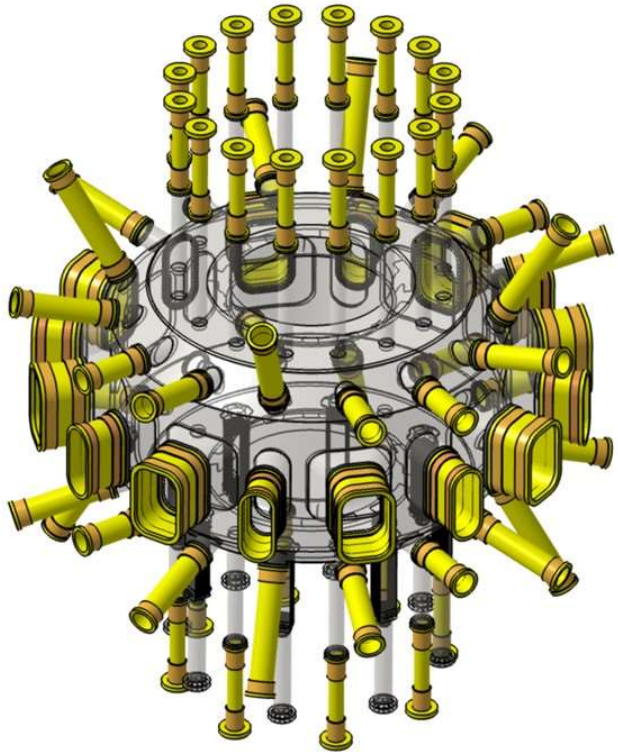
COMPASS-U: Vacuum vessel

Port extensions & bellows

PRELIMINARY MARKET CONSULTATIONS

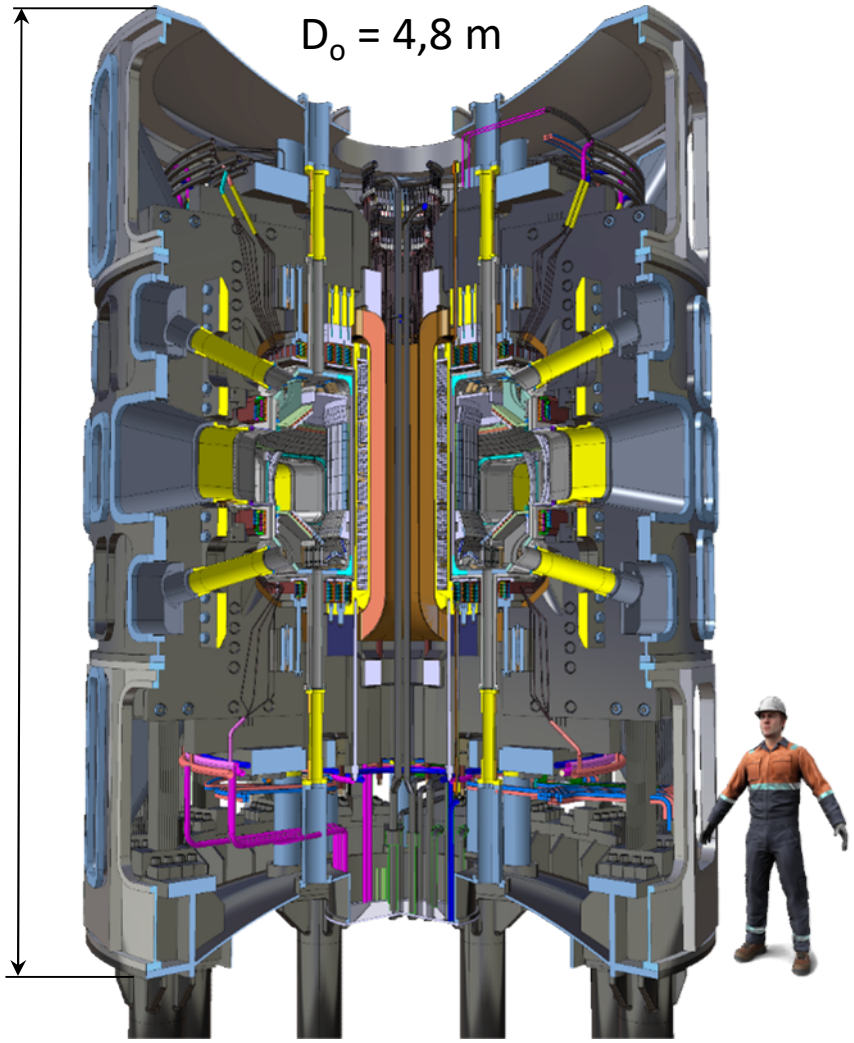


rev. 26.05.2021

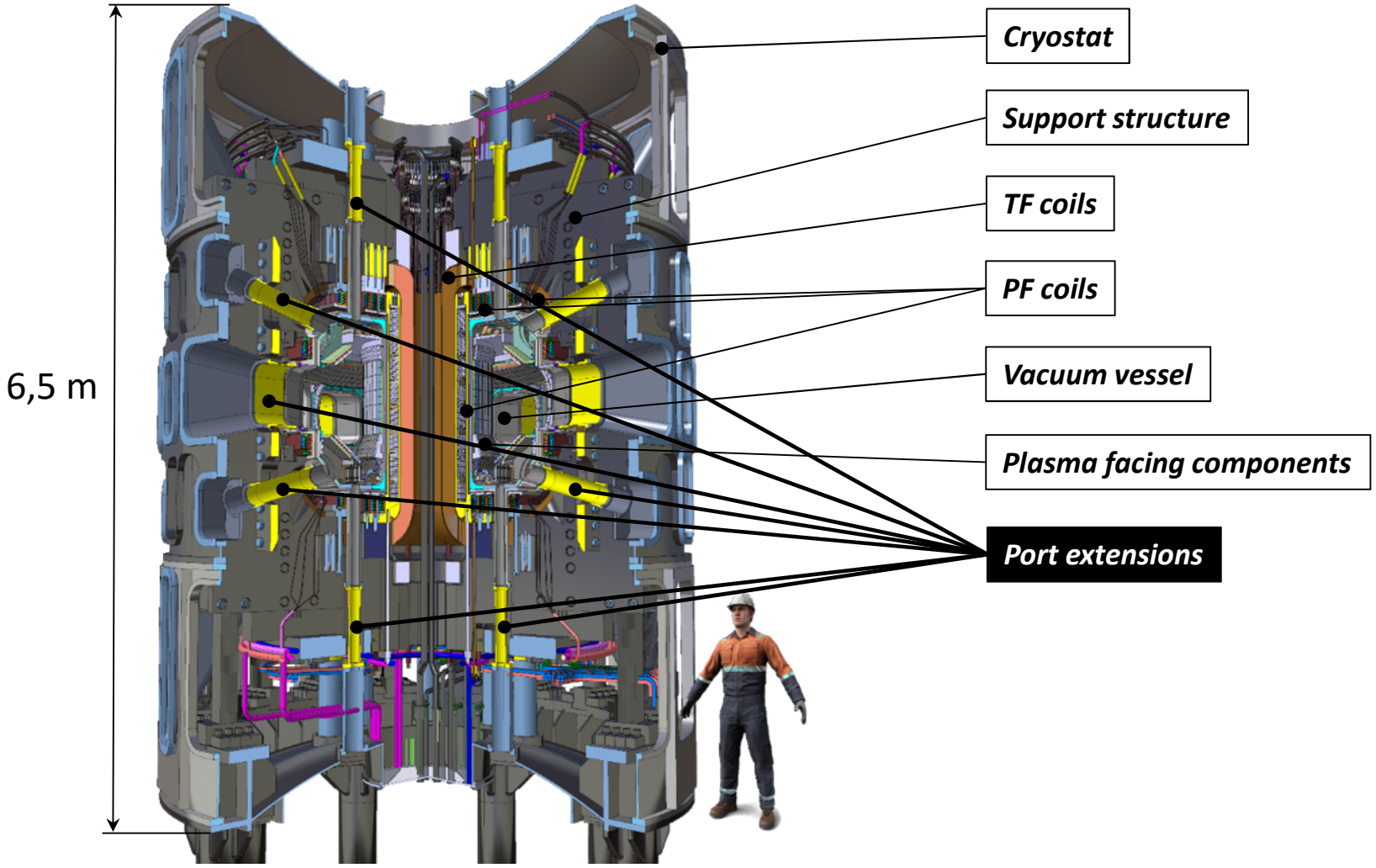
1.1 Brief machine overview – Main tokamak assembly

Main design requirements:

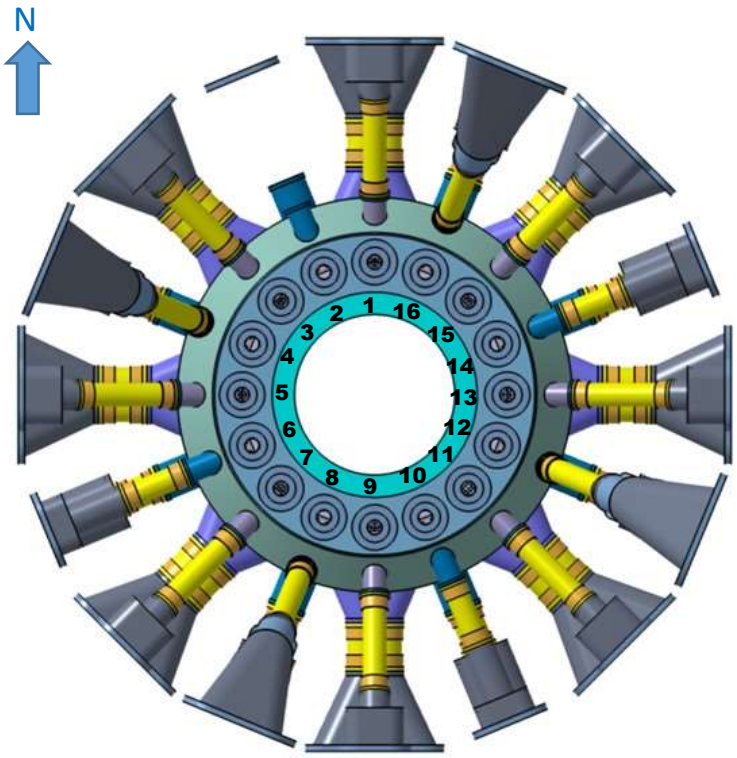
- Toroidal magnetic field B_t = 5 T
- Plasma current I_p = 2 MA
- Major radius R = 0.894
- Minor radius a = 0.27
- Aspect ratio A = 3.3
- Triangularity δ = 0.3-0.6
- Elongation κ = 1.8
- Enough space for different divertors
- Plasma shapes
  - single lower null, neg. triangularity with limited parameters (Phase 1)
  - double null (Phase 2)
  - snowflake, negative triangularity (Phase 3)
- Heating power
  - Phase 1 P_{NBI} >= 3 MW, P_{ECRH} = 1 MW (P*B/R ~ 25)
  - Phase 2 up to P_{NBI} = 8 MW, P_{ECRH} = 10 MW (P*B/R ~ 100)
- Vacuum vessel operation temperature up to 500°C (min. 300°C)



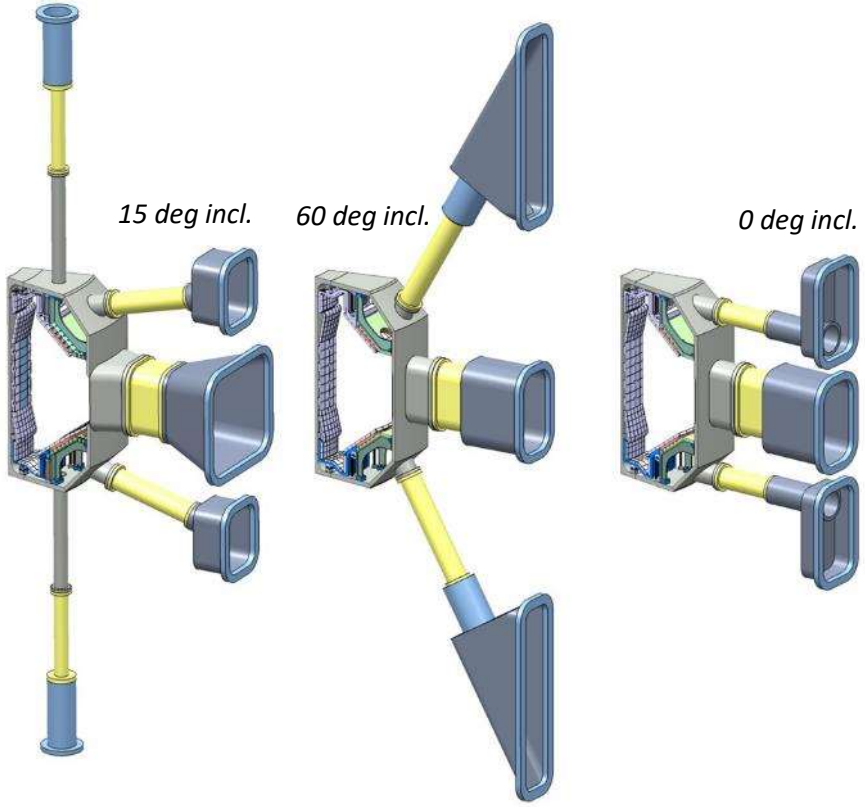
1.1 Brief machine overview – Main tokamak assembly



1.2 Vacuum vessel – Ports layout

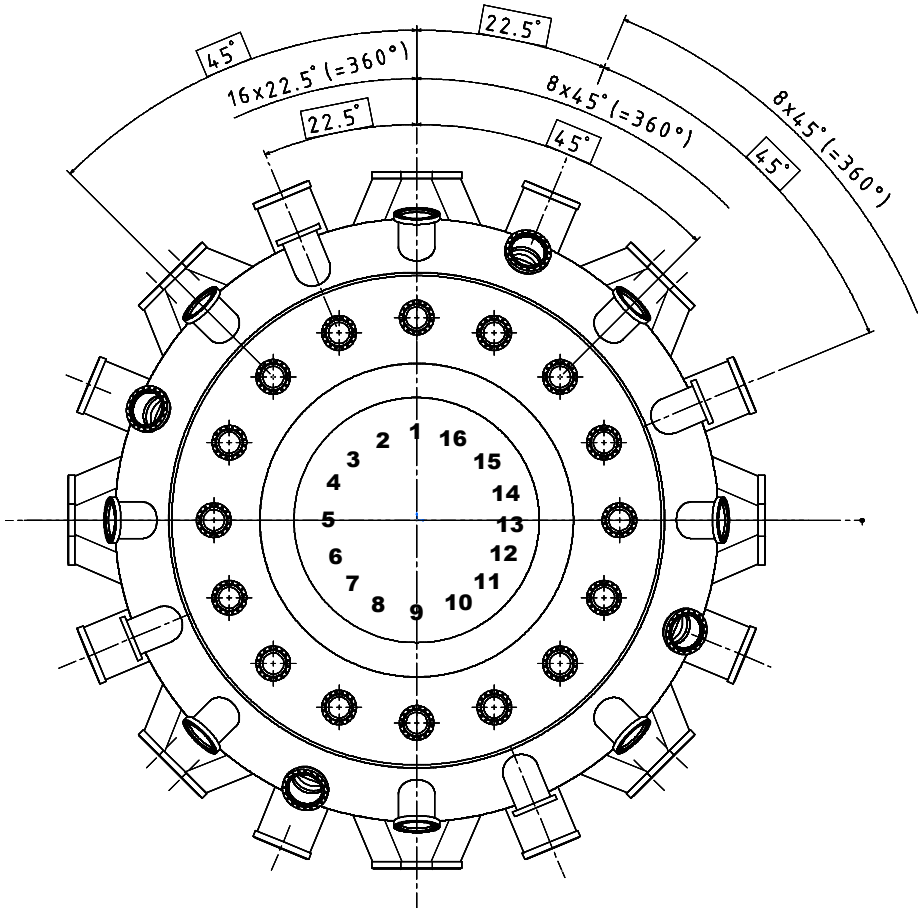


1,3,5,7,9,11,13,15	4,8,12,16	2,6,10,14

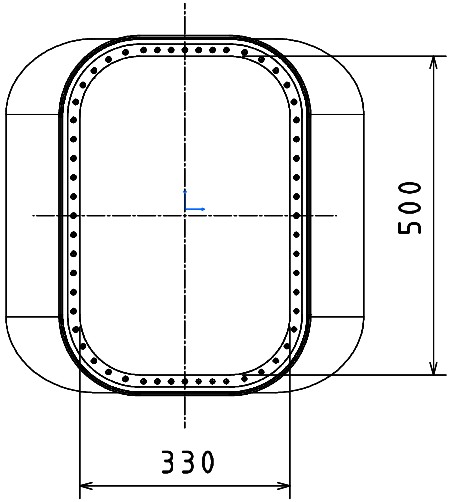


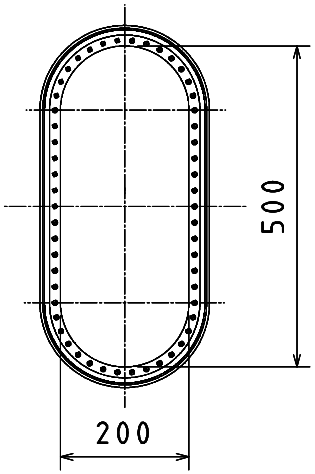
- Ports: 16 Equatorial, 16 Upper-Outboard, 16 Lower-Outboard, 16 Vertical-Upper, 8 Vertical-Lower (in total 72 ports)
- Ports in sector 2 will not be used (blinded) due to the TF and PF coils outlet (in total 3 ports)
- Port extensions will integrate bellows to allow the thermal expansion and movement of the vacuum vessel

1.2 Vacuum vessel – Ports layout

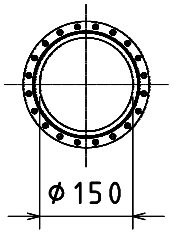


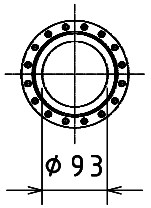
Mid-plane ports dimensions

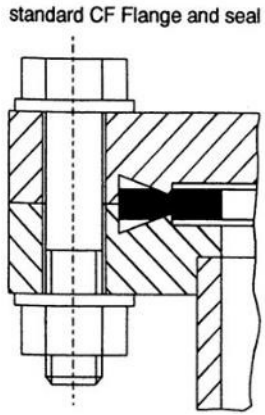




Inclined ports and vertical ports dimensions

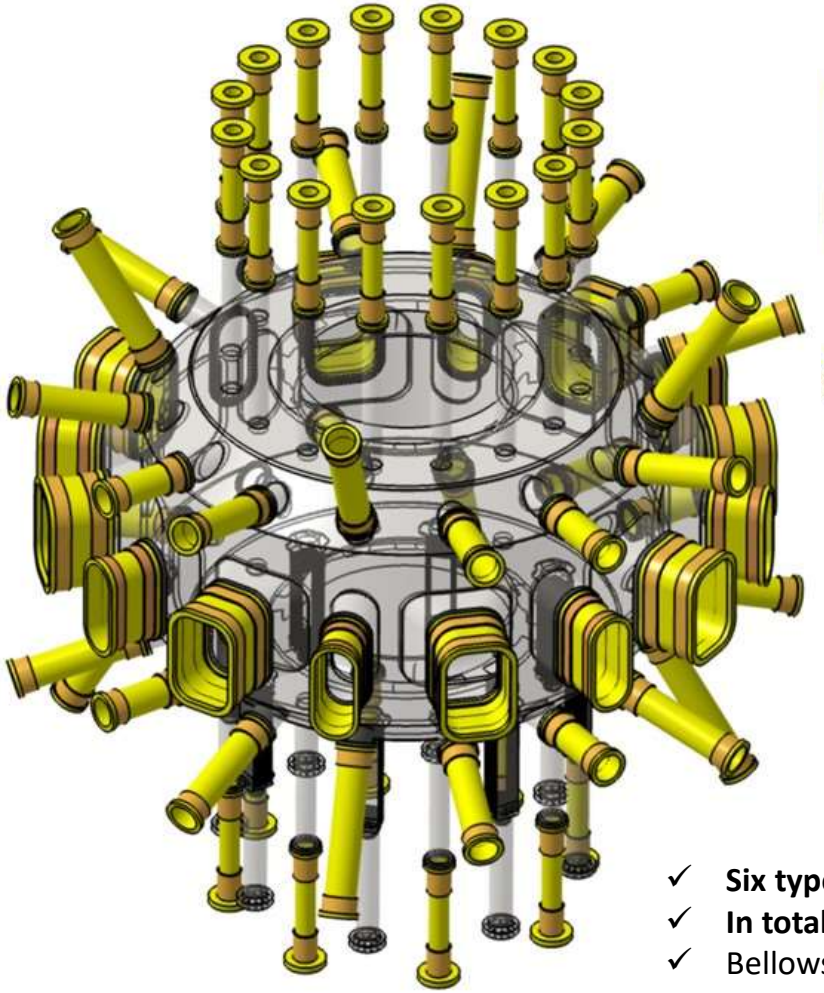






- All port interfaces of the VV will use the **standard CF (ConFlat) sealing concept and will be bolted**.
- The gasket material will be chosen OFHC copper/silver plated or annealed nickel gaskets – depends on **Helium leak tightness** at temperature around 450 °C.

1.3 Vacuum vessel – Port extensions



- ✓ **Six types of extensions** with bellows consisting of fixed and flexible part.
- ✓ **In total 69 port extensions** will be mounted. (3 ports blinded).
- ✓ Bellows have to allow **axial movement up to 15 mm and side shift up to 10 mm.**

- The port extensions are not detail designed and need to be discussed with potential suppliers.

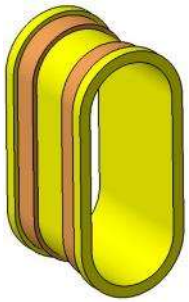
1.4 Vacuum vessel – Port extensions & bellows manufacturing

- In principal three shape types of bellows used on COMPASS-U vacuum vessel:

Circular bellows

- Common type of bellow without any manufacturing issues because of dimensions, range or material.

Oval bellows (race track)



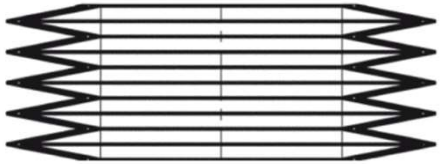
- Less common type of bellow, but still manufacturing should not pose any difficulties because of dimensions, range or material.

Rectangular bellows

- Uncommon type of bellow posing a potential manufacturing and requirement issues according to first market consultations.

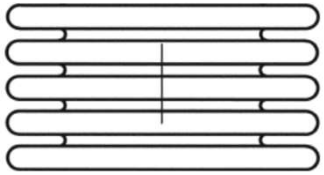
- **Two types of bellows regarding the manufacturing technology:**

Edge welded bellows



- Sheet segments welded together allowing larger lateral, axial and angular motions, lower spring rate.

Flexible hose / shaped bellows



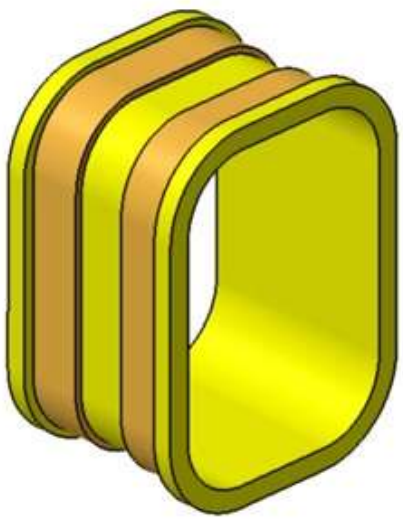
- Easier to manufacture by partial welding and hydro-forming, but not suitable for bigger motions.

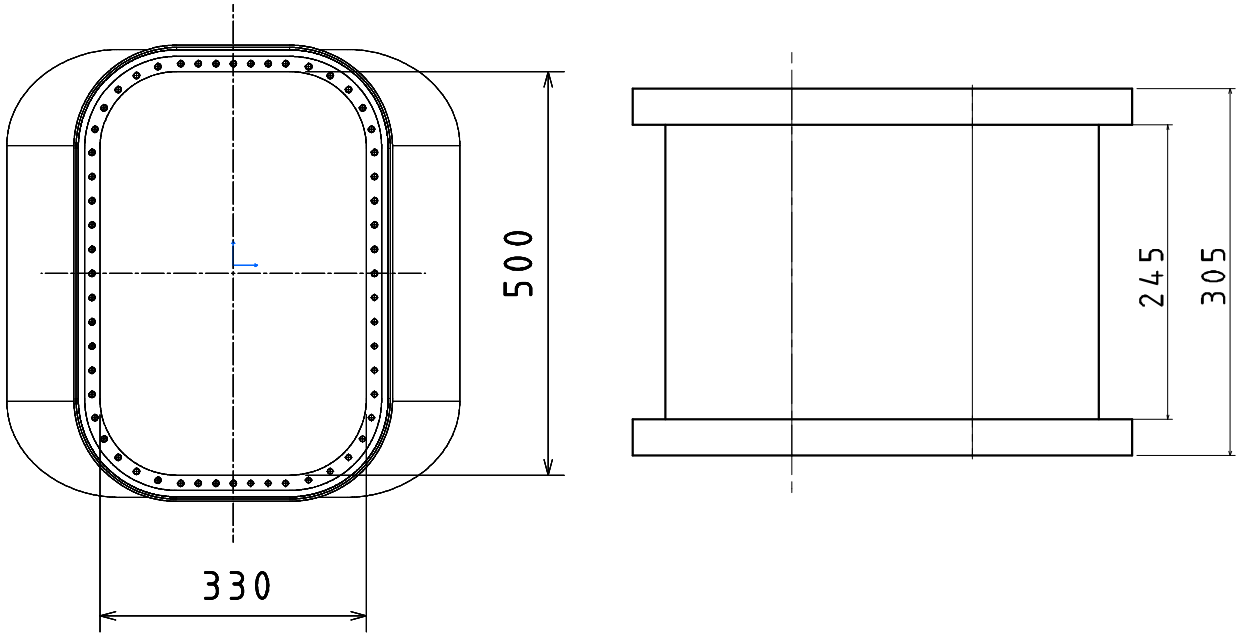
1.4 Vacuum vessel – Port extensions & bellows manufacturing

- For the purposes of COMPASS-U edge welded bellows are preferred, but not necessarily enforced.
- <u>Known issues as per first preliminary market consultations:</u>
  - Rectangular shape of the bellow could be difficult to manufacture and not ideal to compensate foreseen motions
  - Welding seams on the bellow made of Inconel 625 may not fulfill the Helium tightness requirement according to one supplier – achievable tightness only up to 10^{-5} mbar . l/s! (requirement 10^{-8} mbar . l/s)
  - Solution for the vacuum tightness could be to use the steel AISI 316LN, but it could bring problems at elevated temperatures around 450° C

1.5 Mid-plane port extensions – Preliminary dimensions

MX port

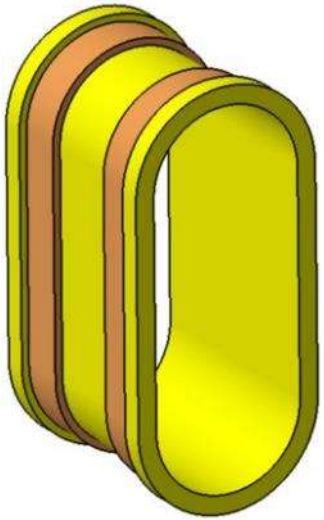


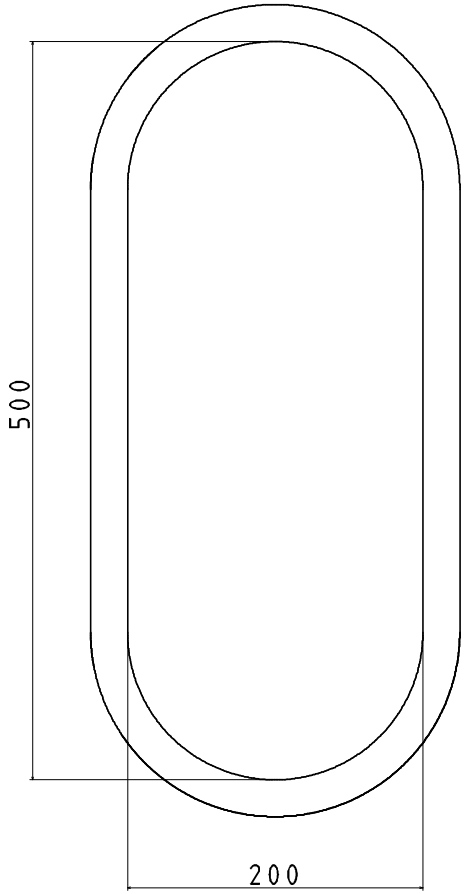


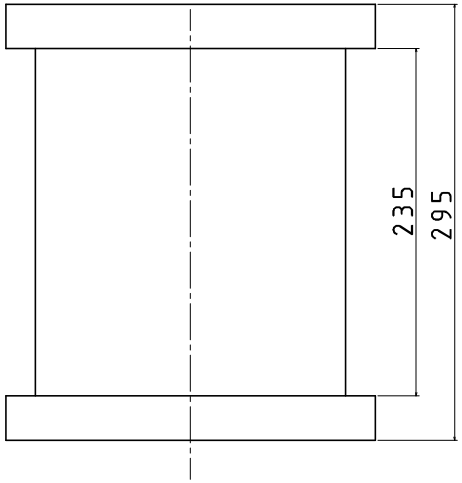
In total 8 pieces.

1.5 Mid-plane port extensions – Preliminary dimensions

MN port



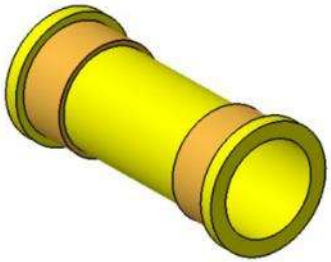




In total 7 pieces.

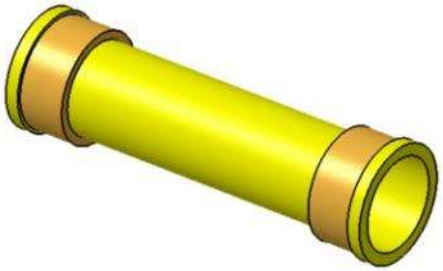
1.5 Circular port extensions – Preliminary dimensions

DUH/DLH port



In total 6 pieces.

DUX/DLX port



In total 16 pieces.

DUC/DLC port

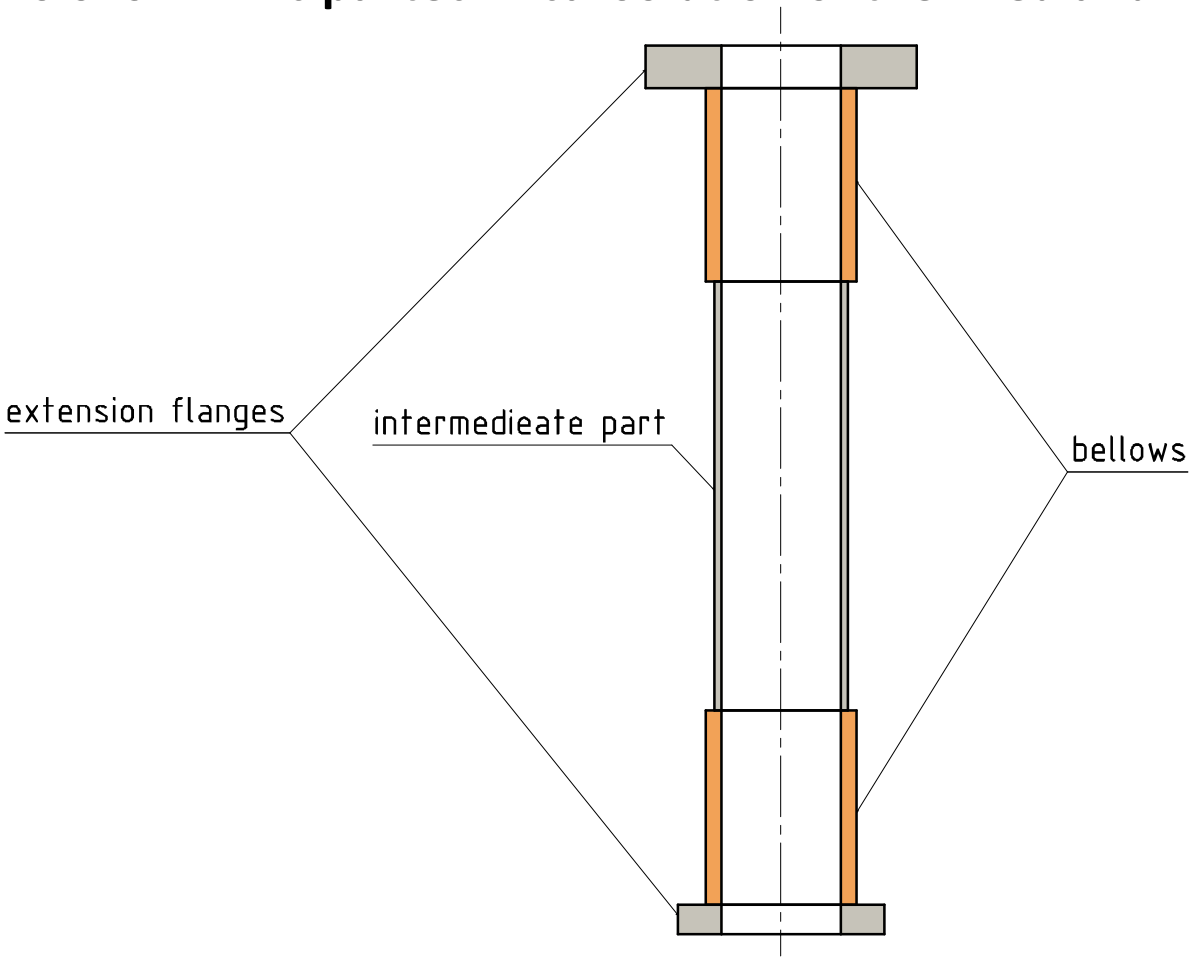
In total 8 pieces.

Vertical port U/L

In total 32 pieces.

Port designation	Dimensions (Di x L) mm
DUH/DLH	∅150 x 414
DUX/DLX	∅150 x 634
DUC/DLC	∅150 x 821
VU/VL	∅93 x 633

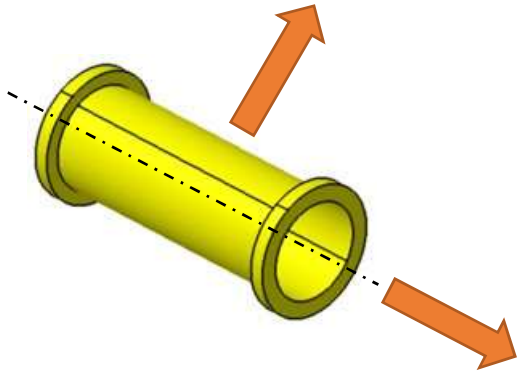
1.6 Port extensions – Principal technical solution of the fixed and flexible part



It is foreseen to divide the extension to three main parts – solid intermediate part and two flexible bellows allowing axial expansion / compression and side shift due to the thermal expansion or disruption movements.

1.7 Port extensions – expected deflection/shift of the individual port extensions

Port designation	Deviation	
	Axial elongation / compression (mm)	Side shift (mm)
MX	±12	±10
MN	±12	±10
DUH/DLH	±12	±10
DUX/DLX	±15	±10
DUC/DLC	±15	±10
VU/VL	±15	±10



Preliminary values of elongation / compression and side shift according to the simulated operating scenarios.
The space around port extensions is limited with adjacent components and systems.