

Support structure of the COMPASS-U tokamak

Appendix_A-Cryostat

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This document is intended for the companies who shown interest in the Preliminary Market Consultation for COMPASS-U **support structure** system to initiate discussion have feedback on fabrication viability of the system.

It will provide very basic information about the system which is in the Design Phase.

- The COMPASS-U will be a high magnetic field (5 T) medium-sized tokamak with high wall temperature (<500°C) operation.
- The scientific program is aimed to address topics of plasma exhaust, liquid metals, enhanced confinement modes and edge plasma physics.

Basic dimensions and parameters:

$R = 0.894 \text{ m}$

$a = 0.27 \text{ m}$

$B_t = 5 \text{ T}$

$I_p = 2 \text{ MA}$

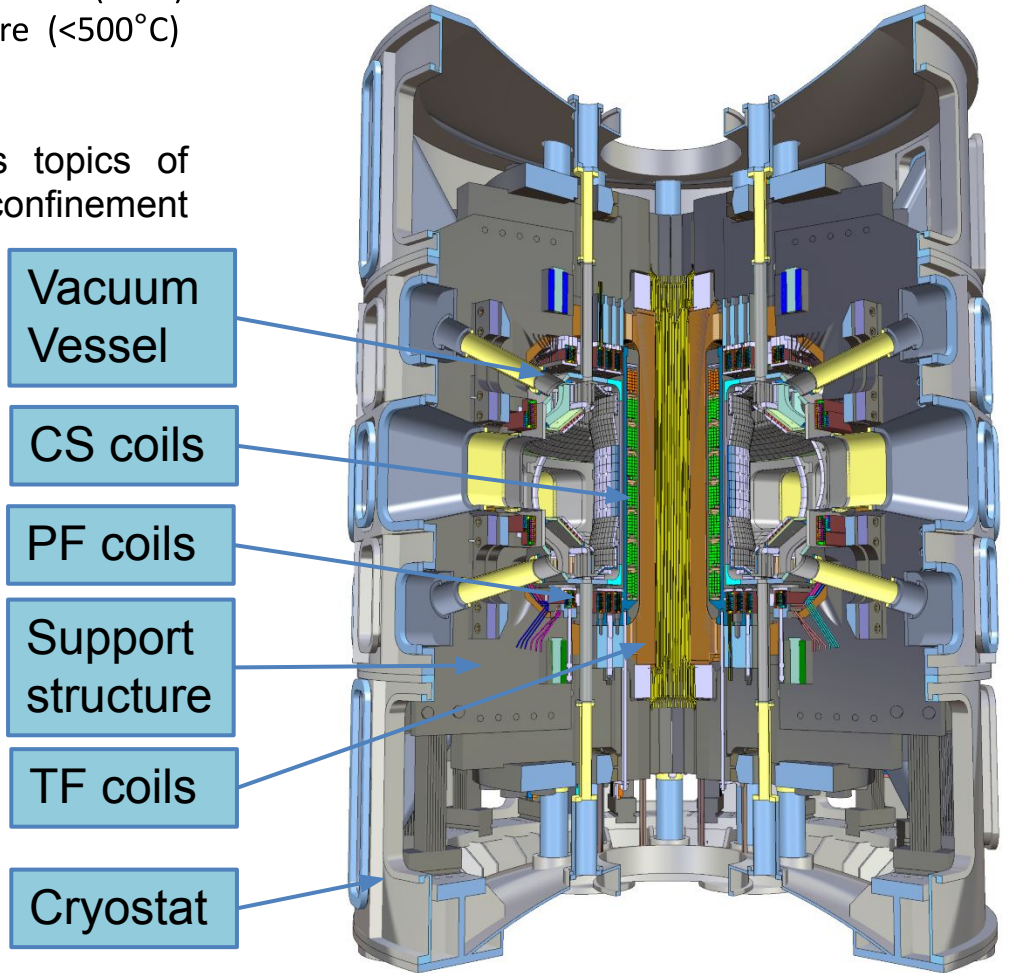
$t_{\text{flat-top}} \sim 2 \text{ s}$

$\delta = 0.5$

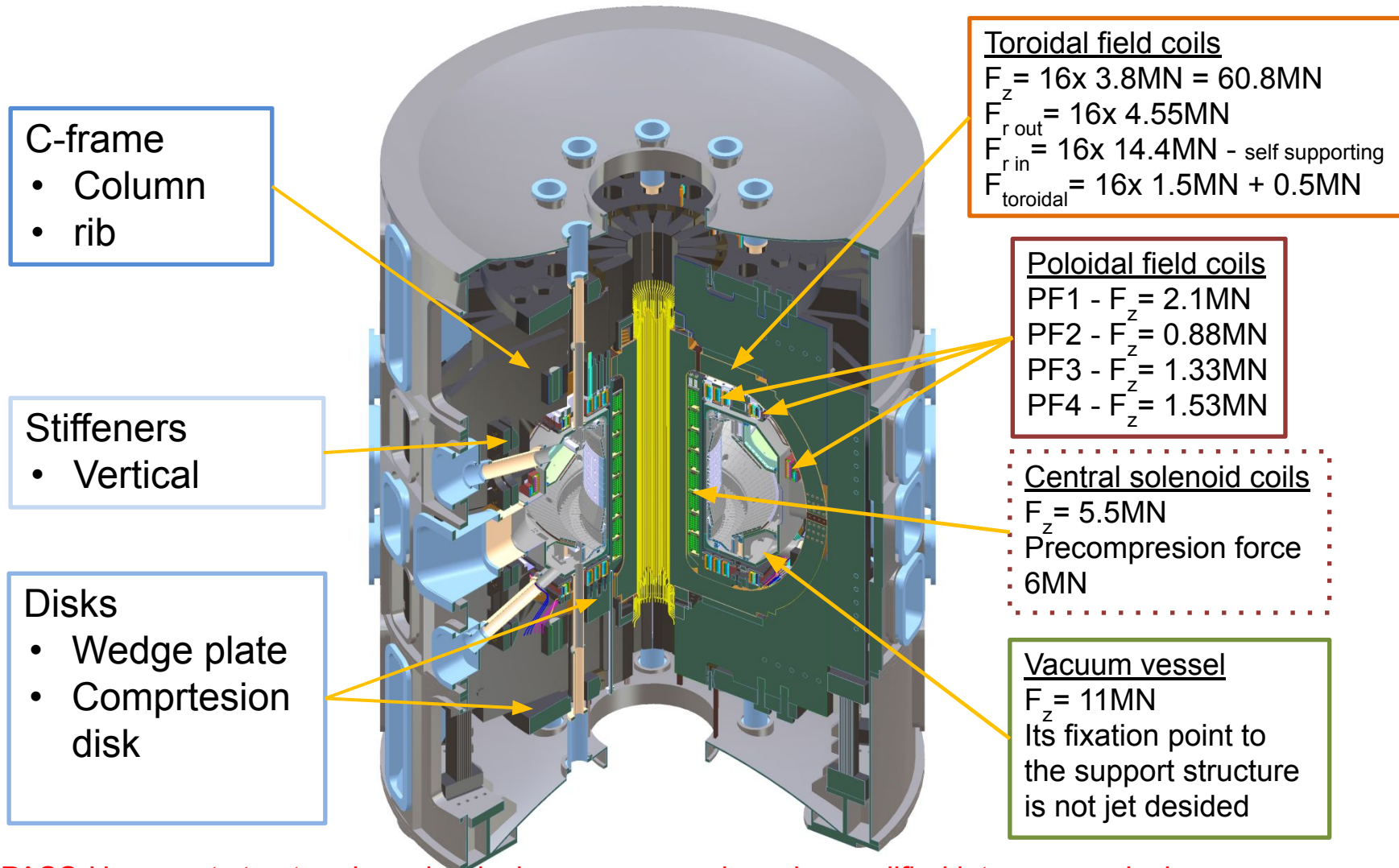
$\kappa = 1.8$

$V_{\text{plasma}} \sim 2 \text{ m}^3$

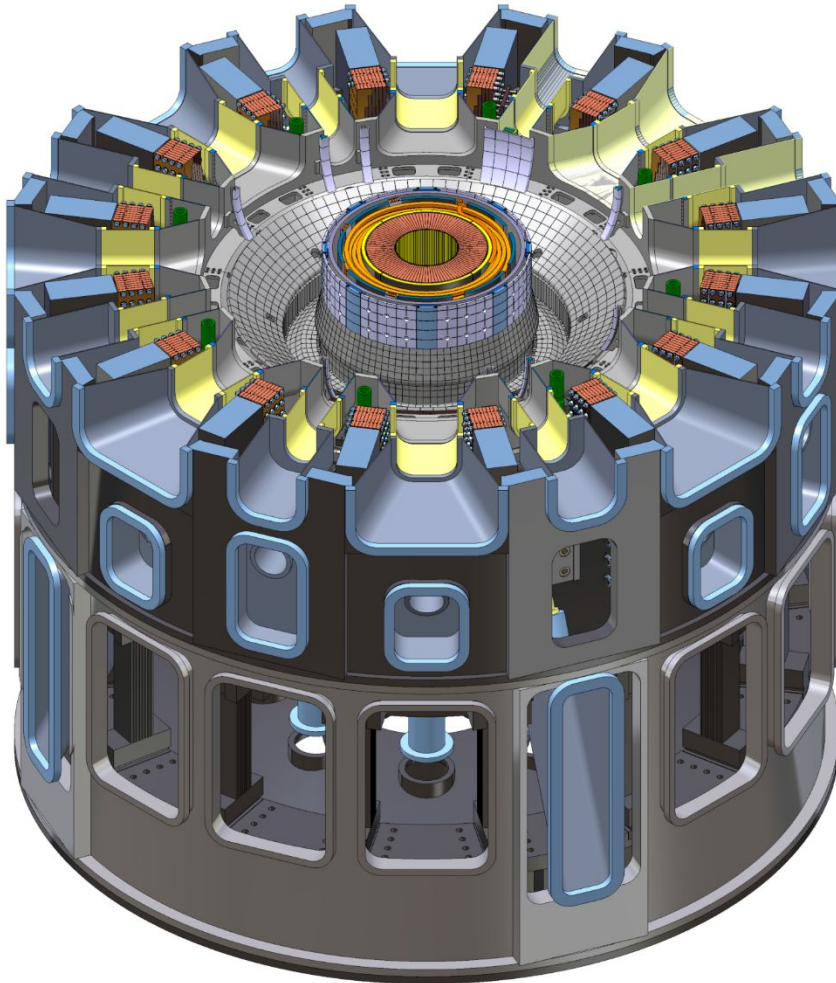
$T_{\text{wall}} \leq 500 \text{ }^\circ\text{C}$



High capability to address the key Plasma Exhaust Physics challenges



COMPASS-U support structure is under design process and can be modified later as per design requirements



The COMPASS-U cryostat should allow reasonable distribution of vacuum vessel ports to allow:

- human access
- additional heating by neutral beams and/or microwaves
- good distribution of diagnostics

COMPASS-U support structure is under design process and can be modified later as per design requirements

Design requirements

- Provide vacuum to insulate component at 77K from vacuum vessel at 500 °C
- Provide support for the tokamak itself

Design constraints

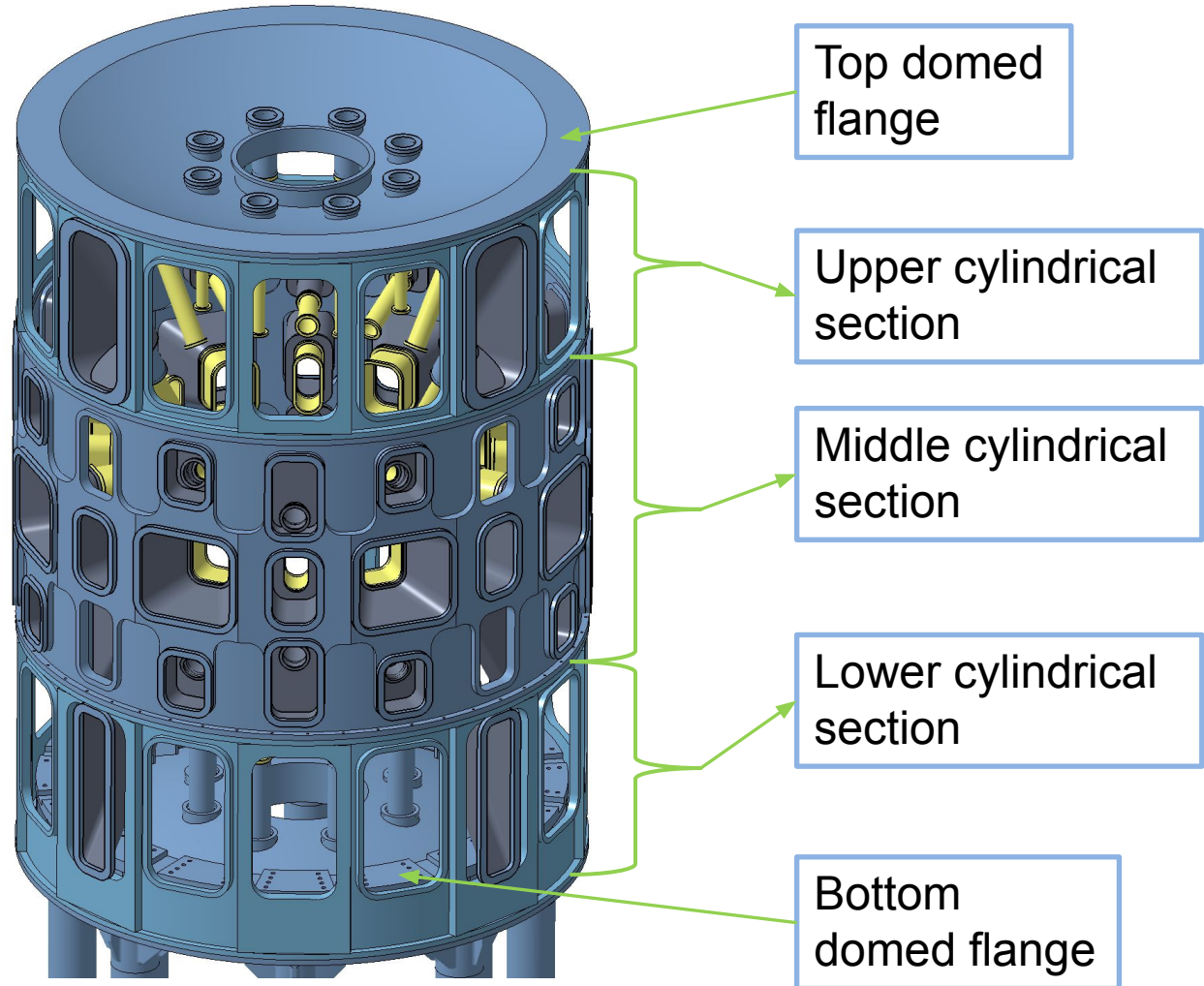
- Provide a reliable structural support for life-time of the tokamak
 - It shall withstand all possible load combinations from electromagnetic, pressure and thermal loads .
- The material of the support structure should be
 - compatible with liquid nitrogen temperatures
 - have reasonably low activation
 - vacuum friendly
 - With low **relative magnetic permeability not higher than 1.03 (to be clarified)**
- Allow easy assembly
- Provide vacuum barrier for **operation** at the **pressure 1×10^{-5} Pa** with the acceptable **leakage** in the range of **1×10^{-10} Pa m³ s⁻¹**
- Price
- Cost
- **Outgassing** of the vacuum surfaces **below 5×10^{-8} Pa m³ s⁻¹ m²**
- All the **welds** are requested to be vacuum compatible **to not create virtual leaks**

Property*	Unit	AISI 304L
Density	(kg/m ³)	7900
Poisson's ratio		0.3
Melting Temp.	°C	1400
Electrical Resistivity	Ω m	7.2E-07
Specific heat	J/kg K	483
Magnetic permeability	m	1.012
Mechanical properties at room temperature (21 °C)		
Youngs modulus	(GPa)	195
Yield Strength	(MPa)	172
Tensile Strength	(MPa)	483
Coefficient of thermal expansion	(μm/m/k)	15.3
Thermal conductivity	(W/m * K)	14.87
Mechanical properties at -200 °C		
Youngs modulus	(GPa)	213
Yield Strength	(MPa)	494
Tensile Strength	(MPa)	1595
Coefficient of thermal expansion	(μm/m/k)	13.4
Thermal conductivity	(W/m * K)	

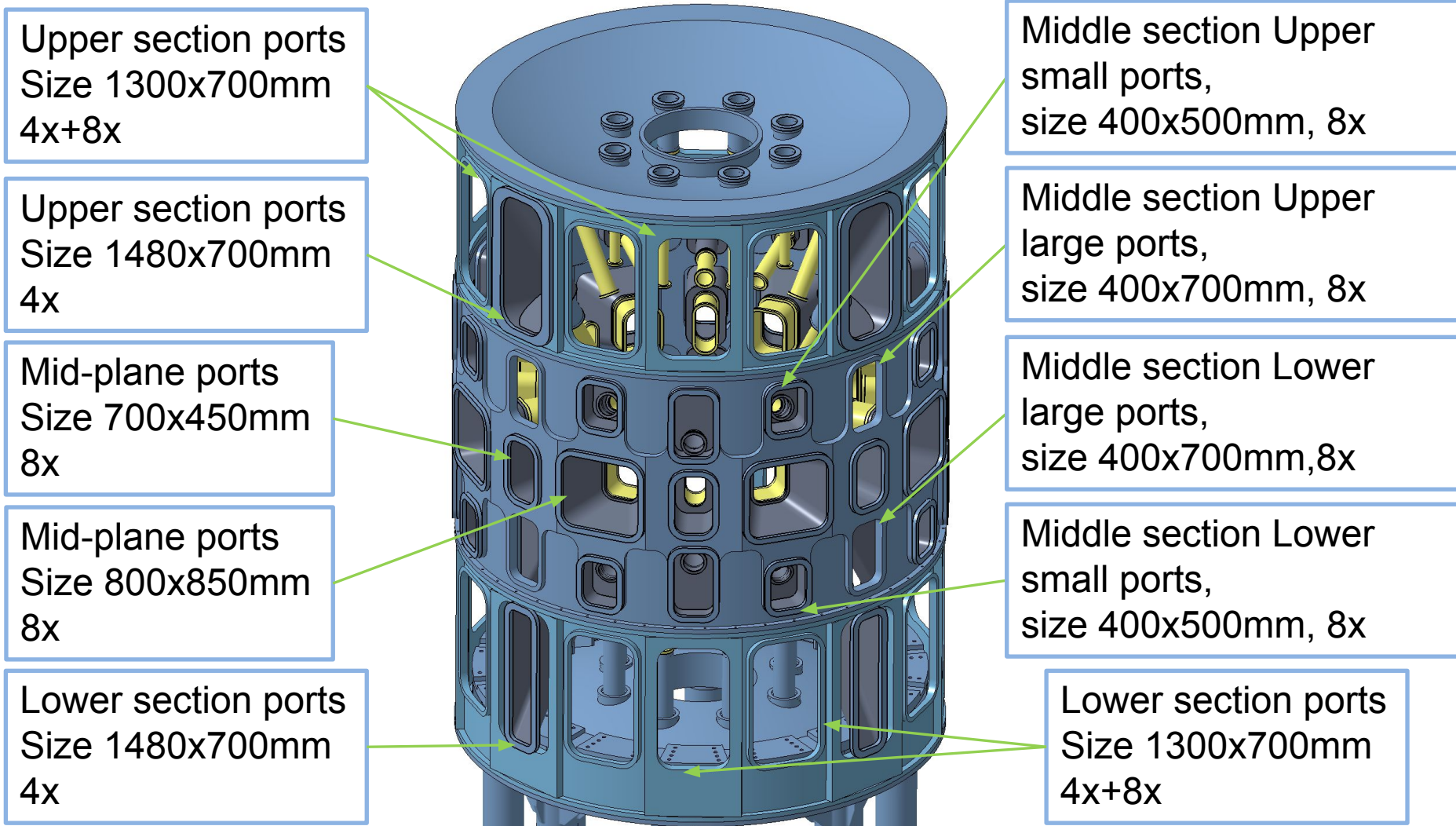
General dimensions of the cryostat are:

- Outer diameter 4.75m
- Height 6.6m
- Size over horizontal flanges 4.7m

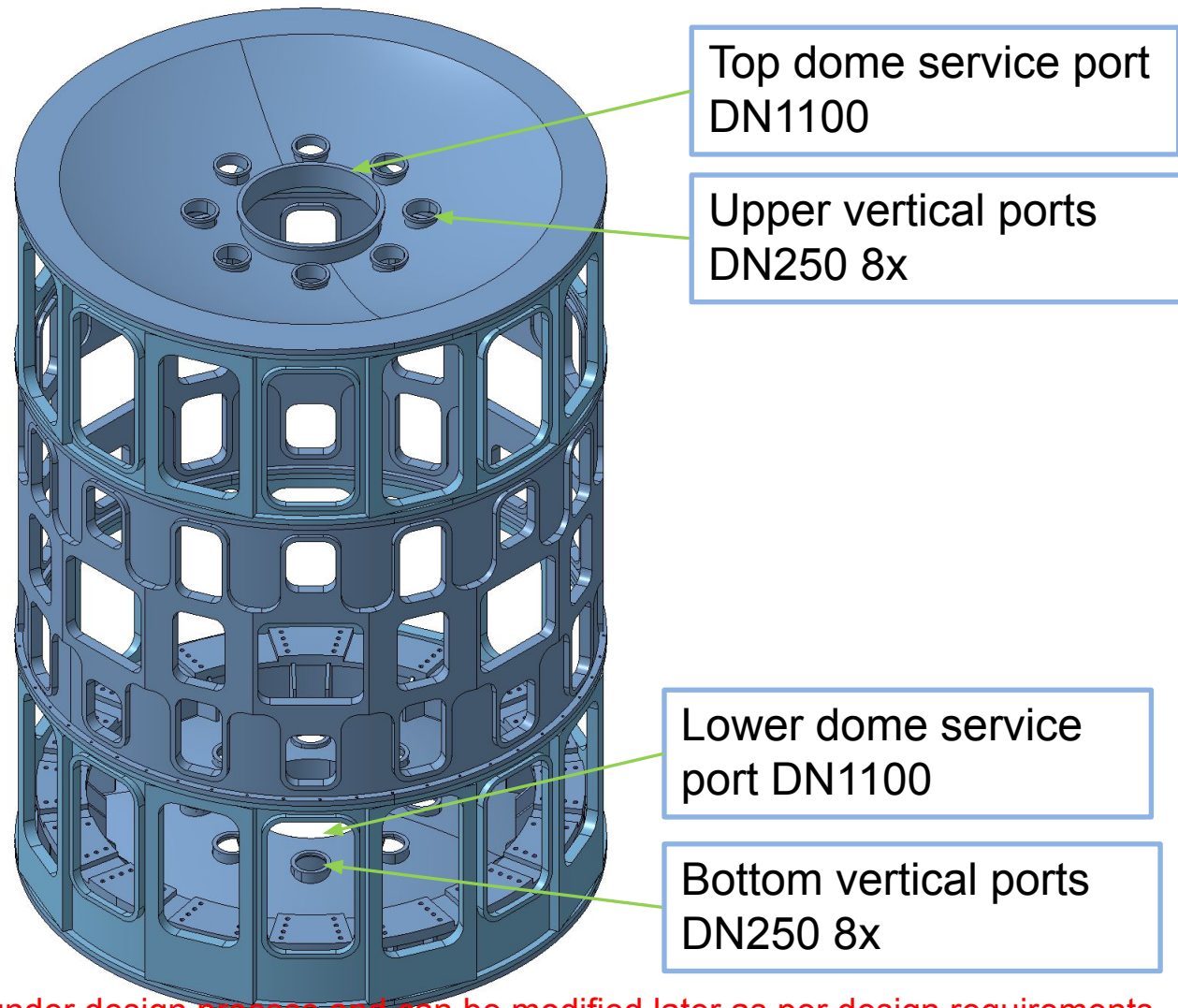
The size of the cryostat can be modified. **All parts has to pass through the assembly hall door, this is 4.8 meter wide.**



COMPASS-U cryostat is under design process and can be modified later as per design requirements



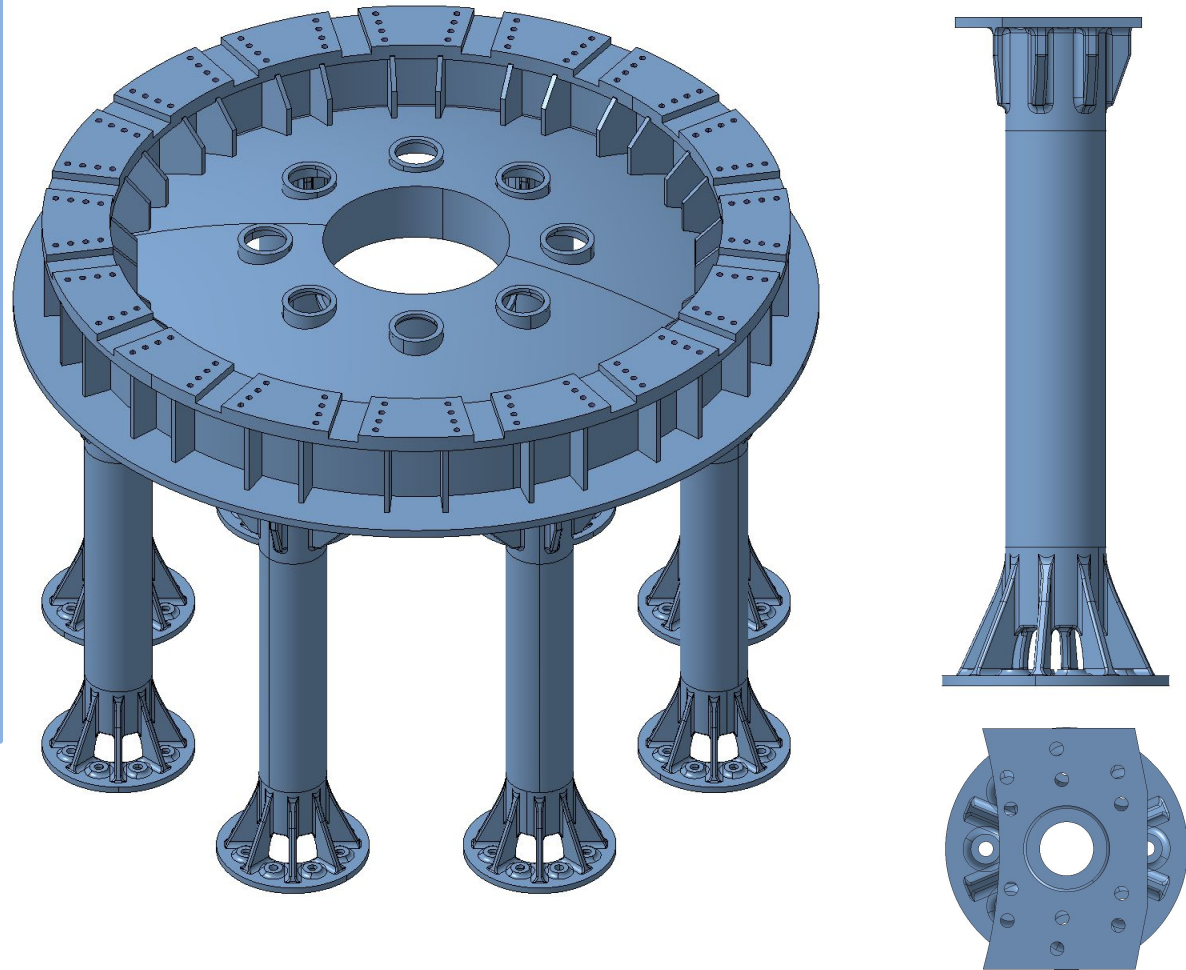
COMPASS-U cryostat is under design process and can be modified later as per design requirements



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The whole tokamak structure is sitting on the bottom domed flange of the cryostat. This bottom flange is sitting on 8 pillars. These will be directly bolted to the foundation slab.

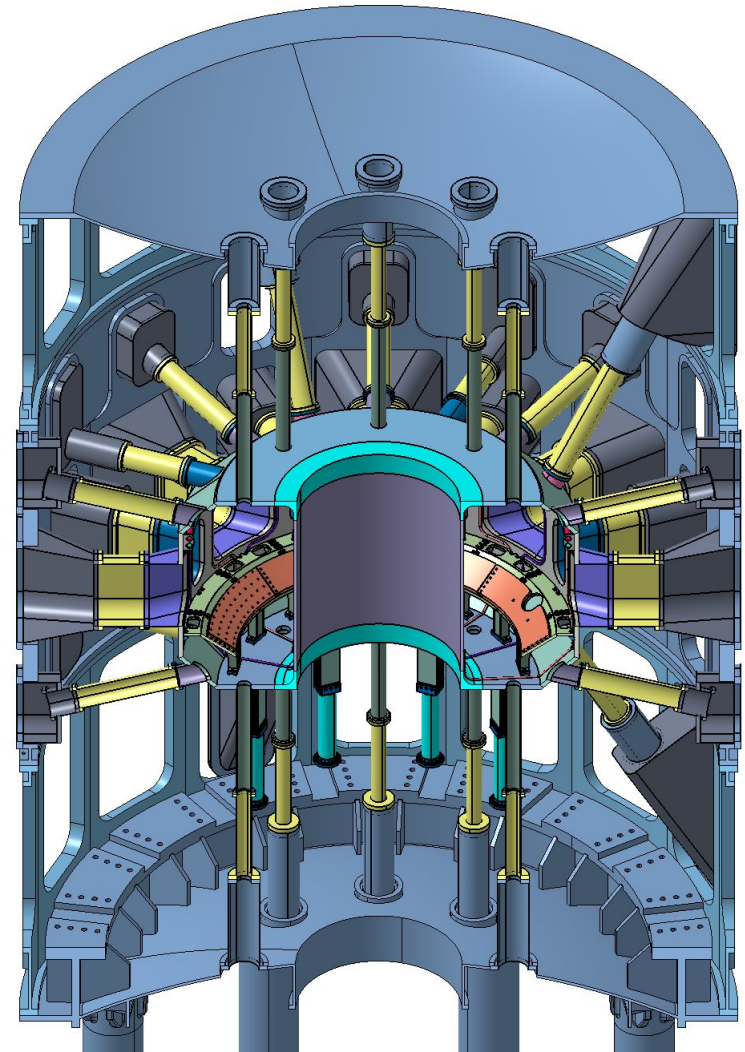
Pillar height is 2650mm, foot diameter is 900mm, the central tube is 400mm in diameter with 20mm thick wall. Top and bottom section is foreseen to be cast.



COMPASS-U cryostat is under design process and can be modified later as per design requirements

Cryostat, vacuum barrier for HV is by the means of the port extensions connected to the main vacuum vessel, primary vacuum barrier for UHV.
Vacuum vessel is at the moment held by the support structure (not displayed)

Types and distribution of the port extension is similar to the previous version of this presentation. Version 1 of the 60deg divertor port was canceled.



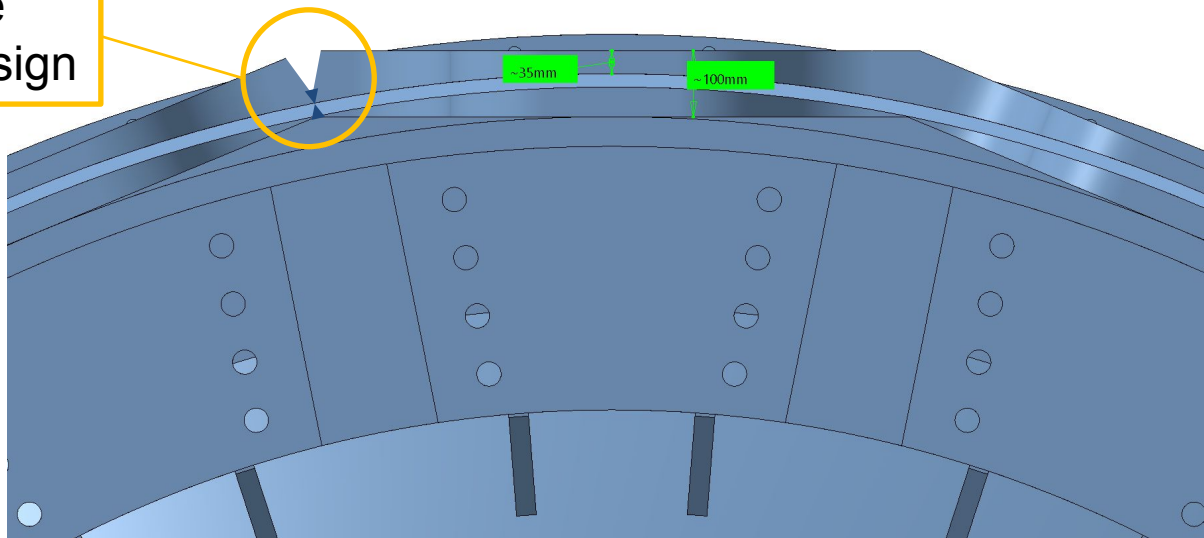
COMPASS-U cryostat is under design process and can be modified later as per design requirements

Cryostat V08-D is relying heavily on the use of thick “block” flanges. The main idea was to reduce the number of welds and thus reduce the labor intensity. The cost for this is heavier assembly.

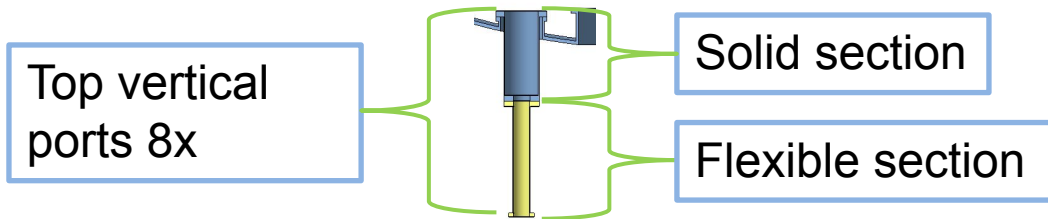
remarks:

- The flange thickness is 100mm, whereas the real thickness can be, at the moment, reduced by up to 35mm.
- There is no requirement on full penetration 100mm thick welds. The weld thickness can be reduced by reducing the flange thickness on the sides as shown bellow.

Possible
weld design

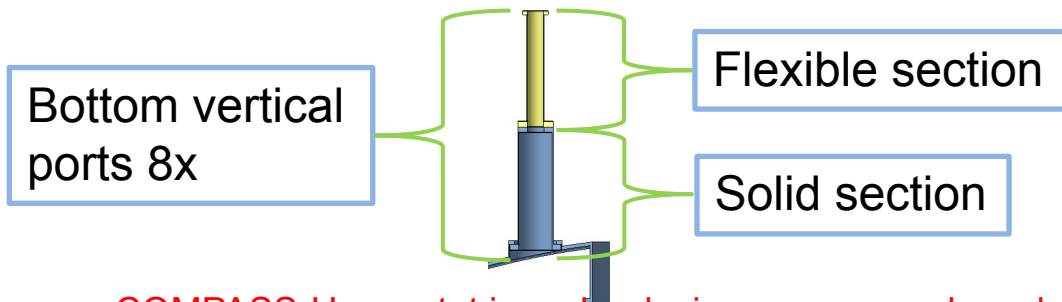


COMPASS-U cryostat is under design process and can be modified later as per design requirements

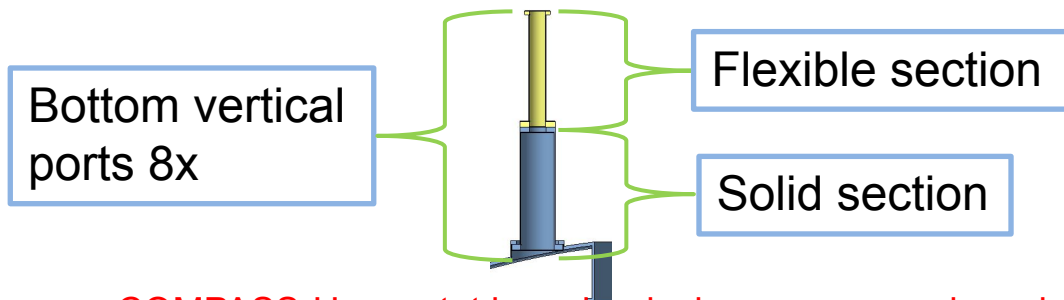
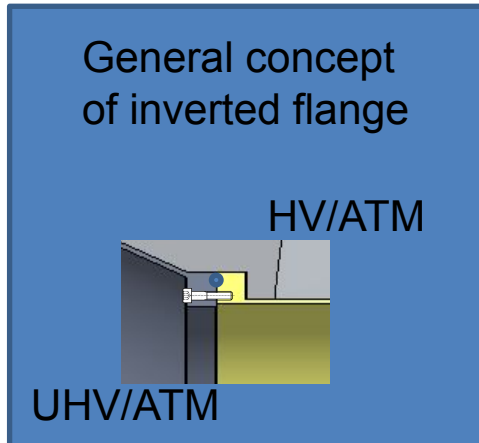
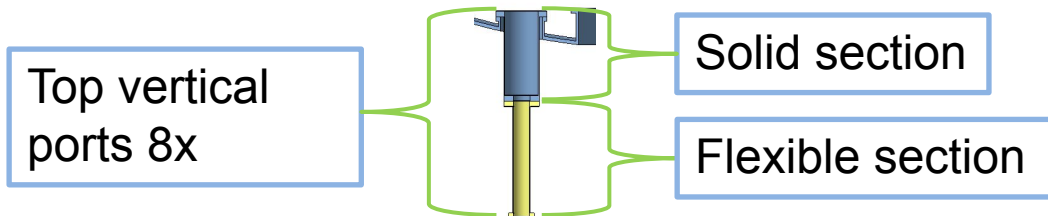


- **Baking temperature of solid and flexible section is 150°C**, flexible part will be next to the **vacuum vessel** which baking temperature is **500°C**

- Top and bottom parts are not of the same length.
- Flexible section is supposed to compensate +/-20mm vertical movement (in the axis direction) and +/-10mm of horizontal movement
- The flexible section as it is shown is 0.68 m long.



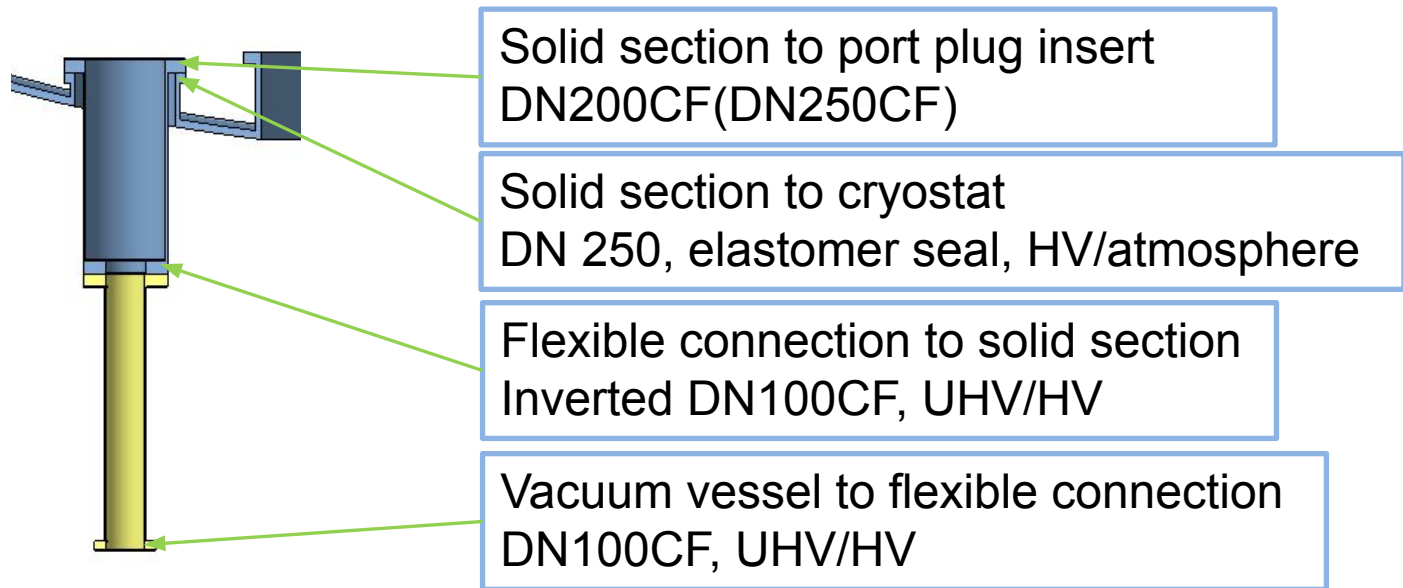
COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

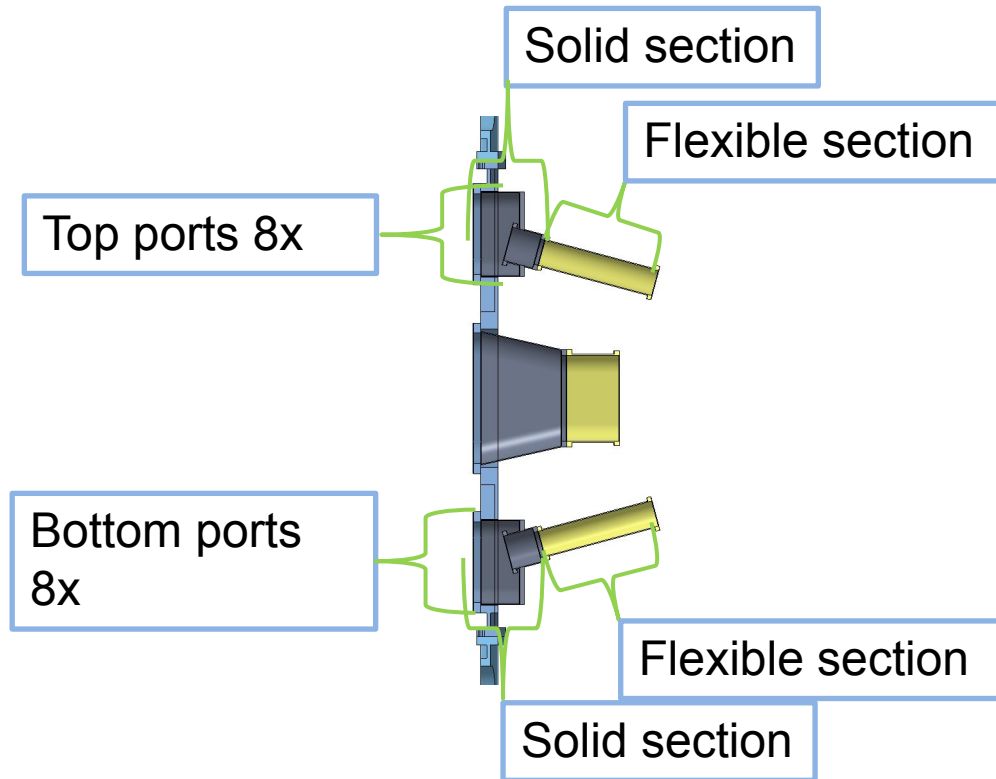
- DN100CF flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.69 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer diameter, DN100CF?), metal sealed, operational in the range -200°C to $?^{\circ}\text{C}$ (not higher than 500°C)
- DN250 elastomer sealed solid section bolted to the cryostat with CF flange from the outside to close the main vacuum (preferably DN200CF)

COMPASS-U cryostat is under design process and can be modified later as per design requirements



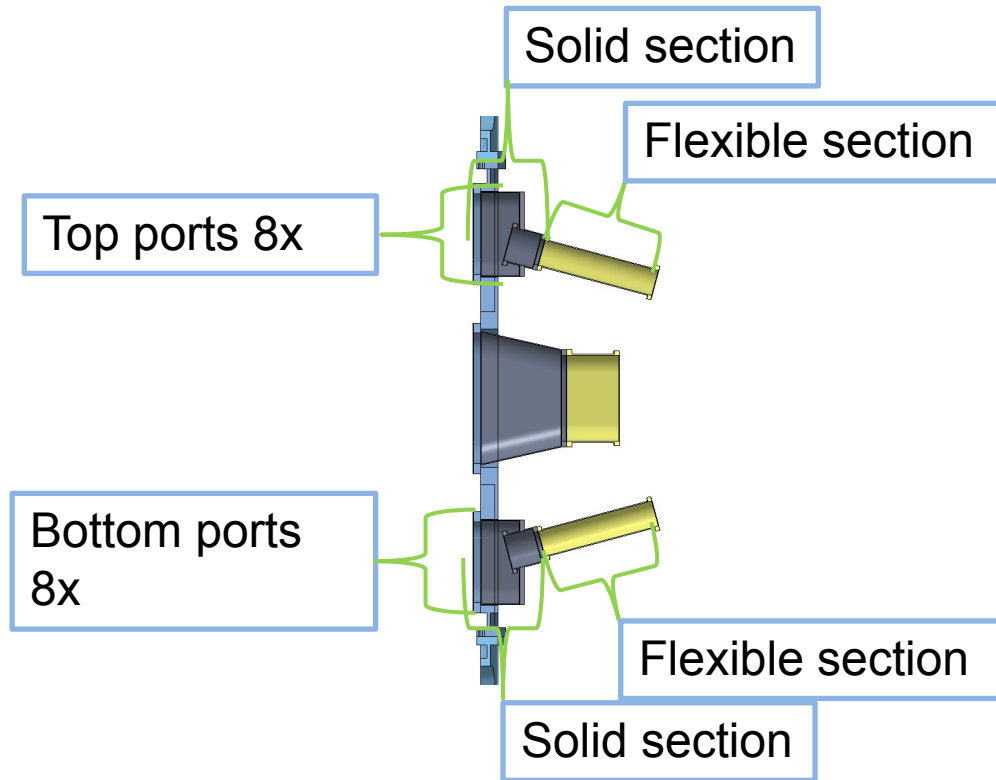
Since the configuration is the same on the top as it is on the bottom, only top section is displayed

COMPASS-U cryostat is under design process and can be modified later as per design requirements



- Upper and bottom 15 degree ports and port extensions are identical
- Flexible section is supposed to compensate $\pm 20\text{mm}$ vertical movement and $\pm 10\text{mm}$ of horizontal movement
- The flexible section as it is shown is 0.65 m long
- **Baking temperature of solid and flexible section is 150°C** , flexible part will be next to the **vacuum vessel** which baking temperature is **500°C**

COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

- DN150CF flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.65 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer diameter, DN150CF?), metal sealed, operational in the range -200°C to $?\text{C}$ (not higher than 500°C)
- DN200CF flange for closing the main vacuum
- 400mm x 500mm rectangular elastomer seal flange closing the cryostat vacuum

COMPASS-U cryostat is under design process and can be modified later as per design requirements

This size of the port can be modified

What is important is the position of the axis of this port

Solid section to cryostat
400mm x500mm, elastomer seal, HV/atmosphere

DN200CF flange for closing the main vacuum, UHV/atmosphere

Flexible connection to solid section
Inverted DN150CF, UHV/HV

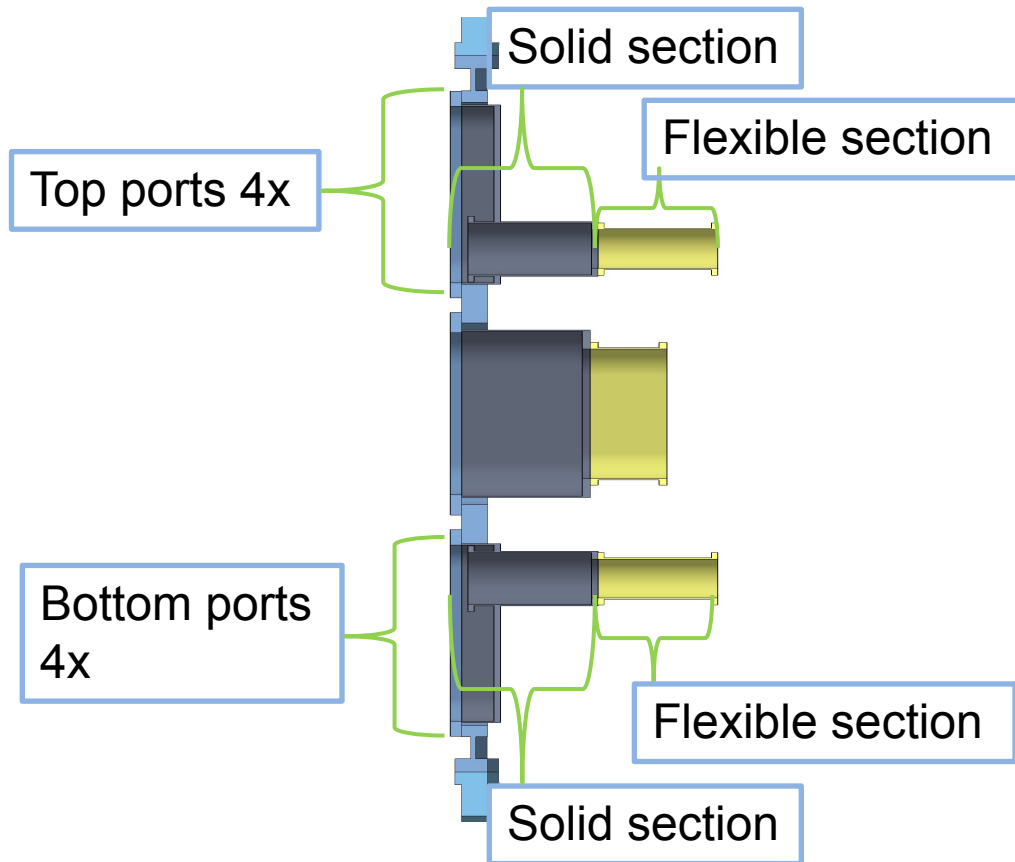
DN150 is required

This size would be nice

Vacuum vessel to flexible connection
DN150CF, UHV/HV

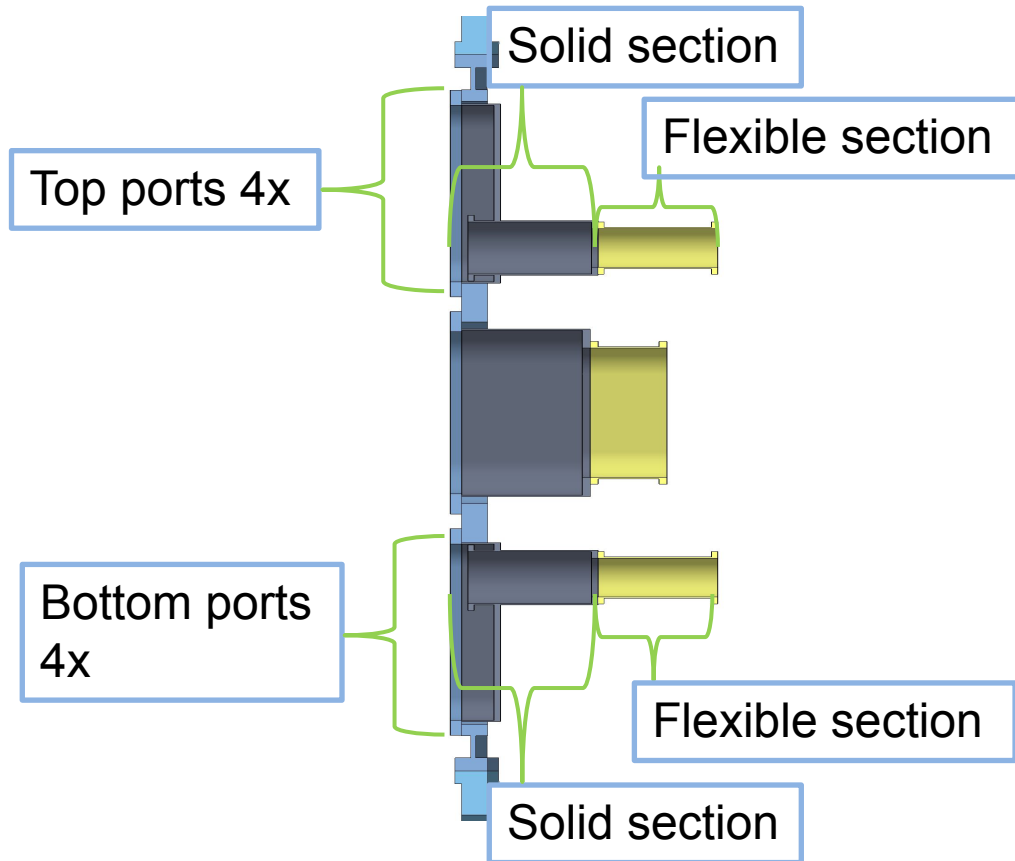
Since the configuration is the same on the top as it is on the bottom, only top section is displayed

COMPASS-U cryostat is under design process and can be modified later as per design requirements



- Upper and bottom horizontal ports and port extensions are identical
- Flexible section is supposed to compensate $\pm 20\text{mm}$ vertical movement and $\pm 10\text{mm}$ of horizontal movement
- The flexible section as it is shown is 0.44 m long
- **Baking temperature of solid and flexible section is 150°C , flexible part will be next to the vacuum vessel which baking temperature is 500°C**

COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

- DN150CF flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.44 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer diameter, DN150CF?), metal sealed, operational in the range -200°C to $?$ C (not higher than 500°C)
- DN200CF flange for closing the main vacuum
- 400mm x 700mm rectangular elastomer seal flange closing the cryostat vacuum

COMPASS-U cryostat is under design process and can be modified later as per design requirements

This size of the port can be modified

What is important is the position of the axis of this port

With the "block" flange concept, it is possible to move the whole elastomer sealed flange downwards to deal with this collision

This size would be nice

Since the configuration is the same on the top as it is on the bottom, only top section is displayed

Solid section to cryostat
400mm x700mm, elastomer seal, HV/atm.

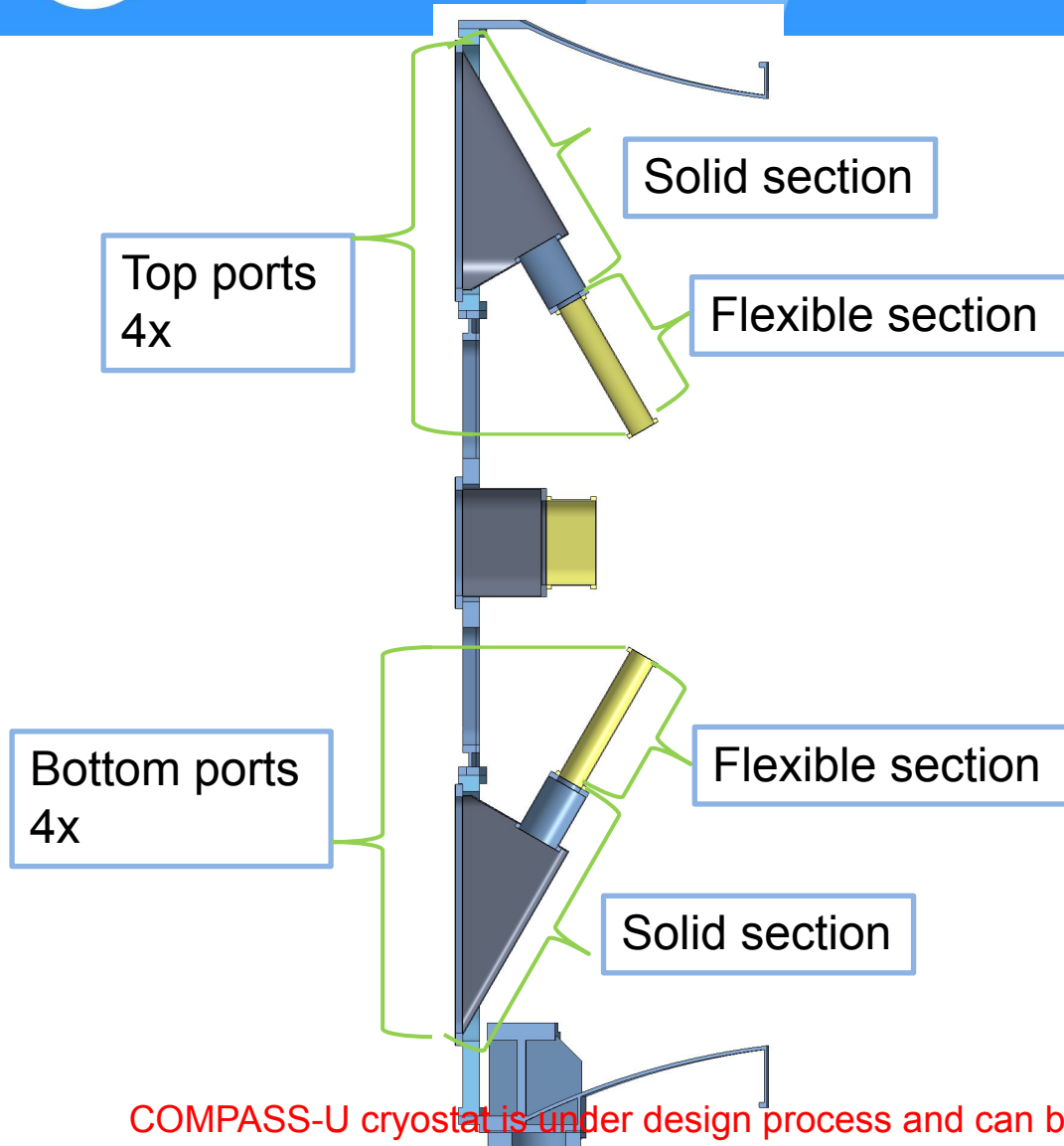
DN200CF flange for closing the main vacuum, UHV/atmosphere

Flexible connection to solid section
Inverted DN150CF, UHV/HV

DN150 is required

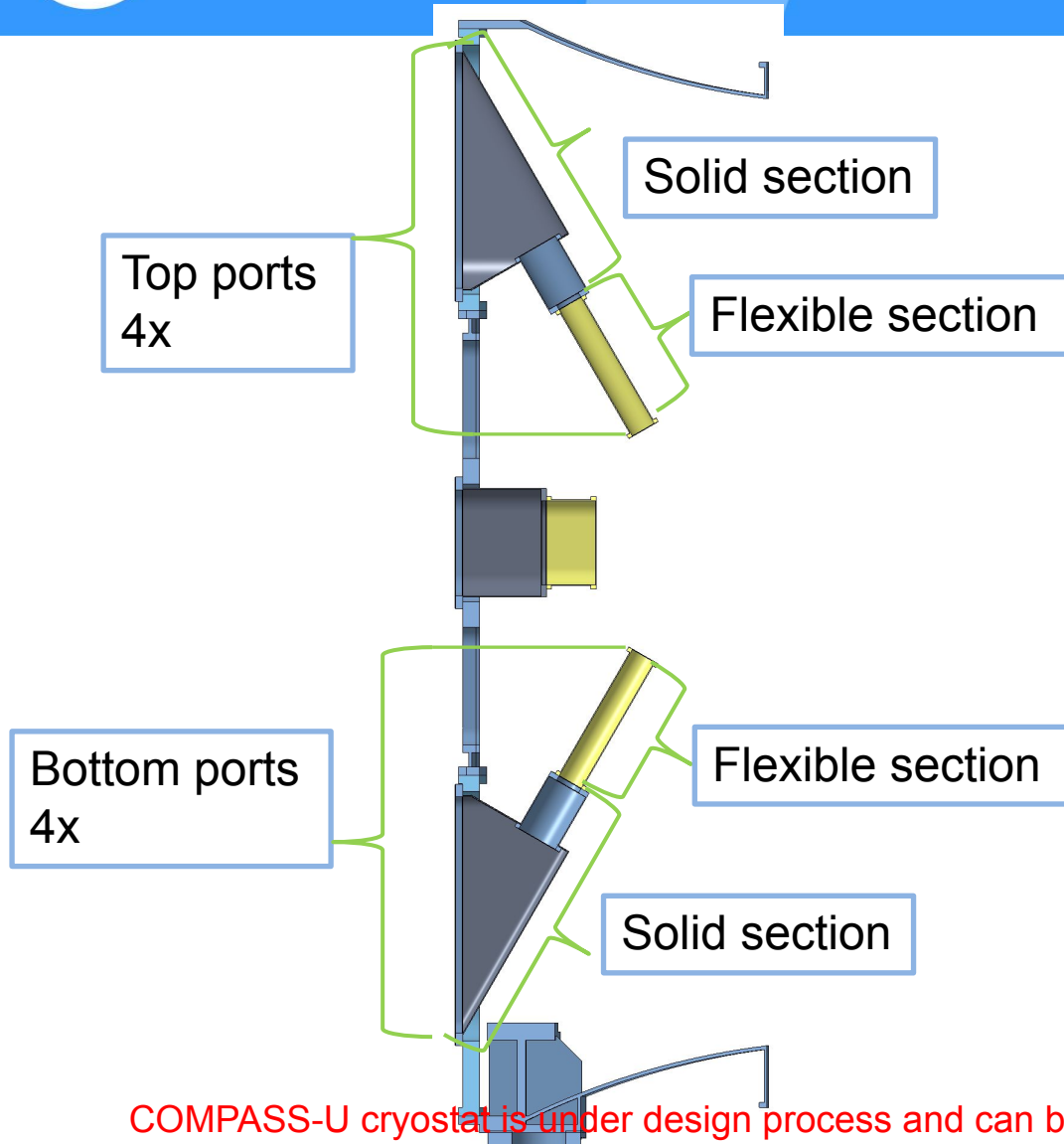
Vacuum vessel to flexible connection
DN150CF, UHV/HV

COMPASS-U cryostat is under design process and can be modified later as per design requirements



- Upper and bottom 60 degree ports are identical, port extensions are not identical
- Flexible section is supposed to compensate +/-20mm vertical movement and +/-10mm of horizontal movement
- The flexible section as it is shown is 0.87 m long
- **Baking temperature of solid and flexible section is 150°C**, flexible part will be next to the **vacuum vessel** which baking temperature is **500°C**

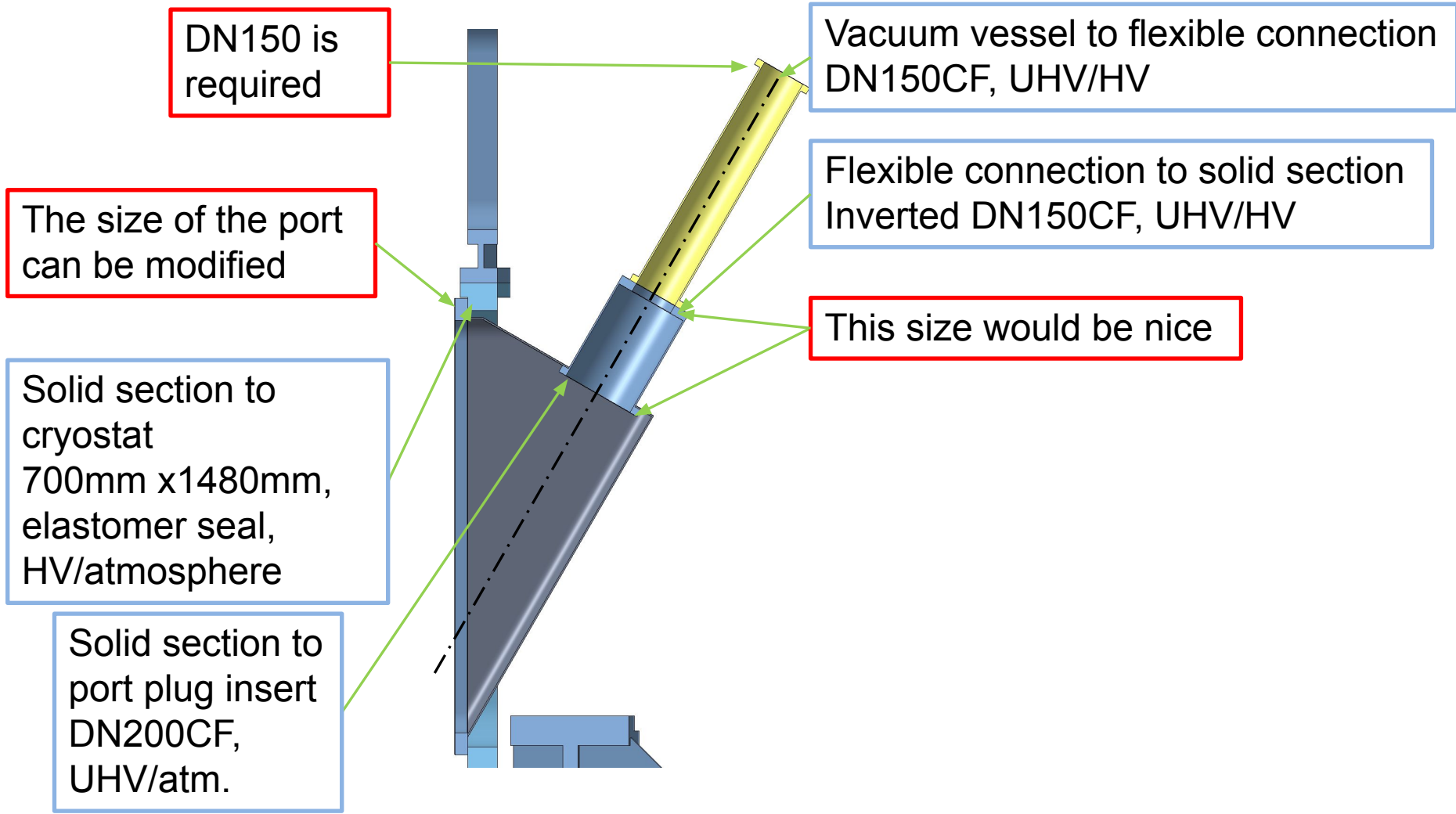
COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

- DN150CF flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.87 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer diameter, DN150CF?), metal sealed, operational in the range -200°C to $?^{\circ}\text{C}$ (not higher than 500°C)
- DN250 elastomer sealed solid section bolted to the cryostat with CF flange from the outside to close the main vacuum (preferably DN200CF)

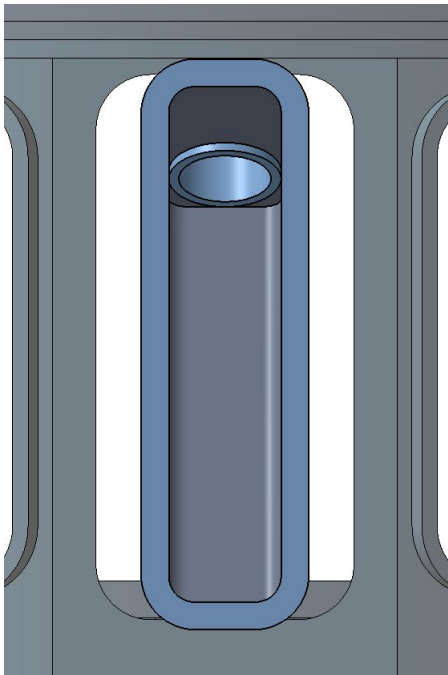
COMPASS-U cryostat is under design process and can be modified later as per design requirements



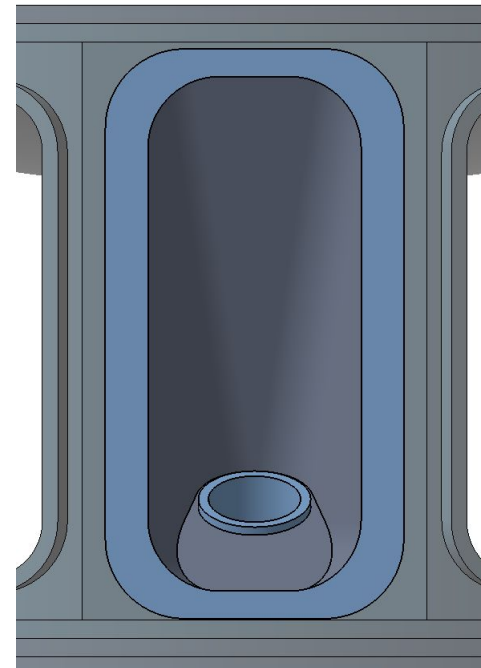
COMPASS-U cryostat is under design process and can be modified later as per design requirements

Main difference in between the upper and bottom 60deg port is in the solid section geometry. The bottom one is at the moment restricted by the 0.5 meter wide cutout in the floor. For that reason, the bottom flange is 400mm wide, whereas the upper one is using the full width (700mm) of the cryostat opening.

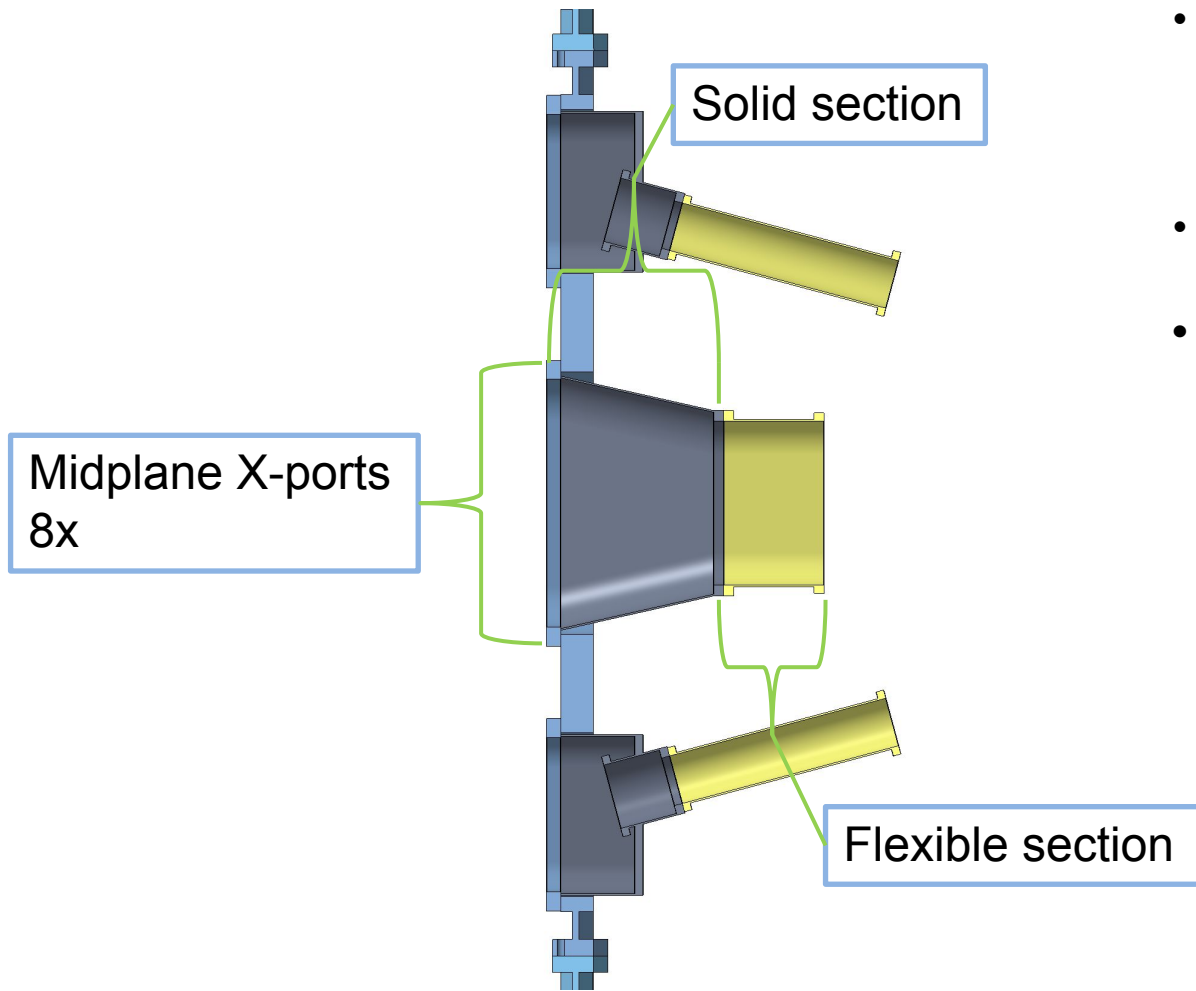
bottom



top

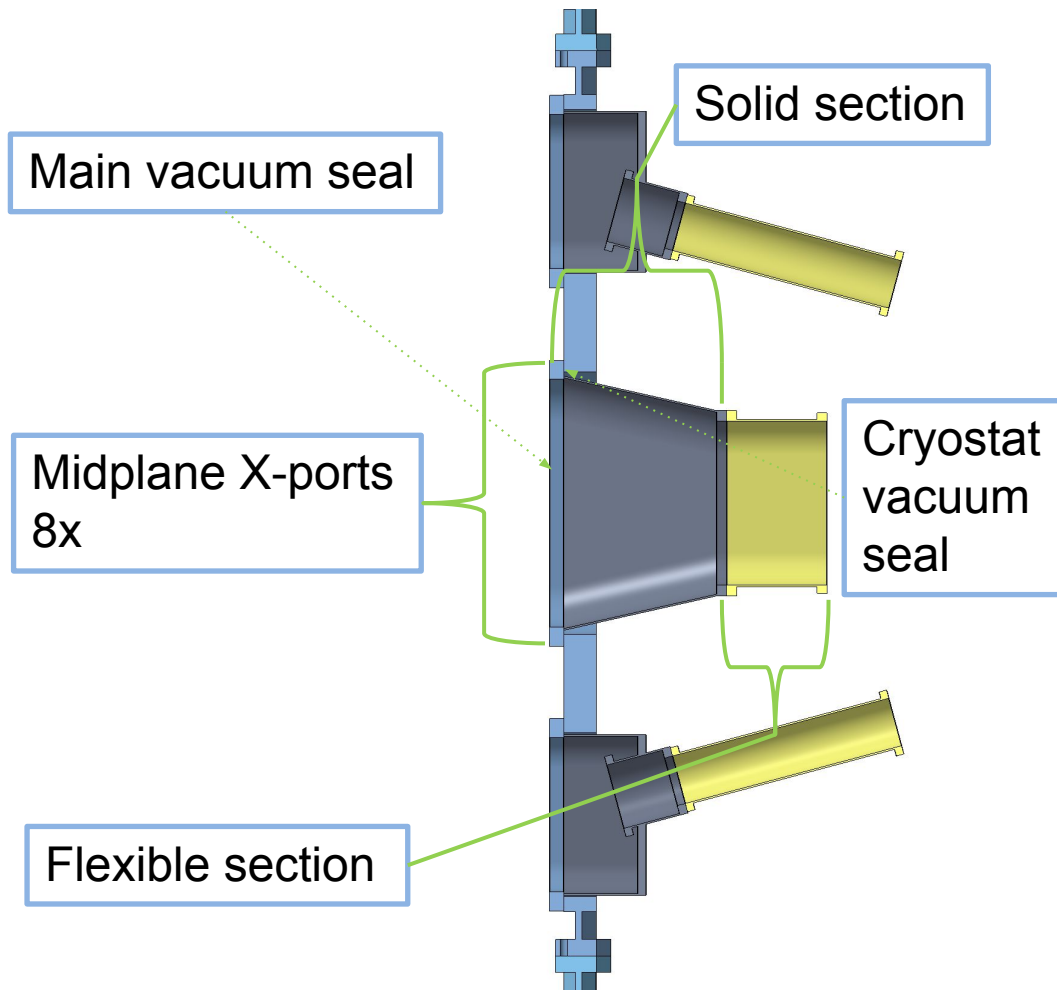


COMPASS-U cryostat is under design process and can be modified later as per design requirements



- Flexible section is supposed to compensate $\pm 20\text{mm}$ vertical movement and $\pm 10\text{mm}$ of horizontal movement
- The flexible section as it is shown is 0.31 m long
- **Baking temperature of solid and flexible section is 150°C** , flexible part will be next to the **vacuum vessel** which baking temperature is **500°C**

COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

- 350mm x 500mm metal sealed flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.31 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer edge, 350mm x 500mm), metal sealed, operational in the range -200°C to ?°C (not higher than 500°C)
- 850mm x 800mm metal sealed flange for closing the main vacuum
- 850mm x 800mm rectangular elastomer seal flange closing the cryostat vacuum

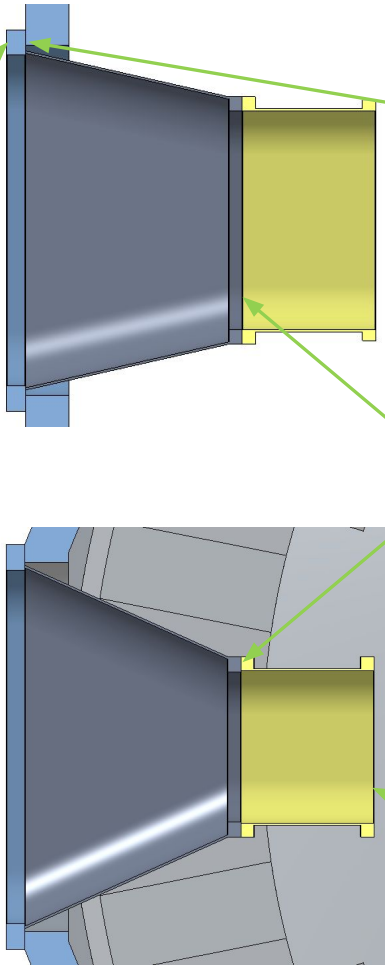
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Metal sealed rectangular flange 850mm x 800mm, UHV/atmosphere

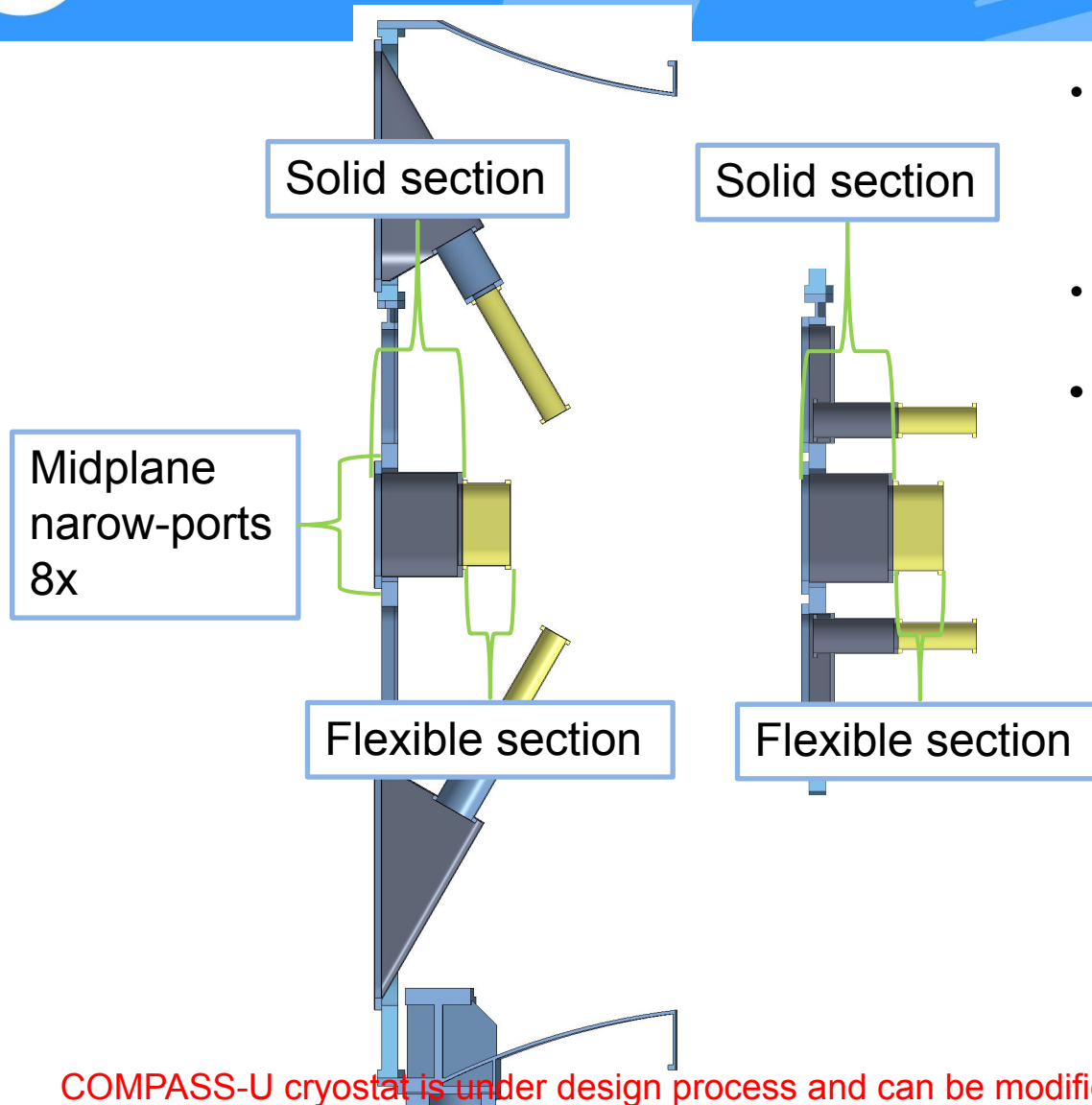
Solid section to cryostat 850mm x 800mm, elastomer seal, HV/atmosphere

Flexible connection to solid section metal sealed rectangular flange 350mm x 500mm, inverted, UHV/HV

Vacuum vessel to flexible connection metal sealed rectangular flange 350mm x 500mm, UHV/HV

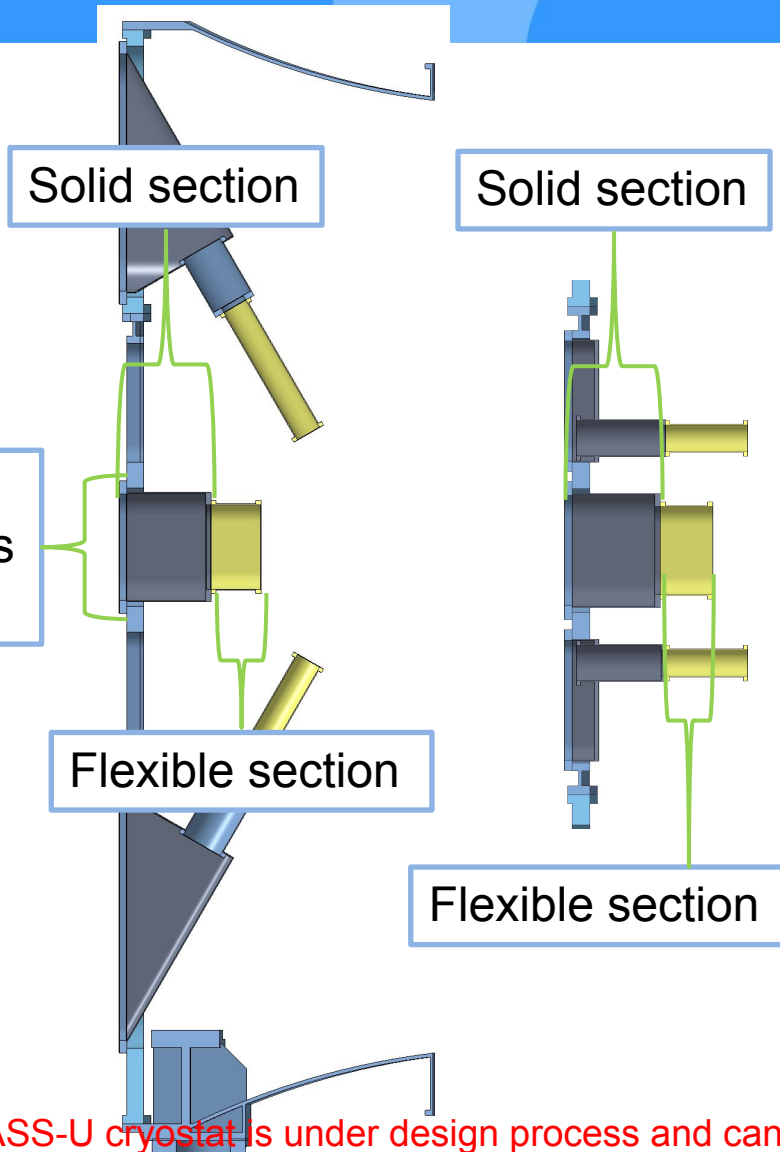


COMPASS-U cryostat is under design process and can be modified later as per design requirements



- Flexible section is supposed to compensate $\pm 20\text{mm}$ vertical movement and $\pm 10\text{mm}$ of horizontal movement
- The flexible section as it is shown is 0.31 m long
- **Baking temperature of solid and flexible section is 150°C , flexible part will be next to the vacuum vessel which baking temperature is 500°C**

COMPASS-U cryostat is under design process and can be modified later as per design requirements



The port configuration is as follows:

- 200mm x 500mm metal sealed flange for the connection to the vacuum vessel (not displayed) operational in the range -200°C to 500°C
- 0.31 m flexible link to deal with the movement of the vacuum vessel with respect to the cryostat
- Inverted flange (bolts from the inside, sealing on the outer edge, 200mm x 500mm), metal sealed, operational in the range -200°C to ?°C (not higher than 500°C)
- 370mm x 625mm metal sealed flange for closing the main vacuum
- 450mm x 700mm rectangular elastomer seal flange closing the cryostat vacuum

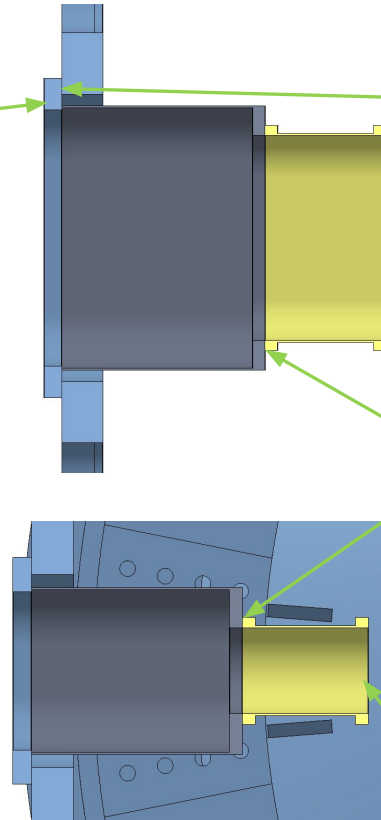
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Metal sealed rectangular flange 370mm x 625mm, UHV/atmosphere

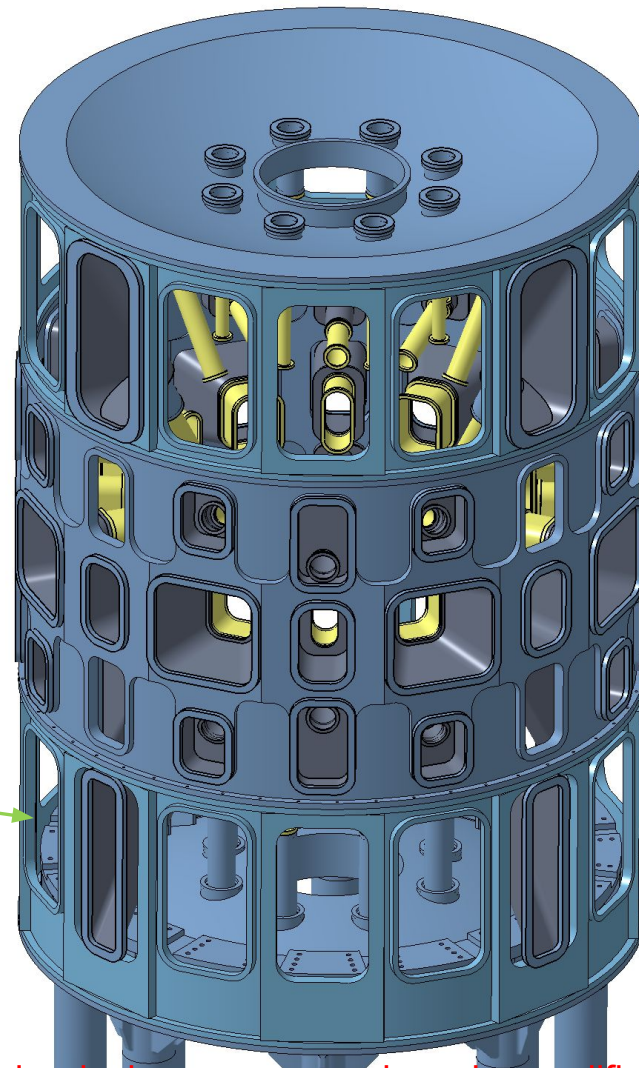
Solid section to cryostat 450mm x 700mm, elastomer seal, HV/atmosphere

Flexible connection to solid section metal sealed rectangular flange 200mm x 500mm, inverted, UHV/HV

Vacuum vessel to flexible connection metal sealed rectangular flange 200mm x 500mm, UHV/HV



COMPASS-U cryostat is under design process and can be modified later as per design requirements



Lower rectangular
service ports 12x

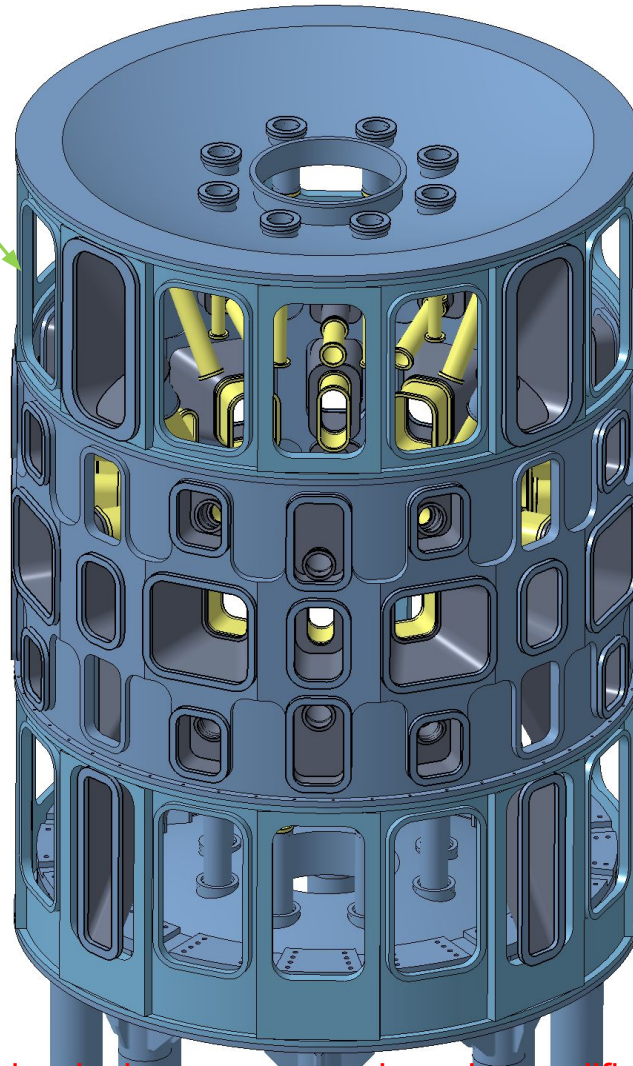
Lower rectangular service ports are designed for:

- Human access
- Power feedthroughs
- Gas (water) feedthroughs

Size and flange extension can be modified

COMPASS-U cryostat is under design process and can be modified later as per design requirements

Upper rectangular
service ports 12x



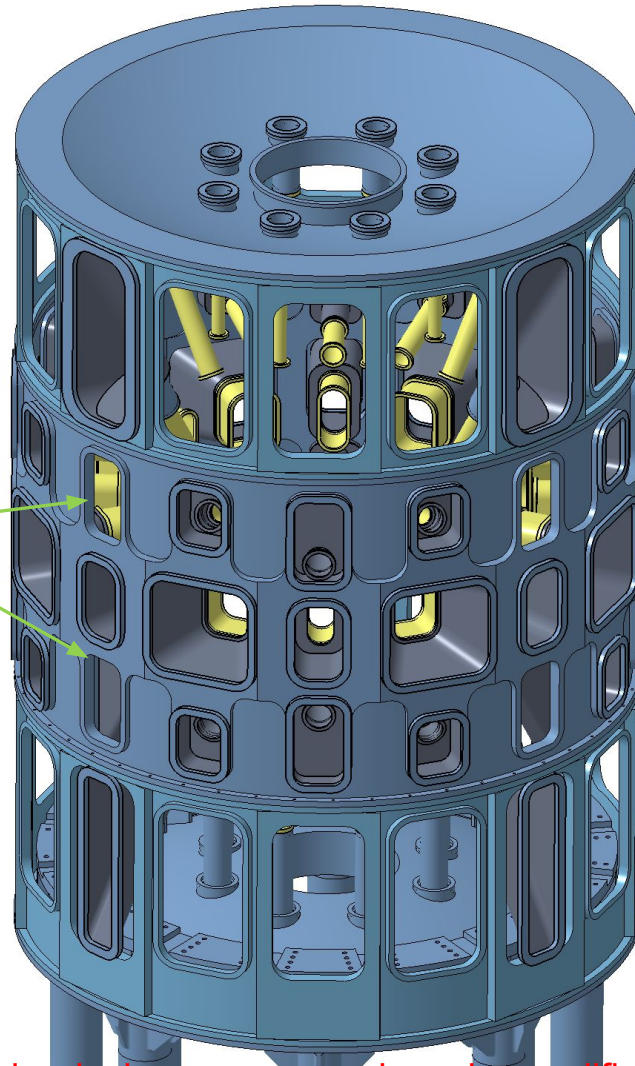
Upper rectangular
service ports are
designed for:

- Human access
- Power feedthroughs
- Gas (water)
feedthroughs

Size and flange
extension can be
modified

COMPASS-U cryostat is under design process and can be modified later as per design requirements

Middle cylinder service ports.
Size
400mmx700mm
8x



Middle cylinder service ports are designed for:

- Power feedthroughs
- Gas (water) feedthroughs

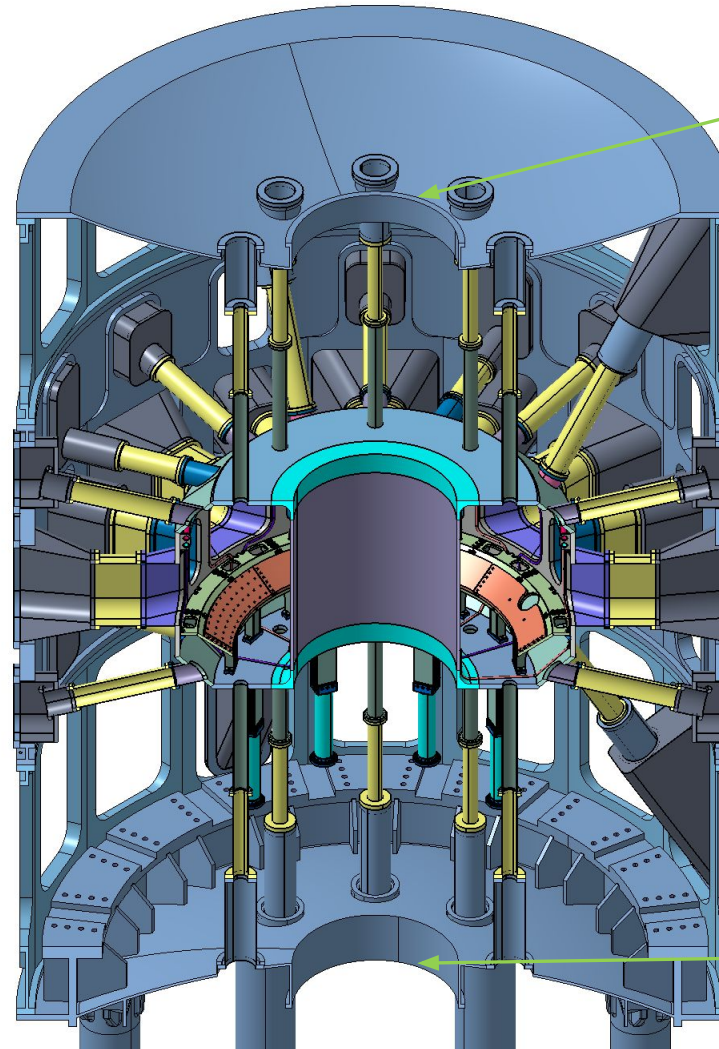
Size and flange extension can be modified

COMPASS-U cryostat is under design process and can be modified later as per design requirements

Bottom and top dome service ports are designed for:

- Power feedthroughs
- Gas (water) feedthroughs

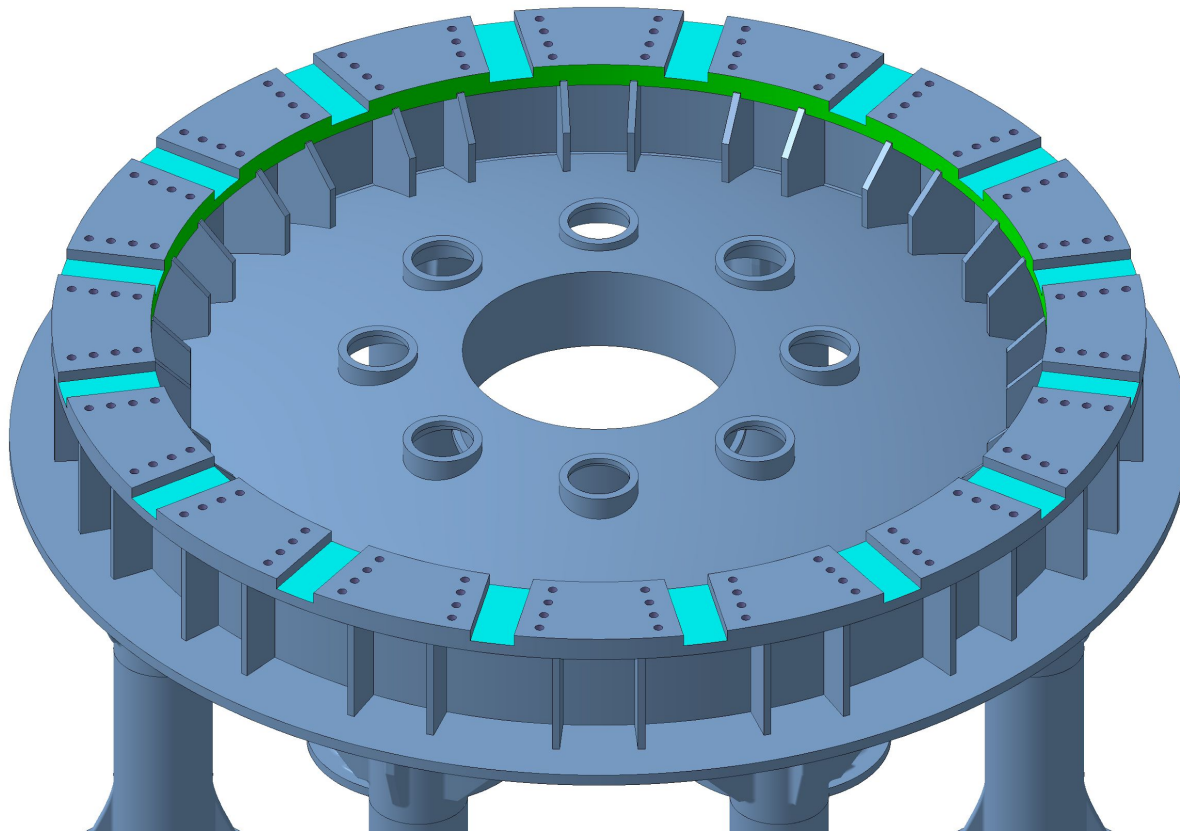
Size and flange extension can be modified. Some form of port extension can appear.



Top dome service port

Bottom dome service port

COMPASS-U cryostat is under design process and can be modified later as per design requirements



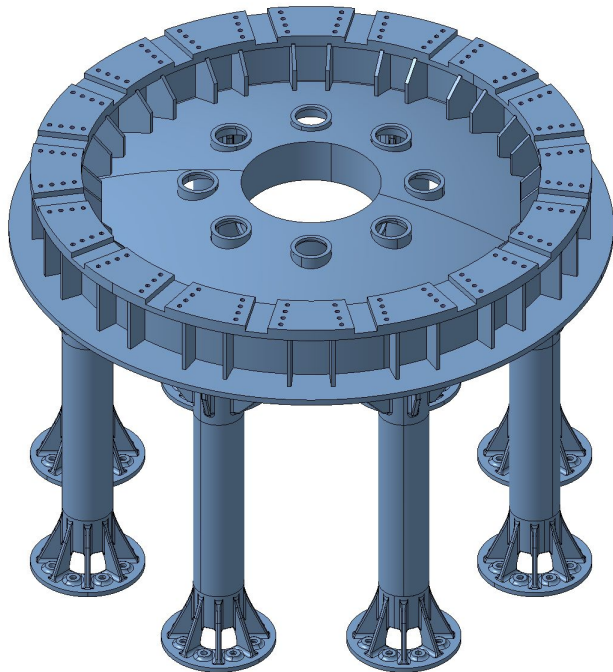
Bottom domed flange of the cryostat will be holding the support structure. Support structure will be centered by the green cylinder, therefore high cylindricity, below 0.1mm, will be required. Blue pads are mounting areas for the support structure legs, therefore high combined flatness, under 0.1mm, will be required.

COMPASS-U cryostat is under design process and can be modified later as per design requirements

- Cryostat will be, as designed at the moment, standing on 8 pillars attached to the bottom flat plate
- cryostat as it is designed at the moment is not fully checked as pressure vessel and needs to be adjusted
- Electrical insulation of the vacuum vessel from the cryostat might be needed (insulation break possibly being part of flexible sections of port extensions)

- Cryostat public tender is expected in the Q3 of 2021
- Delivery of the cryostat base in the Q3 of 2022
- Delivery of the rest of the cryostat parts later

Cryostat base



More information about preliminary market consultation can be found at:

http://www.ipp.cas.cz/o-ufp/Verejne_zakazky/doc.html

At website tenders electronic daily

Notification Number at Tender electronic daily: 2019/S 113-276587
(Číslo oznámení TED: 2019/S 113-276587)

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Attachments:

CU_CUPG-05-00_V08-D_CAD.Stp

CU_CUPG-05-00_V08-D_CAD_Sheet_1

CU_CUPG-05-00_V08-D_CAD_Sheet_2

CU_CUPG-05-00_V08-D_CAD_Sheet_3

CU_CUPG-05-00_V08-D_CAD_Sheet_4