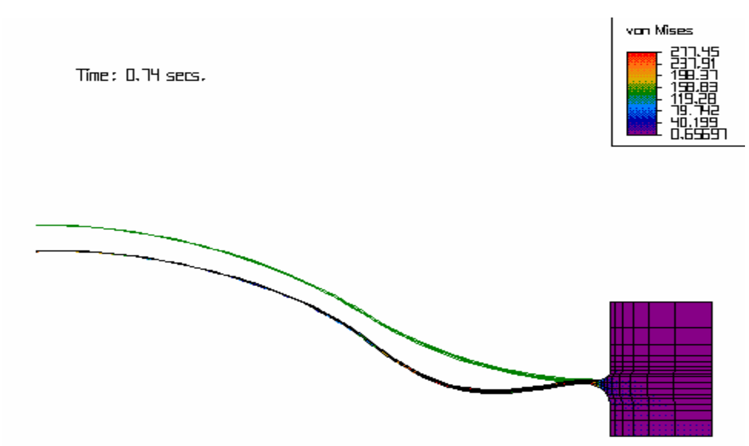
Burst pressure: **at 76.5 psi**

Highest stress location: **at window centre**

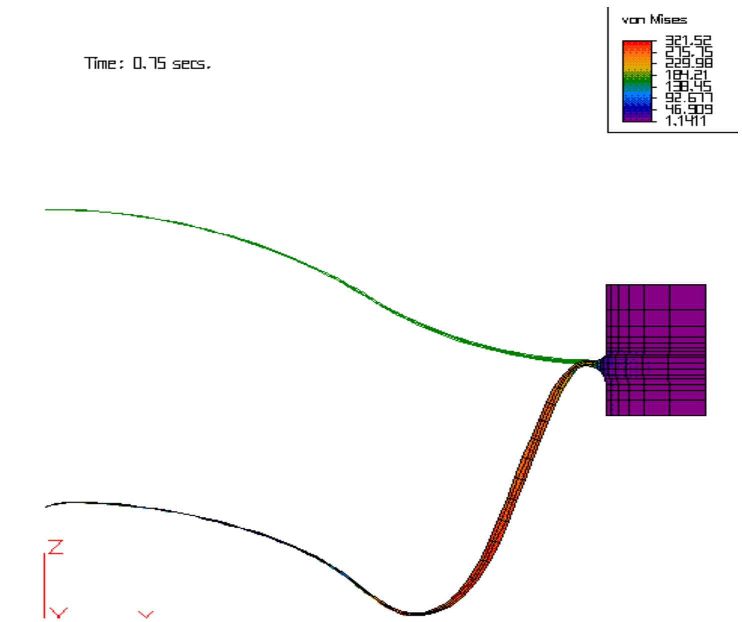
Behaviour of the 34cm Vacuum Window under incremental external load



At 34.8 psi, Window reaches its first yield



At 43 psi, Window is about to buckle



Buckling occurs at 43.5 psi

Points of discussion:

The above results show that the minimum thickness at the window centre has been reduced to just 105 microns for the 21cm Absorber window, and 121 microns for the 34cm Vacuum Window.

The quoted thickness is the minimum thickness to sustain the minimum burst pressure as defined by FermiLab Safety committee, and as such there is no margin for any error.

This error includes: **machining tolerance;**
survey / measurement error;
numerical error in FEA which could be as much as ± 5 – 7%
variation in material properties

On the positive side, we have the following scenarios which could add to the margin of safety.

These are: **hardening of material at cryogenic temperature;**
the re-establishment of a realistic burst pressure

If we are confident that the tolerance offered by modern day machining can guarantee the minimum thickness of the Window, there is no need to utilise the extra margin hidden in the above two scenarios. If however, the minimum thickness is breached, we may have to use up this hidden margin. The justifications are as follow:

Why do we need to re-visit the establishment of the burst pressure?

We believe there is undeclared safety margin in establishing the burst pressure:

From ASMEVIII, div.1, the burst pressure is calculated as 4 times the design pressure.

The design pressure is 1 atmosphere (vacuum) + 10 psi of internal pressure making it a total of 25 psi. However, the vacuum part of this design pressure is "static" and can not be increased due to whatever change in the operating condition, e.g. should LH2 expand and pressure built up which can not be released on time. Under the situation, the realistic burst pressure should be:

4 x design pressure + 1 x vacuum pressure, or
(4 x 10 + 15) psi = 55 psi

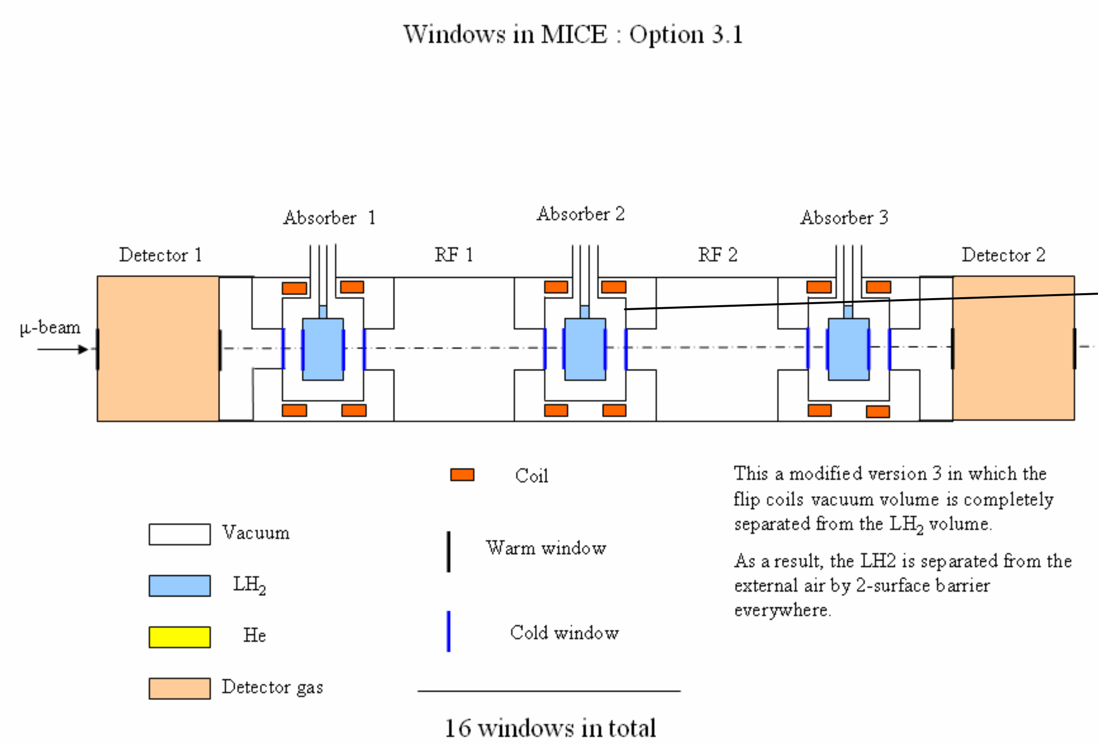
It is in my belief that a burst pressure of 55 psi will allow a safety margin of 4 x the design pressure. This nearly halves the current burst pressure the we are subjecting our windows to.

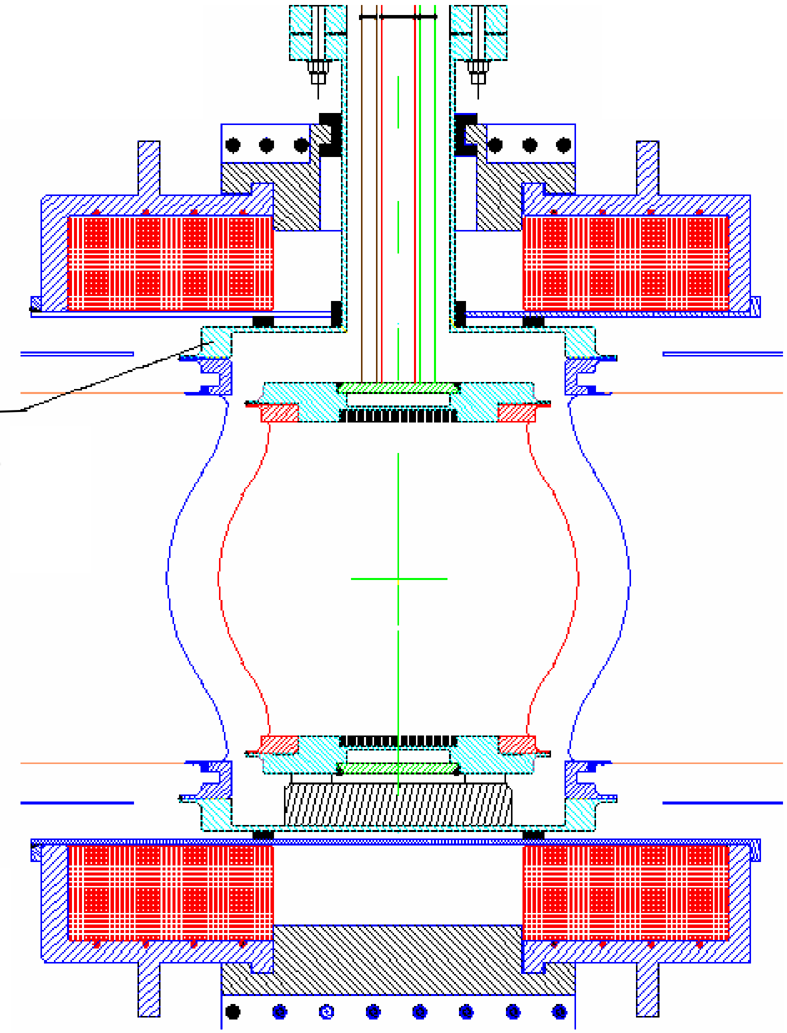
For this reason, I would be happy to recommend the 21cm window to go as thin as 105 microns, and 121 micron for a 34cm Vacuum Window, and still meeting the appropriate safety requirements.

Alternative MICE Absorber arrangement from Oxford"

The Proposed Design

The Safety Requirement

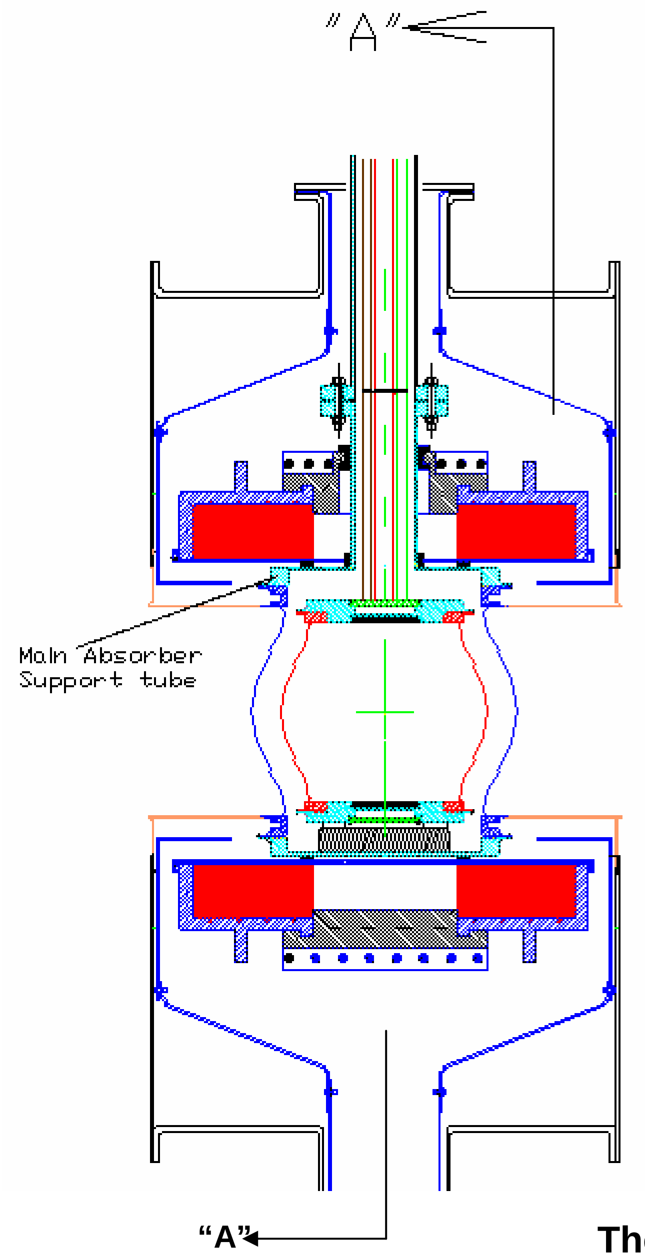




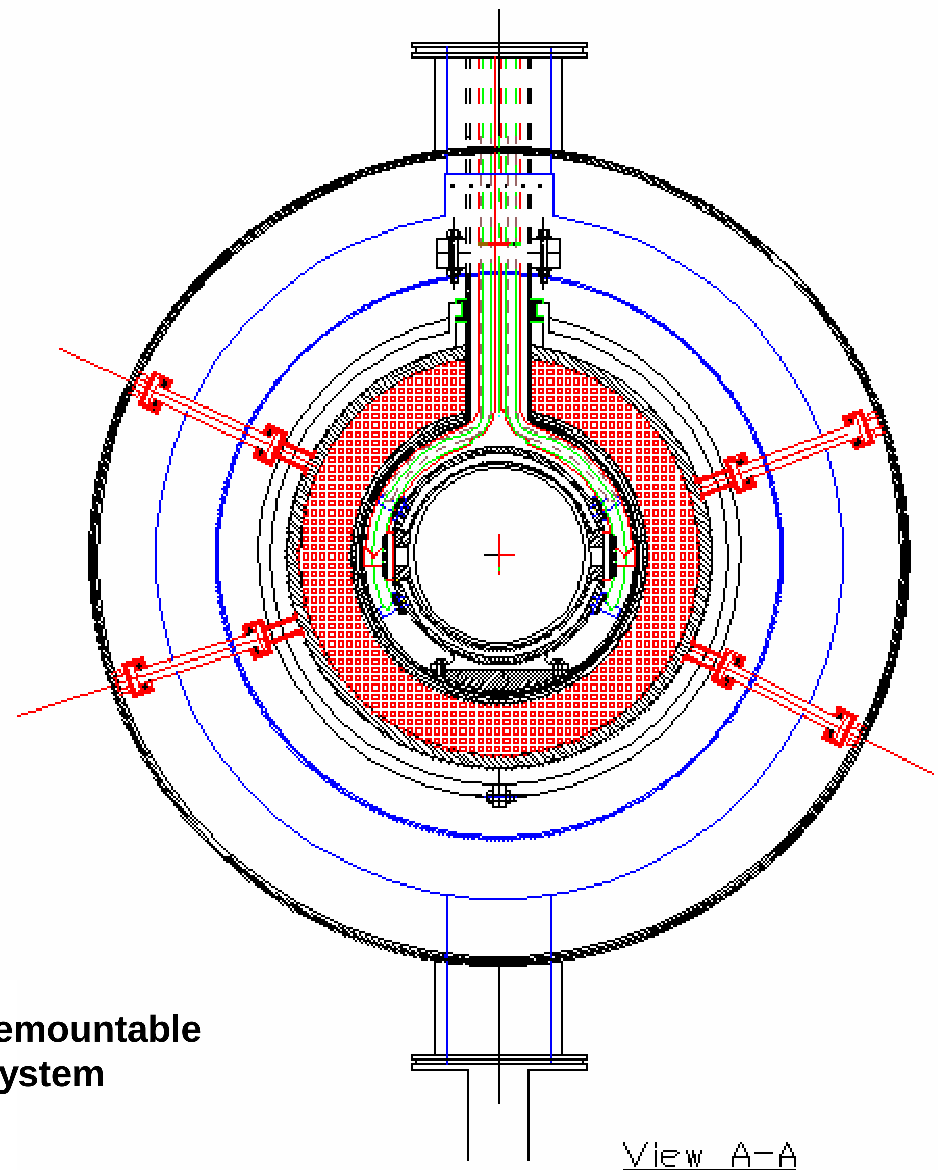
The Safety provision as suggested by RAL which requires a complete isolation of LH2 from cryo-pumping

The Oxford design which satisfies the safety requirement and allows a complete removal of the absorber without disturbing the magnet set-up

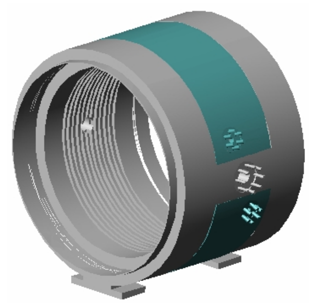
The Focusing Coil system



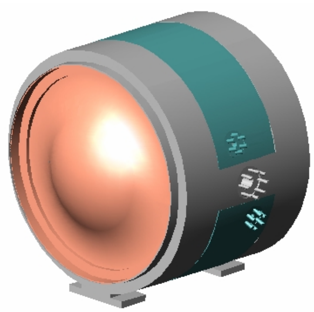
The Fully demountable
Absorber System



The Main Parts of the System

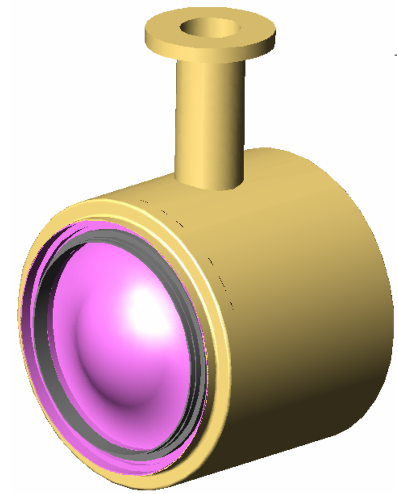


Absorber Body

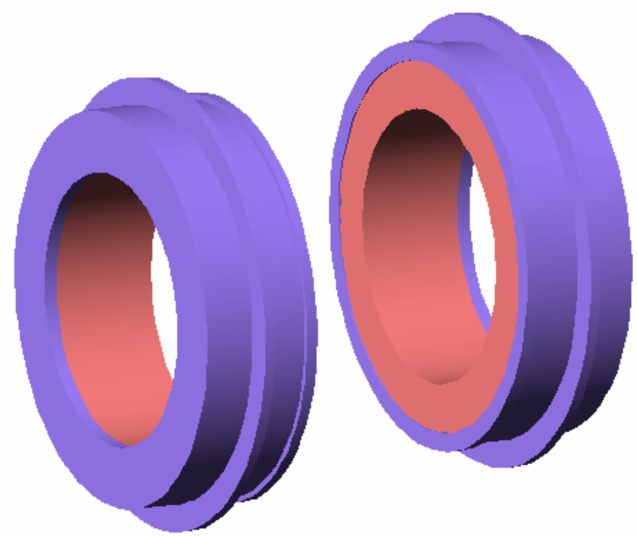


Absorber Body with Absorber Window

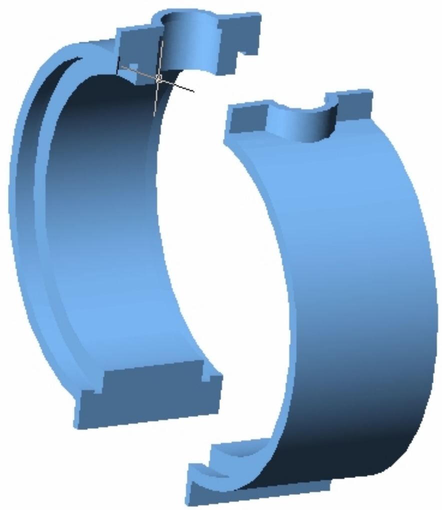
Inner support tube to isolate LH2 from Cryo-pumping (see Option 3.1 of RAL safety requirement)



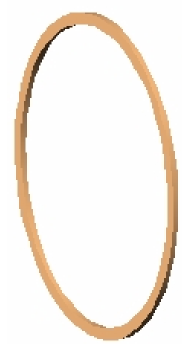
Inner support tube with Vacuum Window attached



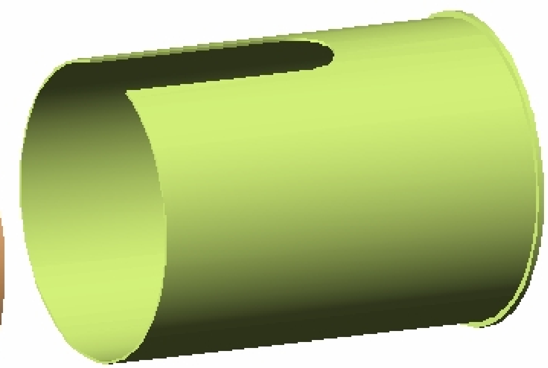
A pair of Focusing Coil with Outer Tubes



Clamping tube for securing the Coil and mounting to Vacuum Vessel



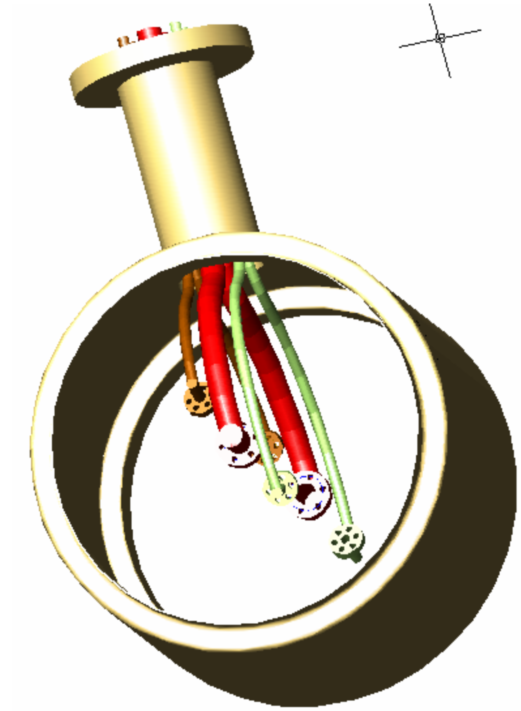
End Ring for inner Coil Tube



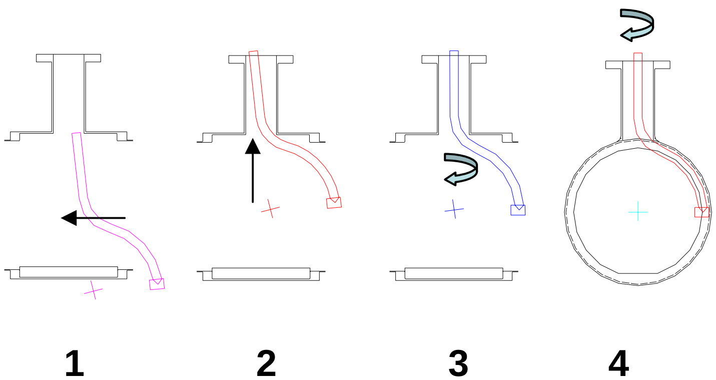
Inner Coil Tube to provide extra restraint to Outer tube from bulging out during magnet quenching

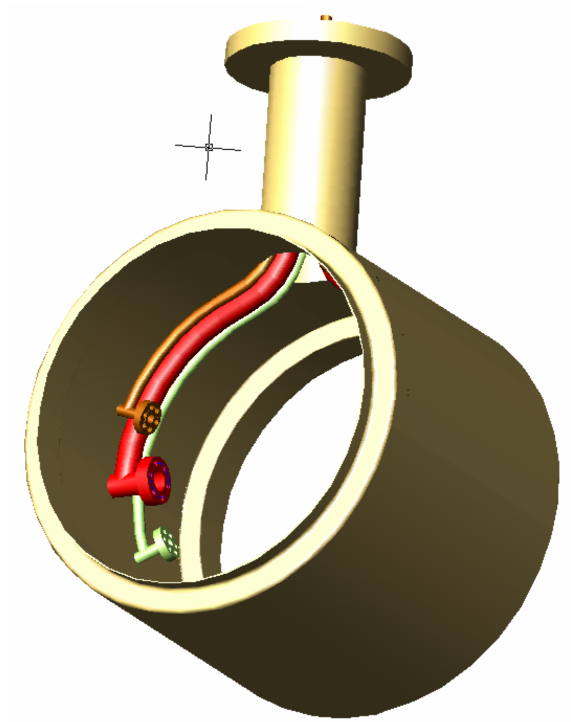
The Assembly Sequence

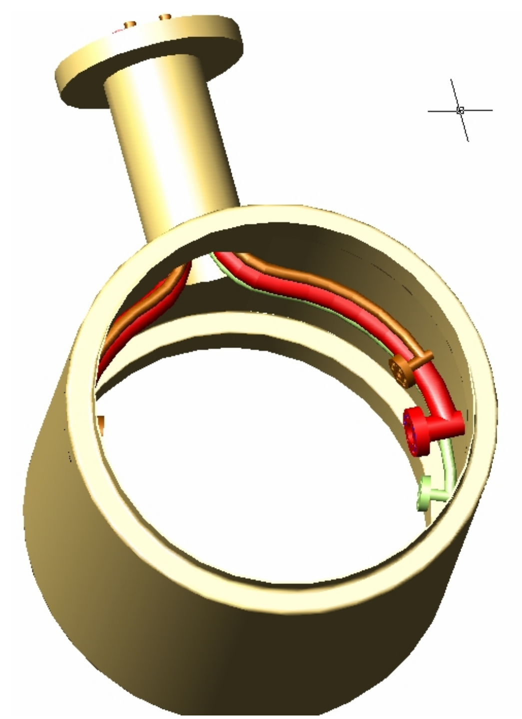
1. Temporary mount the Inner Support tube upright and insert the pipe-work. Pipe-work temporary docked aside and suspended to allow clear access for the Absorber Body



Note: images of the pipe-work insertion will be added later. The 2-D diagrams below shows how access clearance could be achieved for the pipe-work

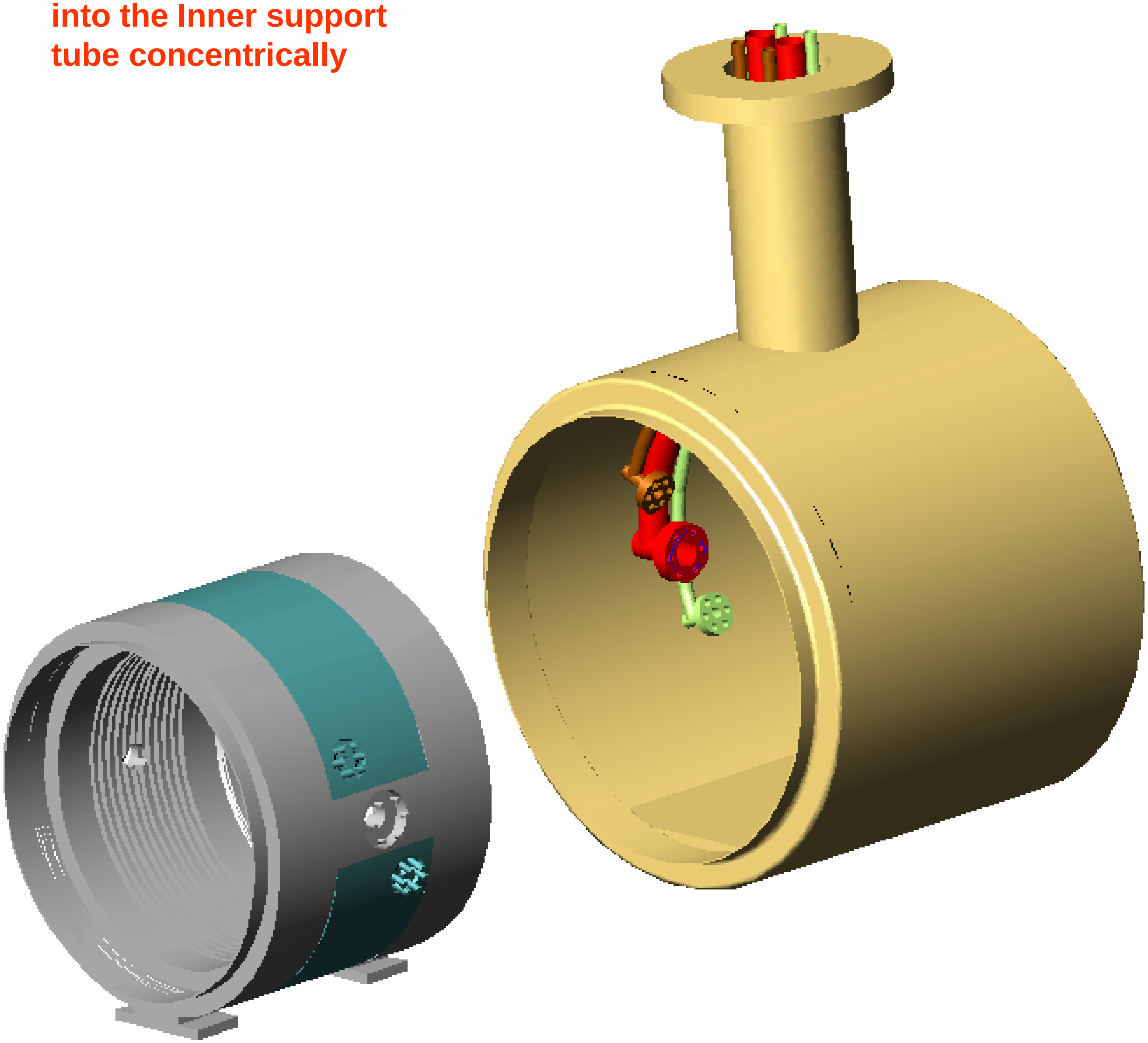




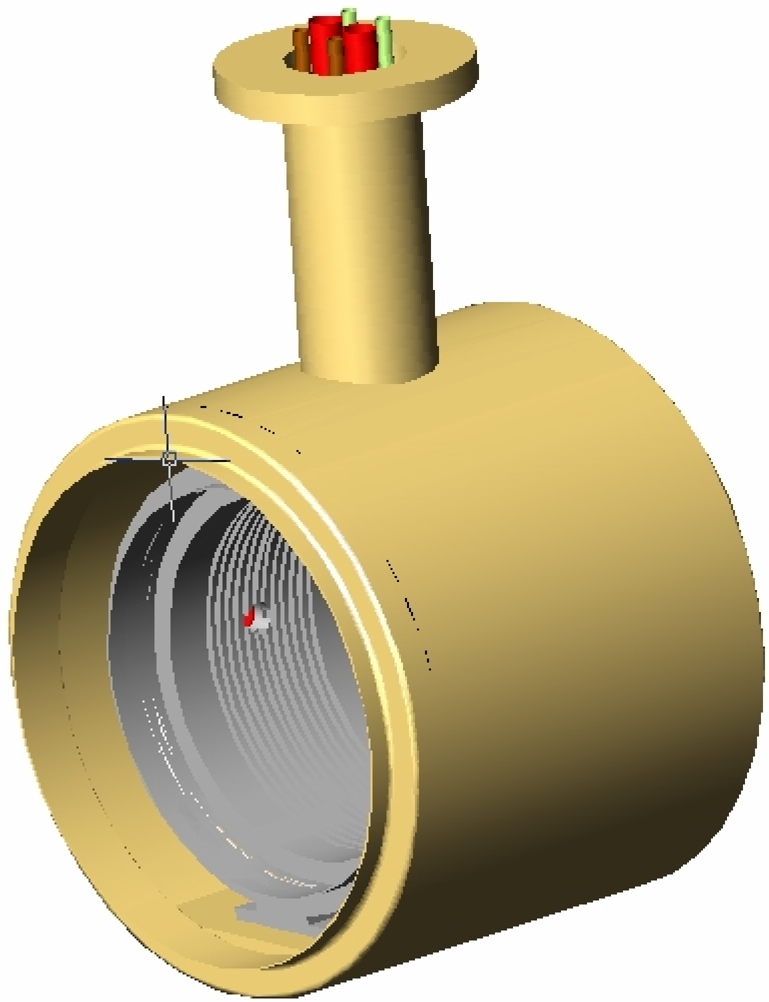


Diagrams 1 to 4 show the insertion sequence of pipe-work into the Inner support tube.

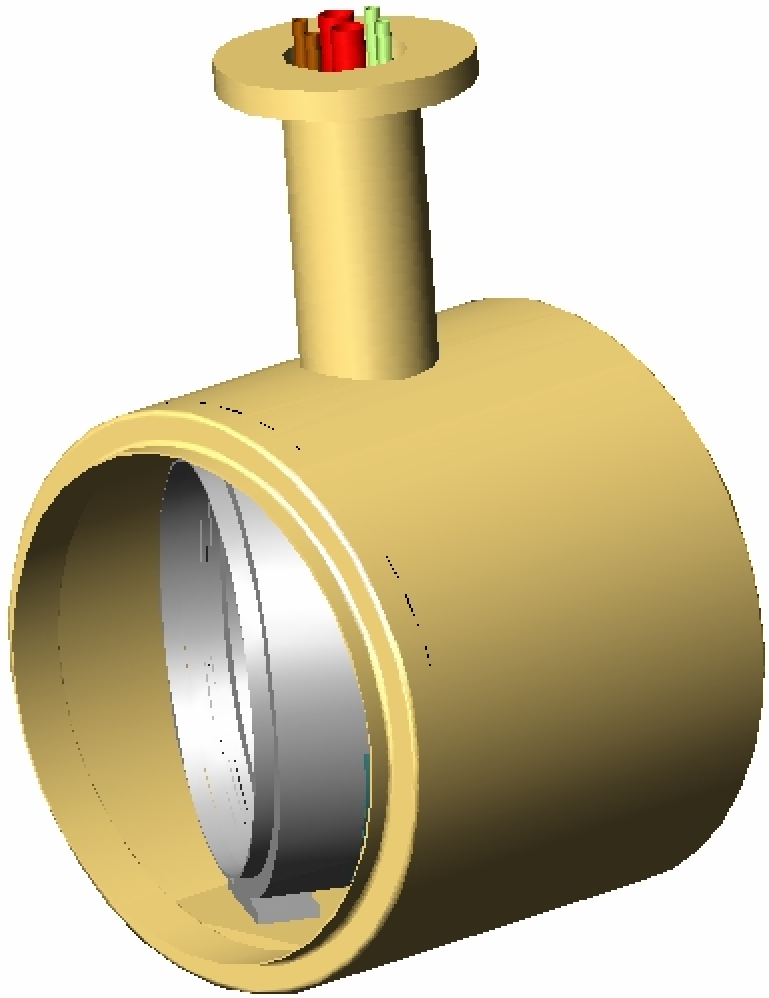
2. Insert Absorber Body into the Inner support tube concentrically



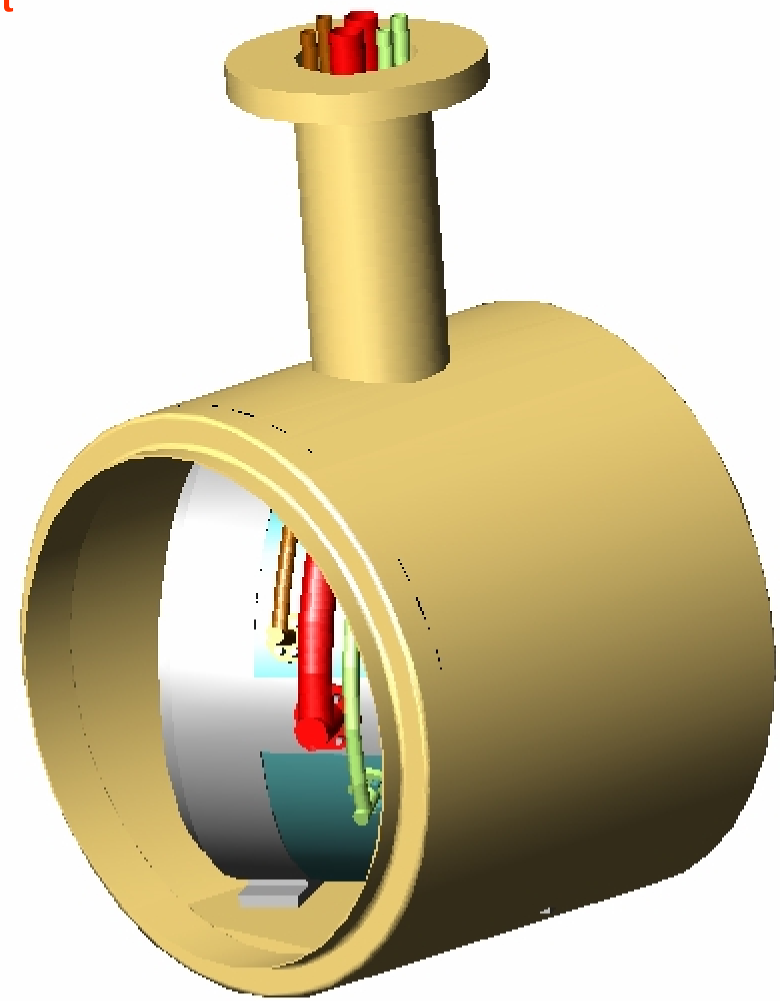
3. Continue to insert the
Absorber Body into
the Inner support tube



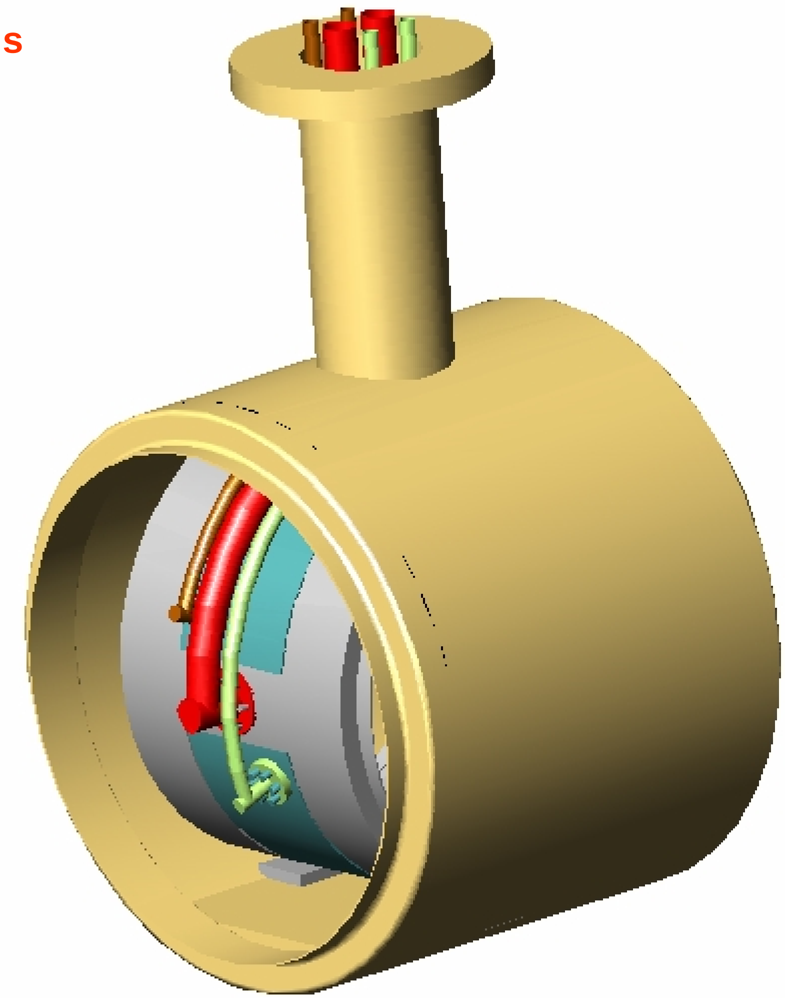
4. Rotate Absorber Body inside Inner Support Tube (showing Absorber body at 30o)



5. Continue to rotate Absorber Body inside Inner Support Tube (showing Absorber body at (60o)



6. Continue to rotate Absorber Body inside Inner Support Tube until Absorber body is at 90o. Then secure feed pipes



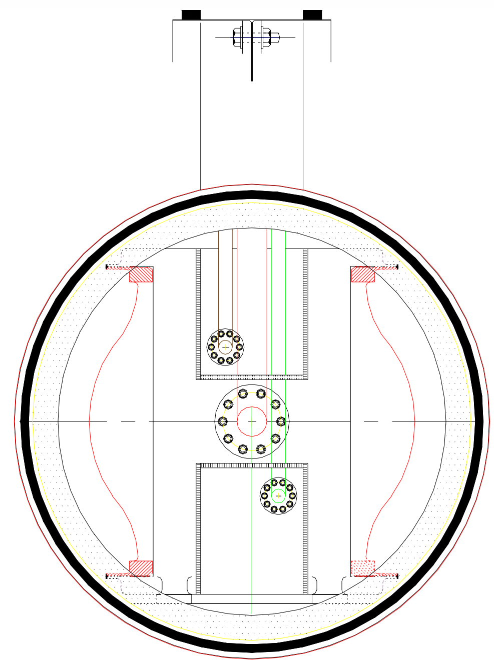
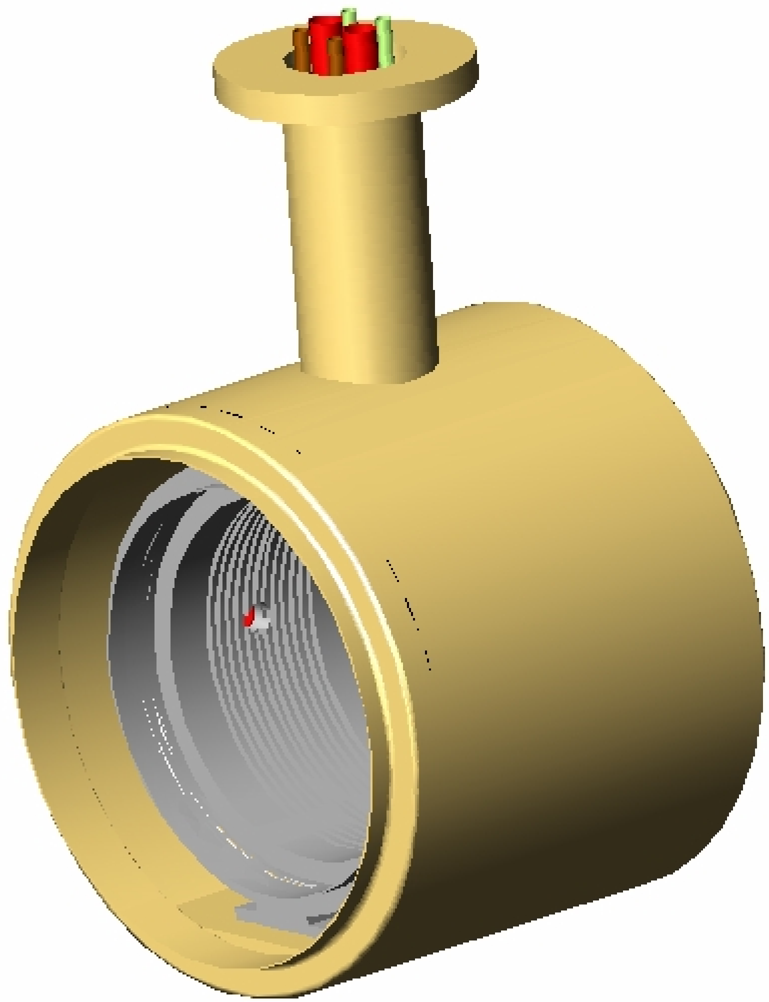


Diagram shows LH2 and GHe pipes secured to absorber body at this position

7. Having secured the feed pipes, the Absorber Body is rotated back to be concentrical to the Inner Support Tube



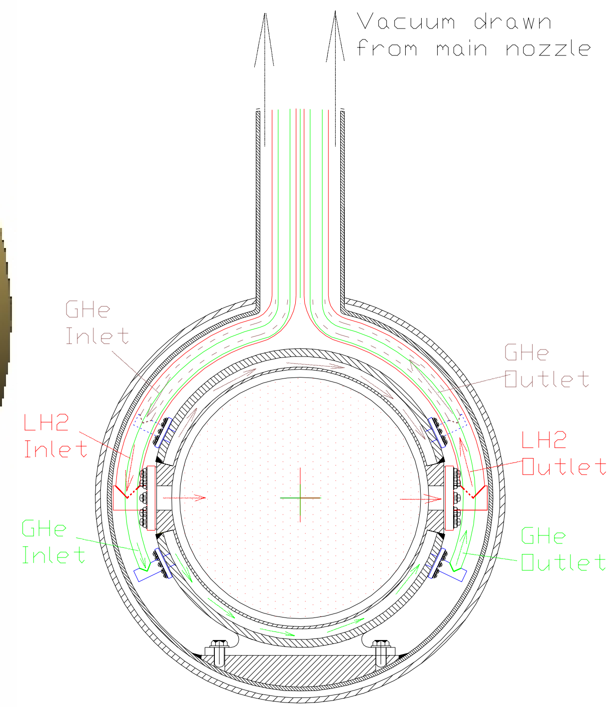
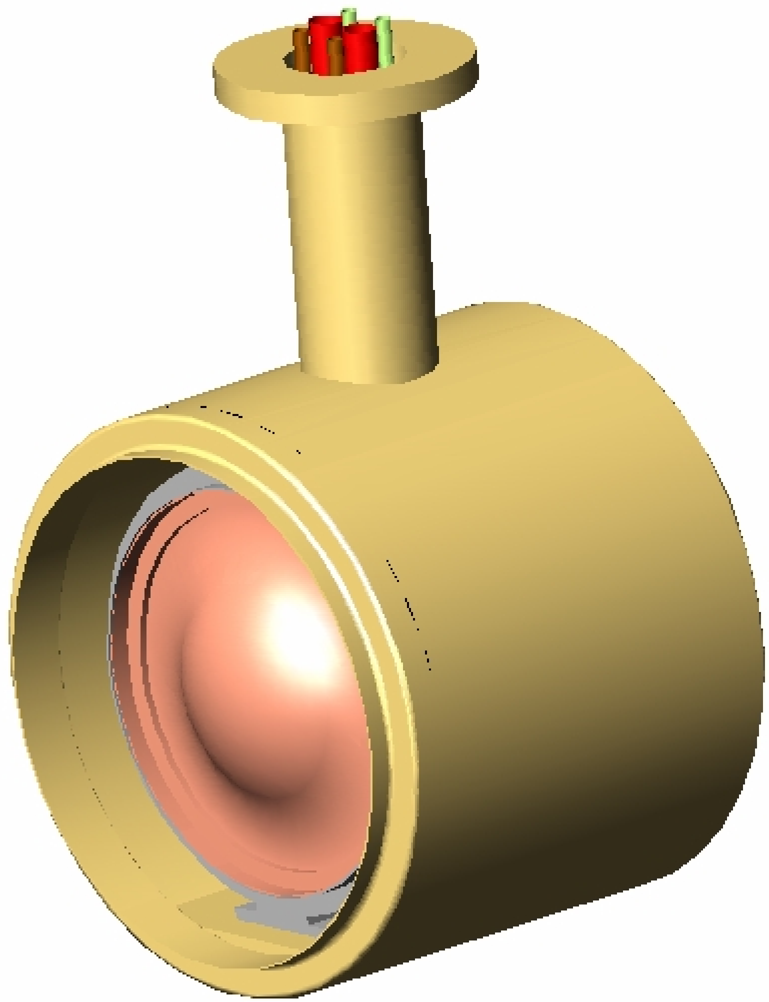
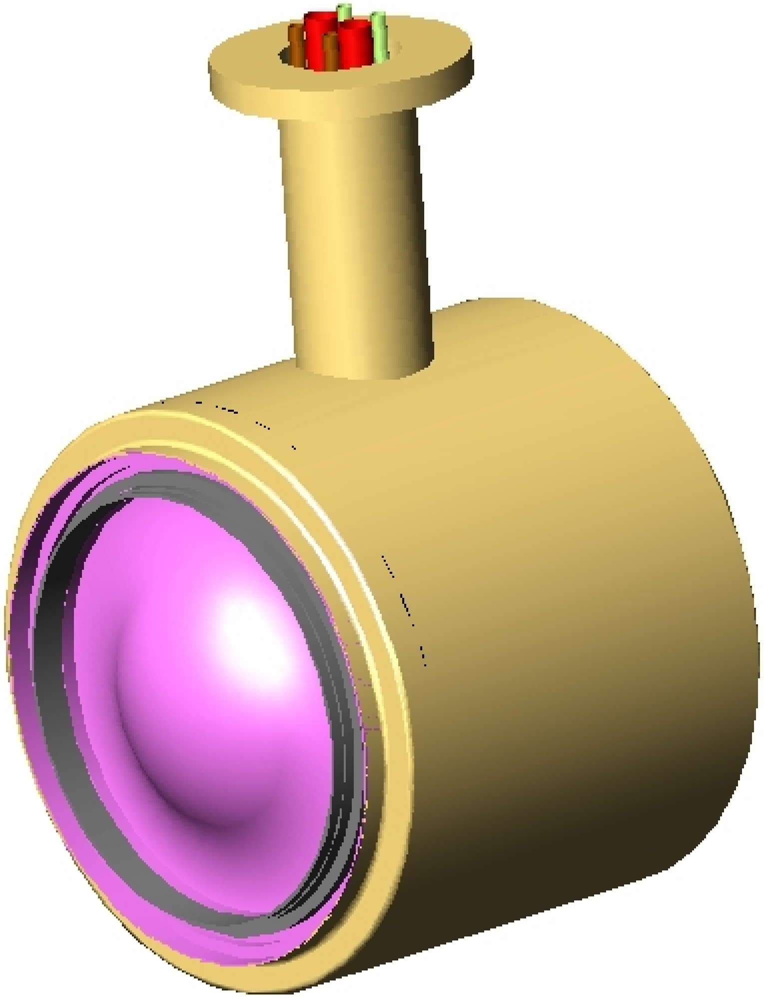


Diagram shows space between Absorber Body with feed pipes connected and the Inner Support Tube

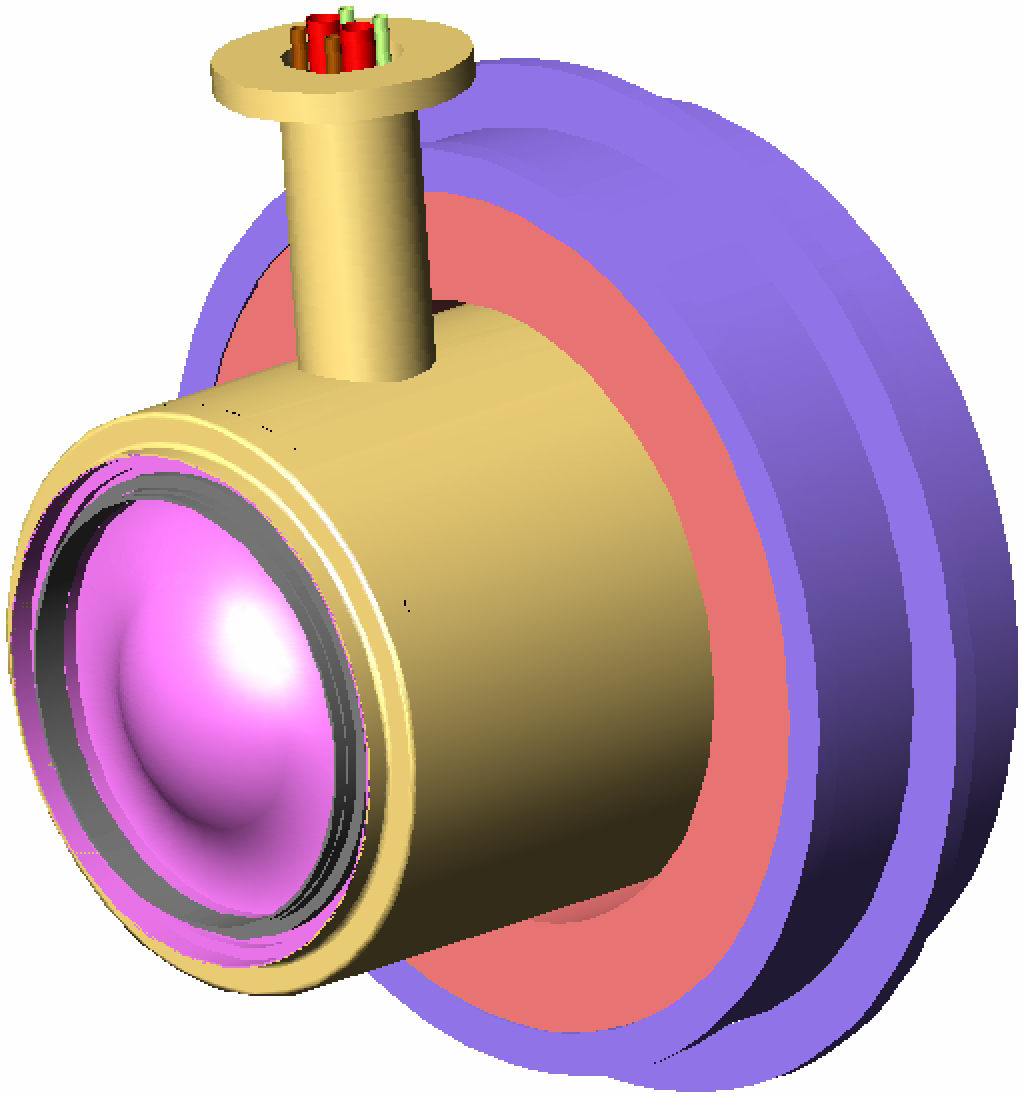
8. “Screw” the Window into the Absorber Body, seal weld and temporary connect all the feed pipes to perform pressure test to the Absorber



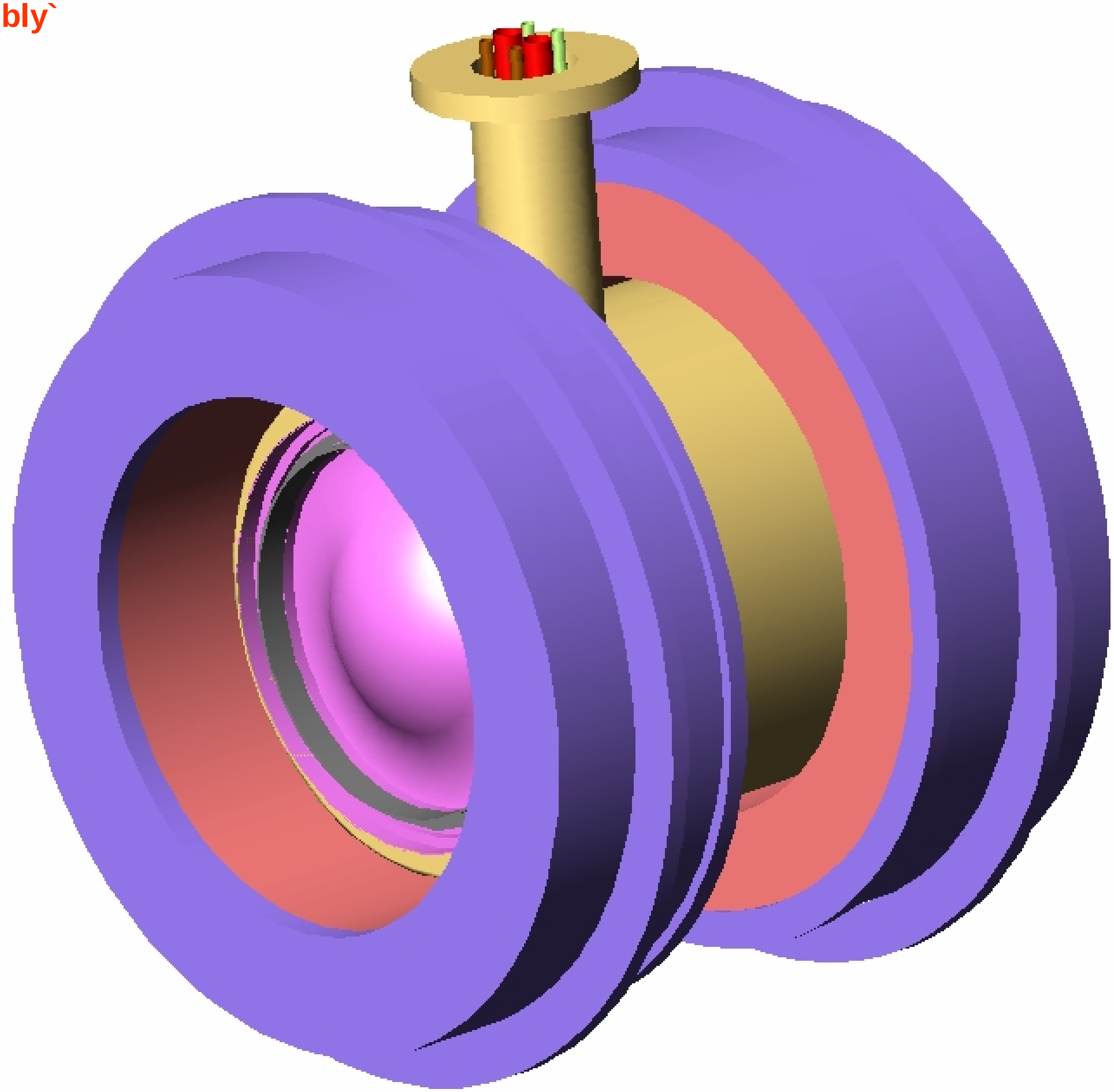
9. “Screw” the Vacuum Window into the Support Tube, seal weld and temporary blank off the Support Tube to perform pressure / vacuum test to the Support tube



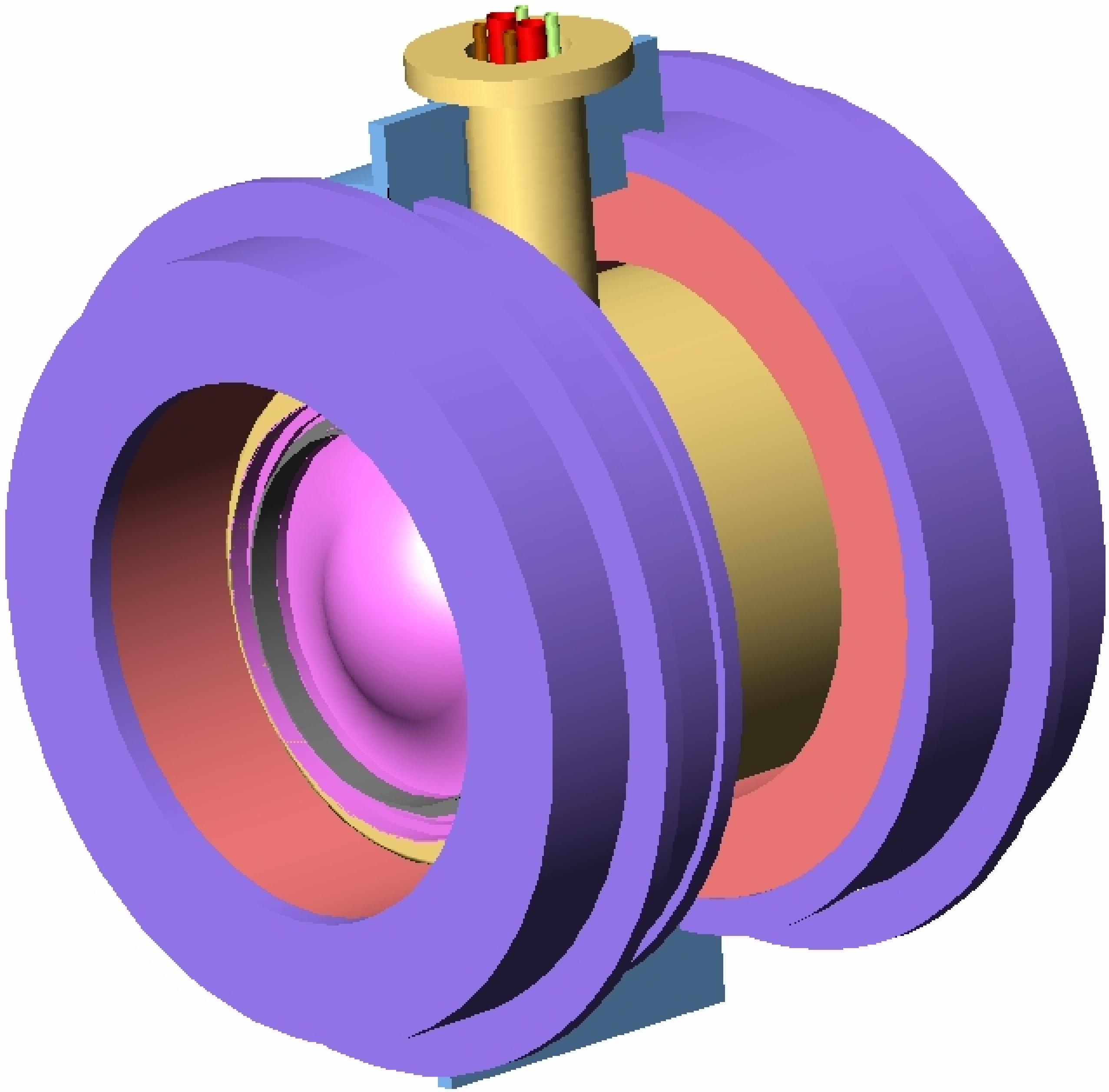
10. Insert one half of the coil sub-assembly



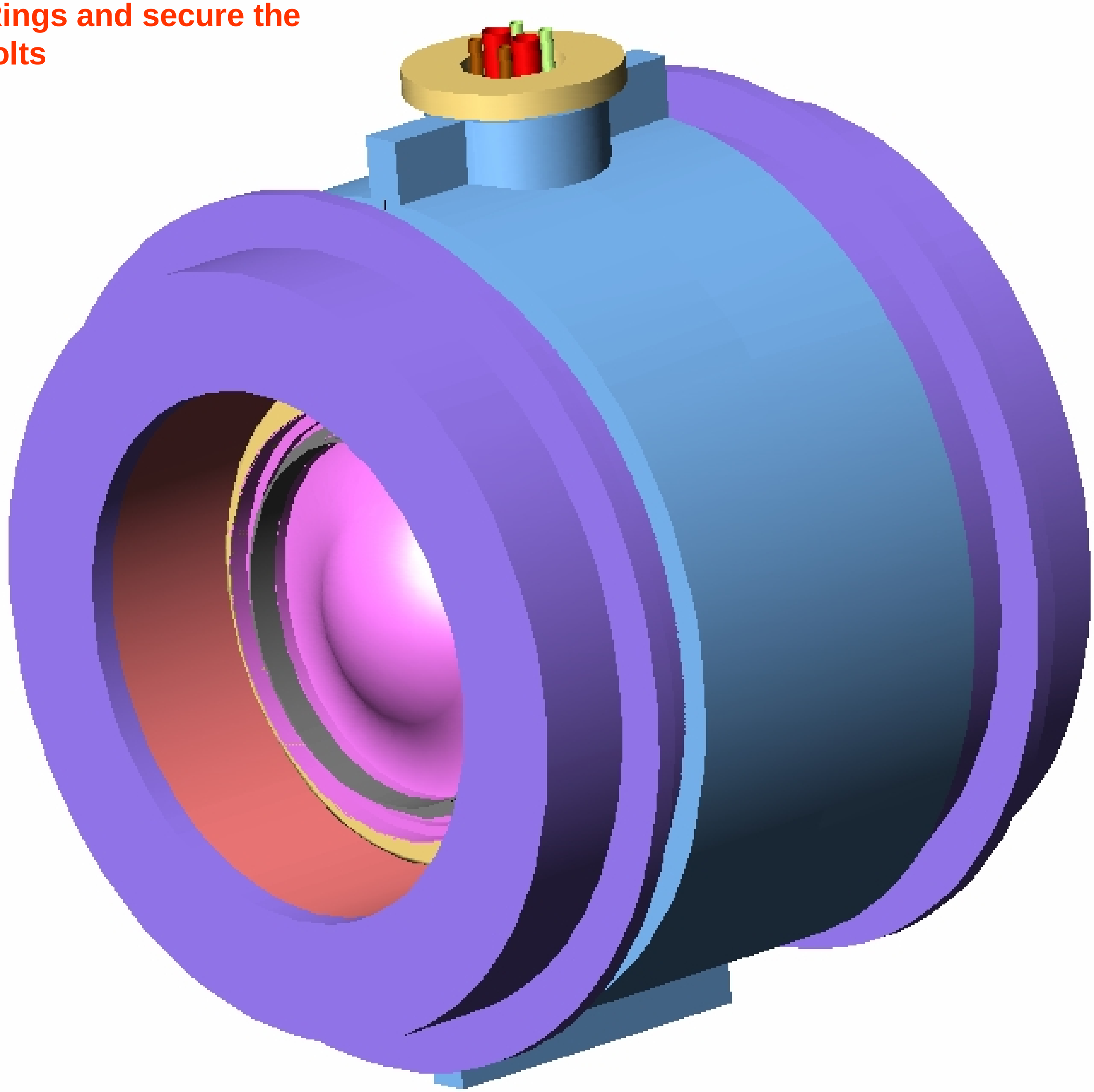
11. Insert the other half of the coil sub-assembly`



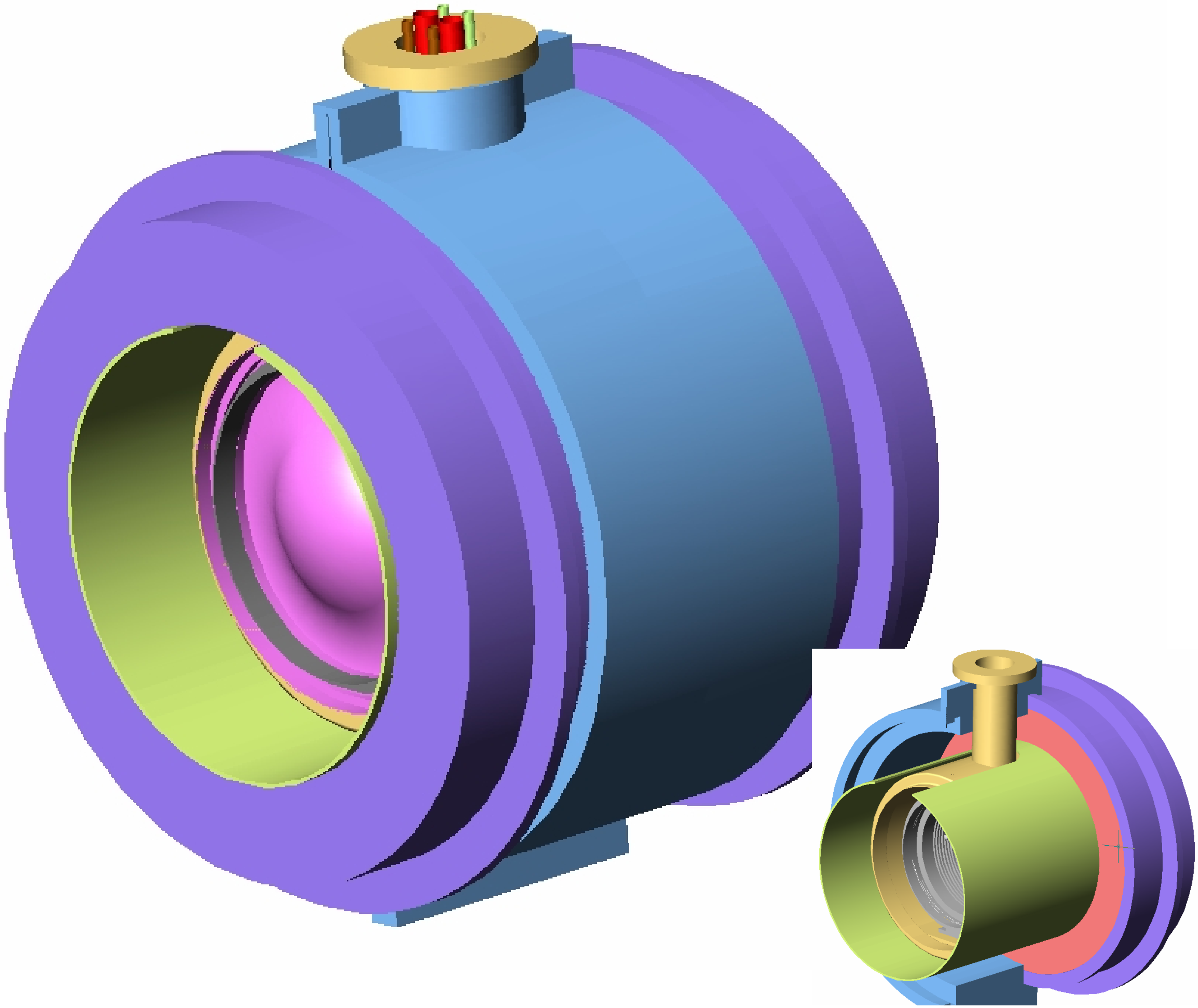
12. Insert one half of the clamping Rings



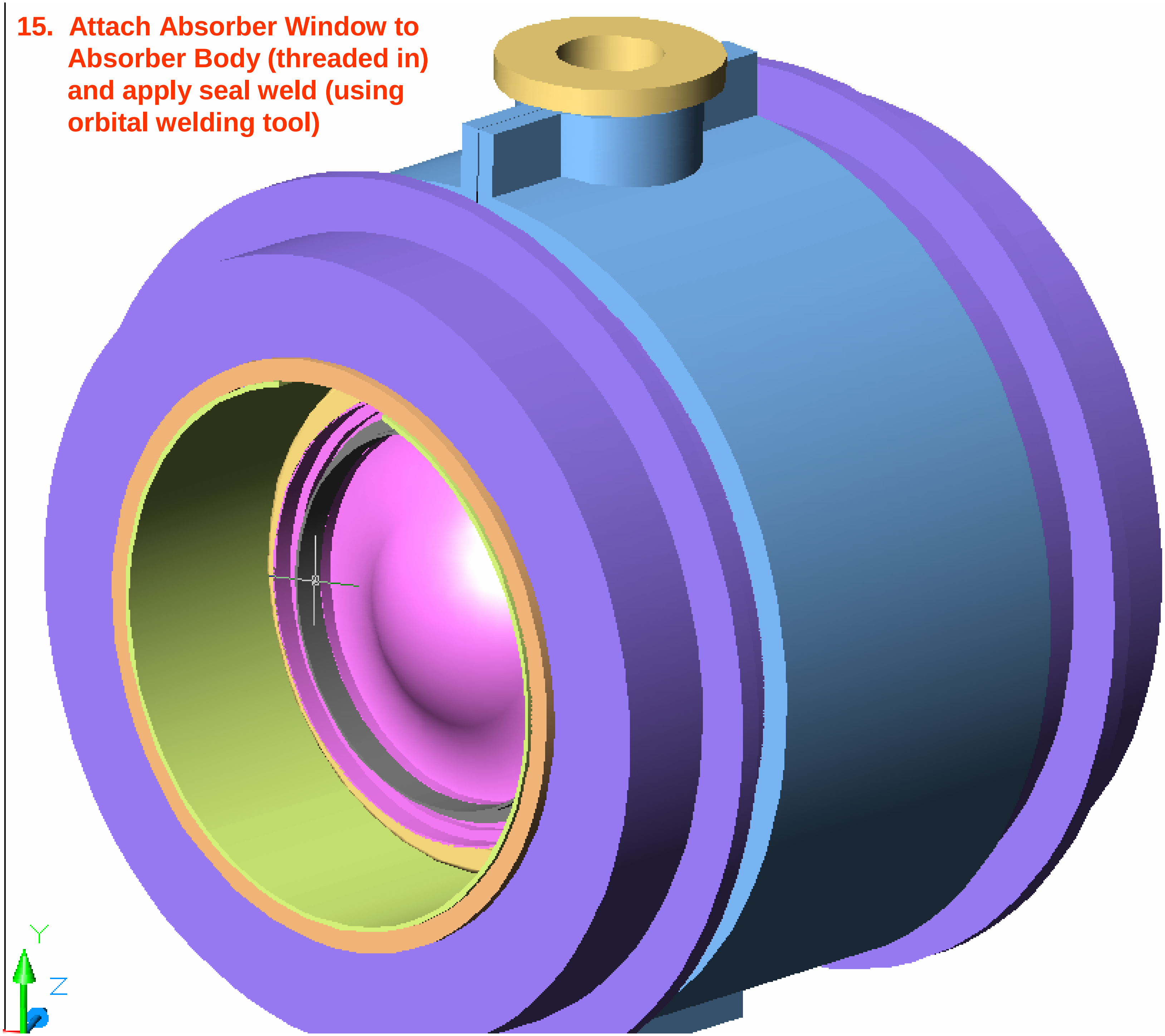
13. Insert the other half of the clamping Rings and secure the pair with bolts

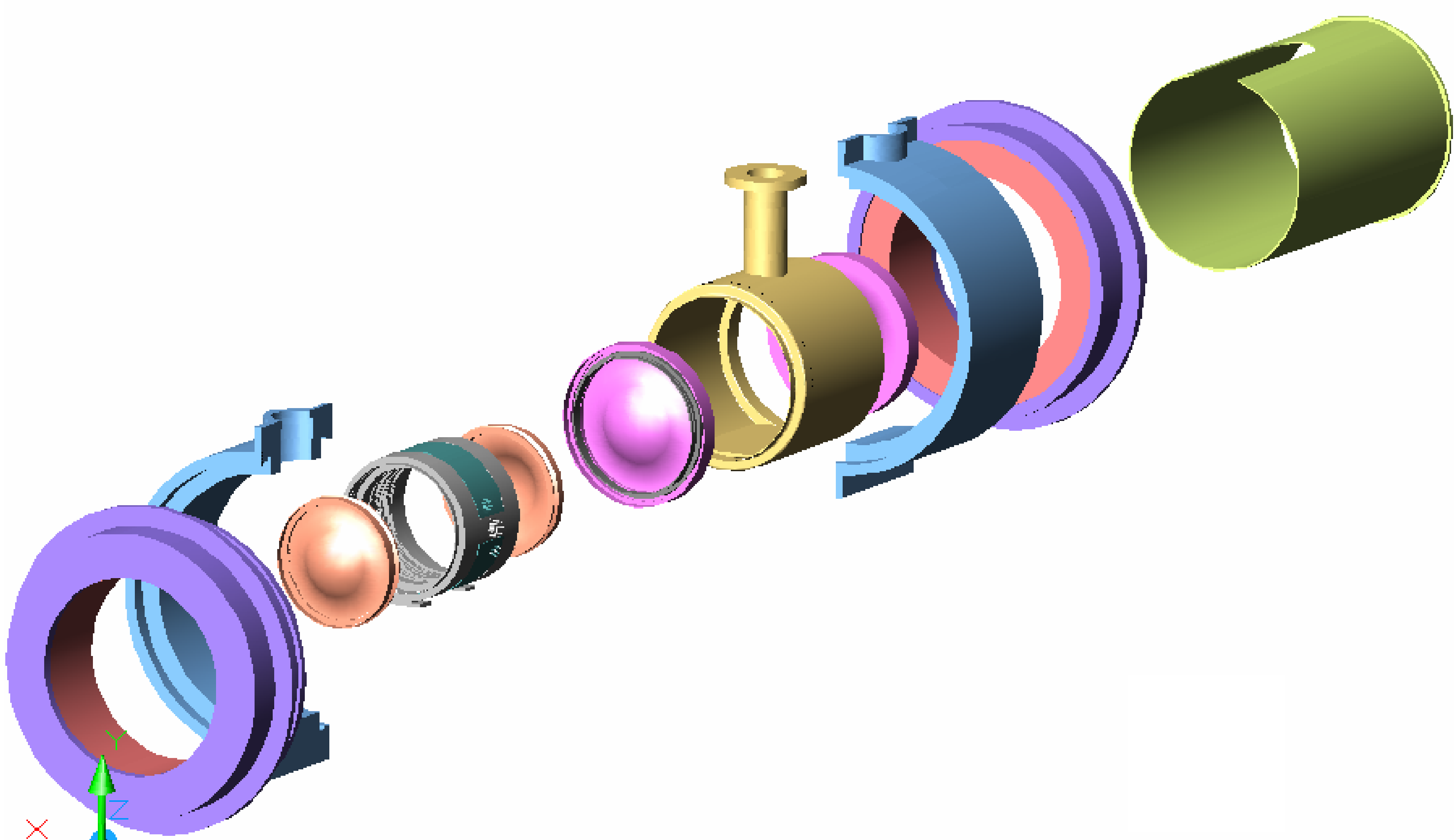


14. Insert the Inner Coil tube



15. Attach Absorber Window to Absorber Body (threaded in) and apply seal weld (using orbital welding tool)





The “assembly view” of all the components