

# Support structure of the COMPASS-U tokamak

David Šesták, and the COMPASS-U team

This document is intended for the companies who shown interest in the Preliminary Market Consultation for COMPASS-U Support structure 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:**

$R = 0.894 \text{ m}$

$a = 0.27 \text{ m}$

$B_t = 5 \text{ T}$

$I_p = 2 \text{ MA}$

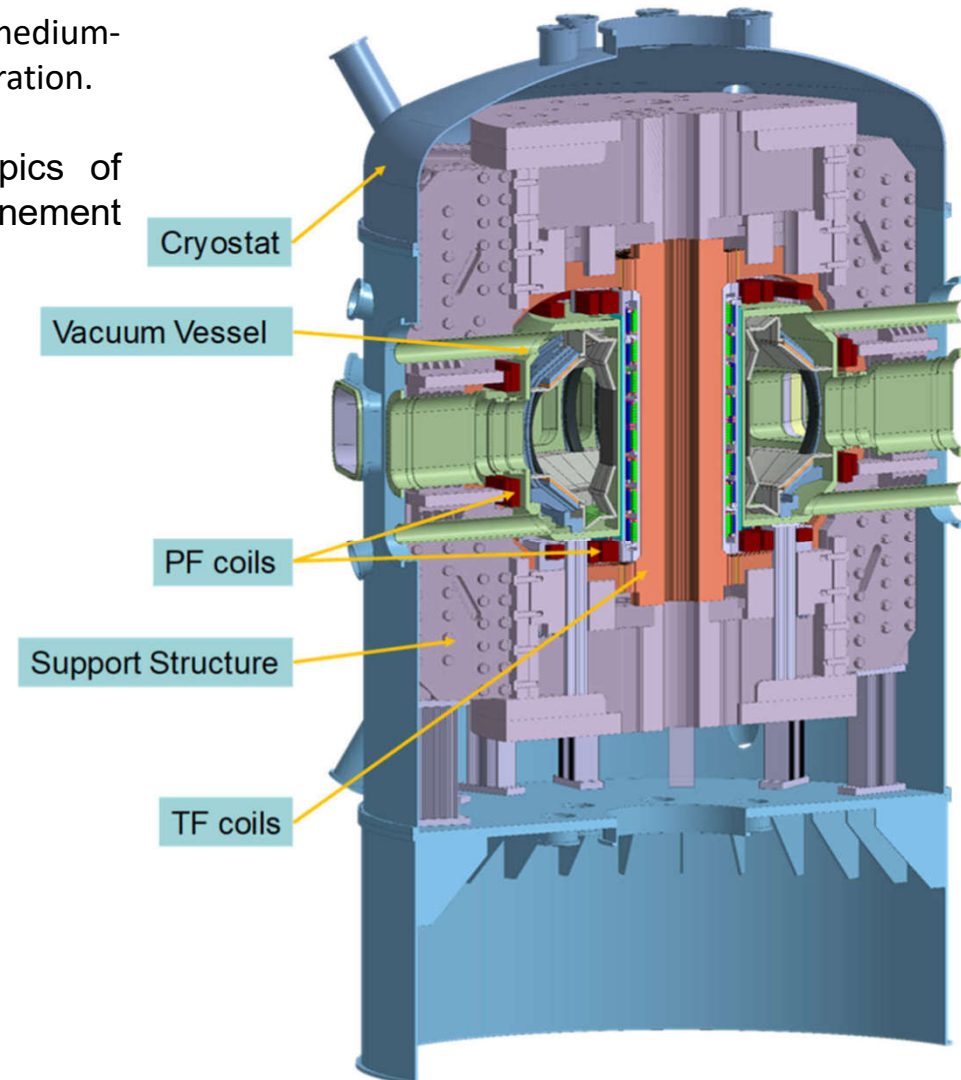
$t_{\text{flat-top}} \sim 2 \text{ s}$

$\delta = 0.5$

$\kappa = 1.8$

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

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



High capability to address the key Plasma Exhaust Physics challenges

### Design requirements

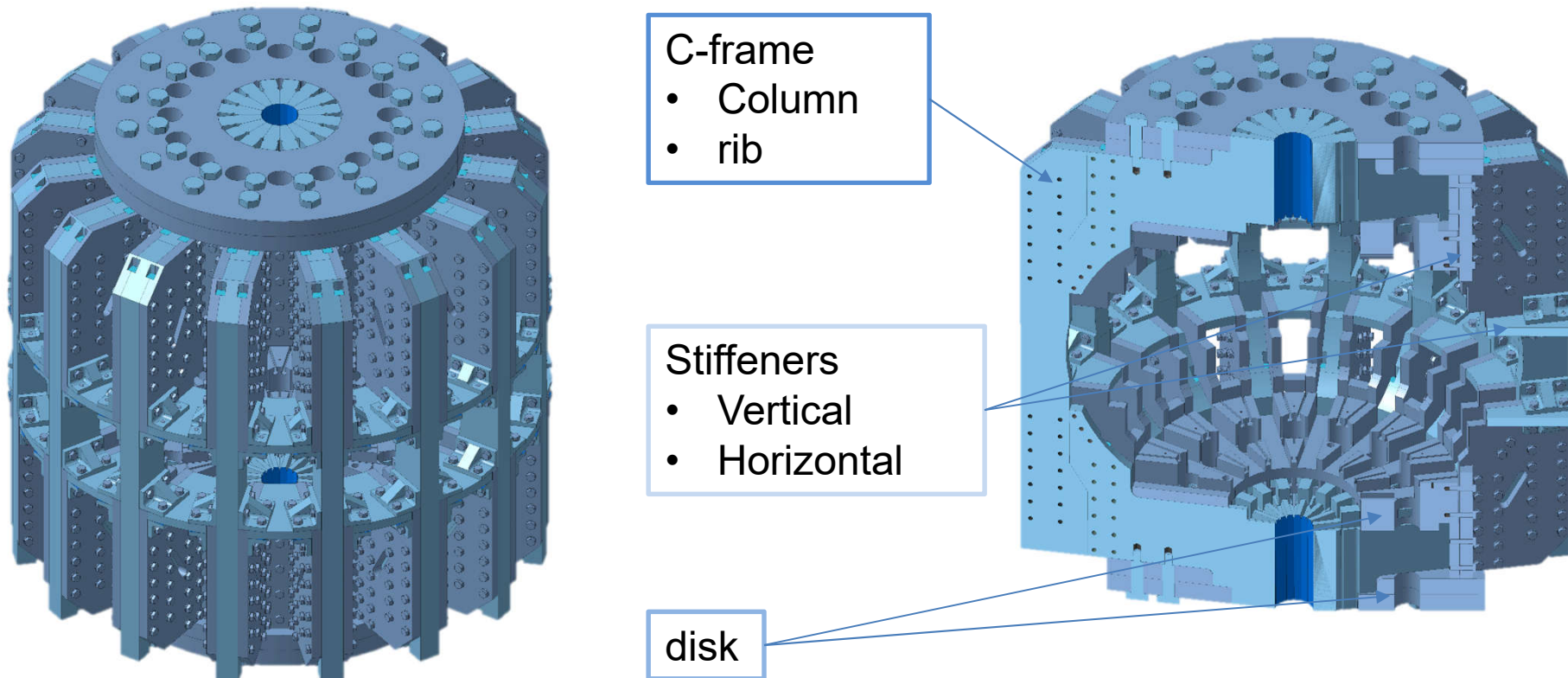
- Provide support for magnets of toroidal and poloidal field at liquid nitrogen temperature
- Provide support for vacuum vessel at 500°C?
- Provide support for multilayer insulation?

### Design constraints

- Provide a reliable structural support for life-time of the tokamak
  - It shall withstand all possible load combinations from electromagnetic and seismic loads .
- The material of the support structure should be
  - compatible with liquid nitrogen temperatures
  - have reasonably low activation
  - vacuum friendly
  - With low magnetic permeability
- Allow easy assembly
- Ideally have the same coefficient of thermal expansion (contraction) as copper coils
- Price
- Manufacturability

Property*	Unit	Inconel 625	C10 200	AISI 304	AISI 316	Nitronic 50
Density	(kg/m <sup>3</sup> )	8440	8900	7900	7960	7880
Poisson's ratio		0.28	0.31	0.3	0.3	0.312
Melting Temp.	°C	1290	1080	1400	1375	1415
Electrical Resistivity	$\Omega m$	1.3E-06		7.2E-07	7.7E-07	8.2E-07
Specific heat	J/kg K	410	390	483	494	
Magnetic permeability	m	1.0006		1.012		1.0021
<b>Mechanical properties at room temperature (21 °C)</b>						
Youngs modulus	(GPa)	207	120	195	195	199
Yield Strength	(MPa)	454	320	172	173	414
Tensile Strength	(MPa)	910	330	483	483	827
Coefficient of thermal expansion	( $\mu m/m/k$ )	12.8	16.7	15.3	15.3	16.2
Thermal conductivity	(W/m * K)	9.8	390	14.87	14.18	15.6
<b>Mechanical properties at -200 °C</b>						
Youngs modulus	(GPa)	207	135	213	208	
Yield Strength	(MPa)	708	370	494	505	883
Tensile Strength	(MPa)	1380?	400	1595	1276	1558
Coefficient of thermal expansion	( $\mu m/m/k$ )	9?	10.6	13.4	13.4?	
Thermal conductivity	(W/m * K)	7.4				

The COMPASS-U support structure is in general assemble from 16 C-frames, 6 disks, 32 vertical and 32 horizontal stiffeners. Its main function is to hold in place toroidal and poloidal field coils. It can hold the vacuum vessel. The height of support structure is 4.4 meter and width is 4.37 meter.



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

Toroidal field coils

$F_z = 16 \times 3.8\text{MN} = 60.8\text{MN}$   
 $F_{r\text{ out}} = 16 \times 4.55\text{MN}$   
 $F_{r\text{ in}} = 16 \times 14.4\text{MN}$  - self supporting  
 $F_{\text{toroidal}} = 16 \times 1.5\text{MN} + 0.5\text{MN}$

Poloidal field coils

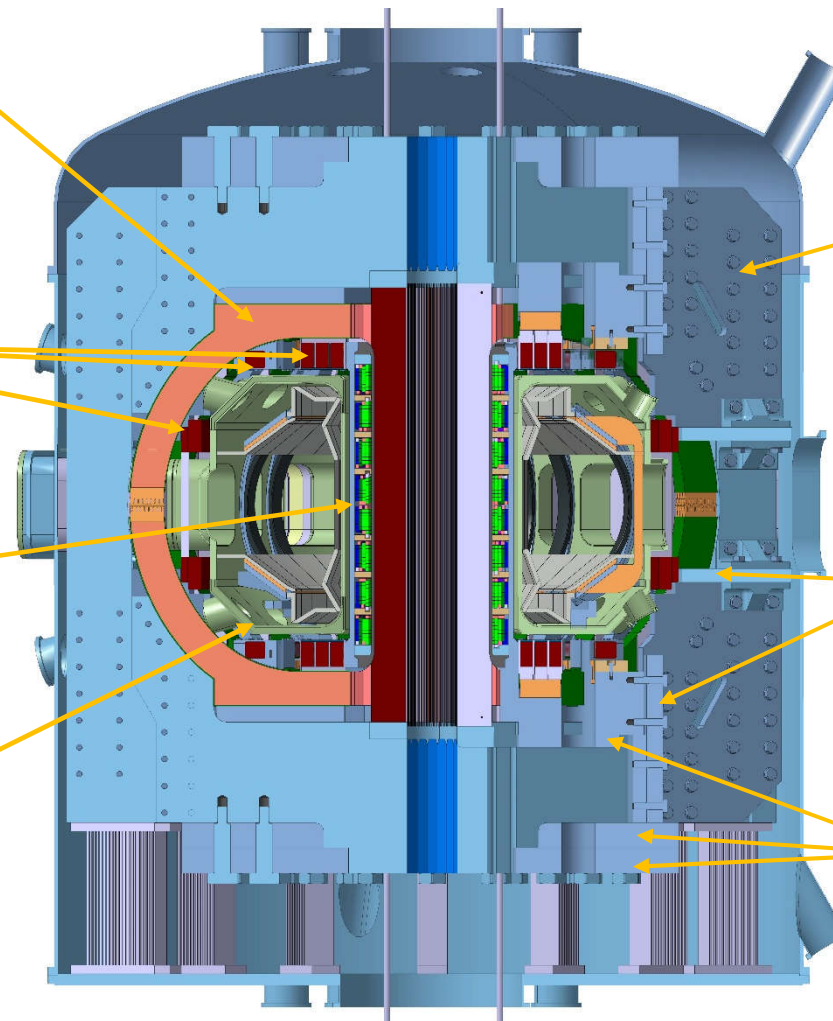
PF1 -  $F_z = 2.1\text{MN}$   
 PF2 -  $F_z = 0.88\text{MN}$   
 PF3 -  $F_z = 1.33\text{MN}$   
 PF4 -  $F_z = 1.53\text{MN}$

Central solenoid coils

$F_z = 5.5\text{MN}$   
 Precompression force  
 6MN

Vacuum vessel

$F_z = 11\text{MN}$   
 Its fixation point to  
 the support structure  
 is not yet decided



C-frame

- Column
- rib

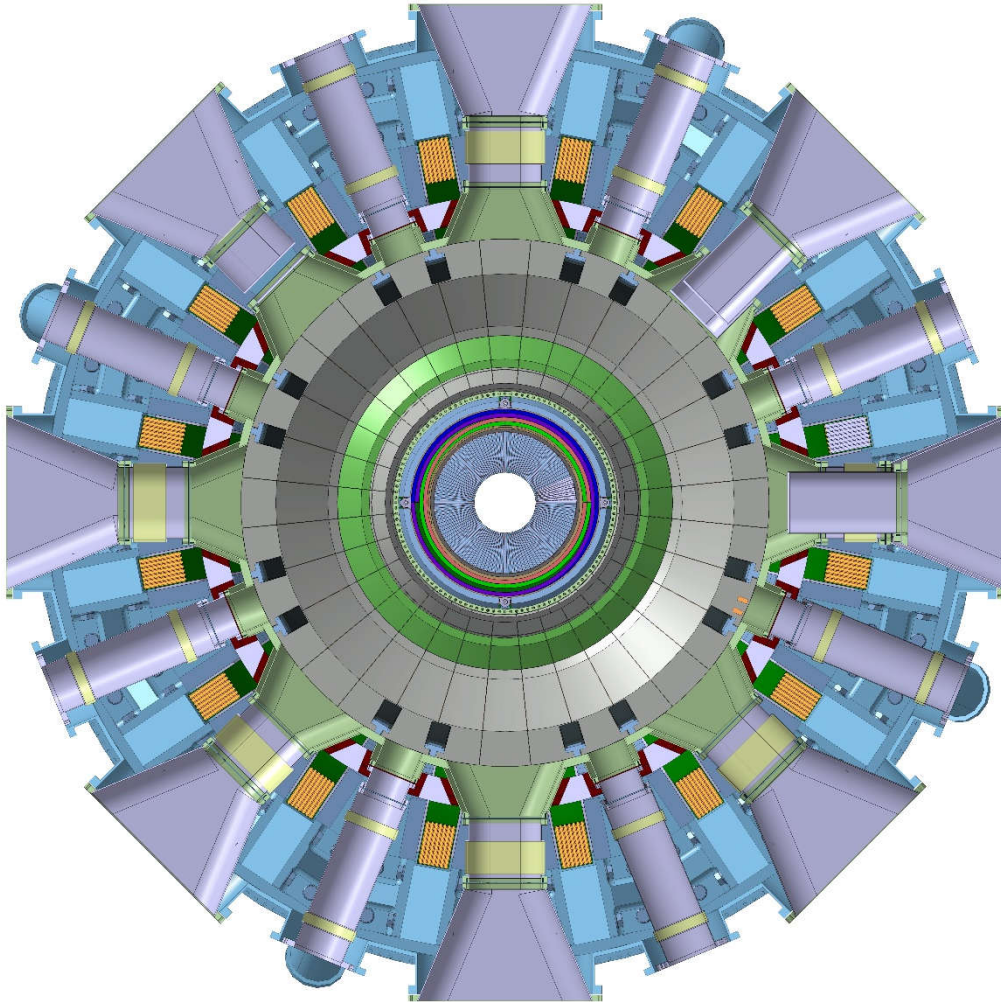
Stiffeners

- Vertical
- Horizontal

disk

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

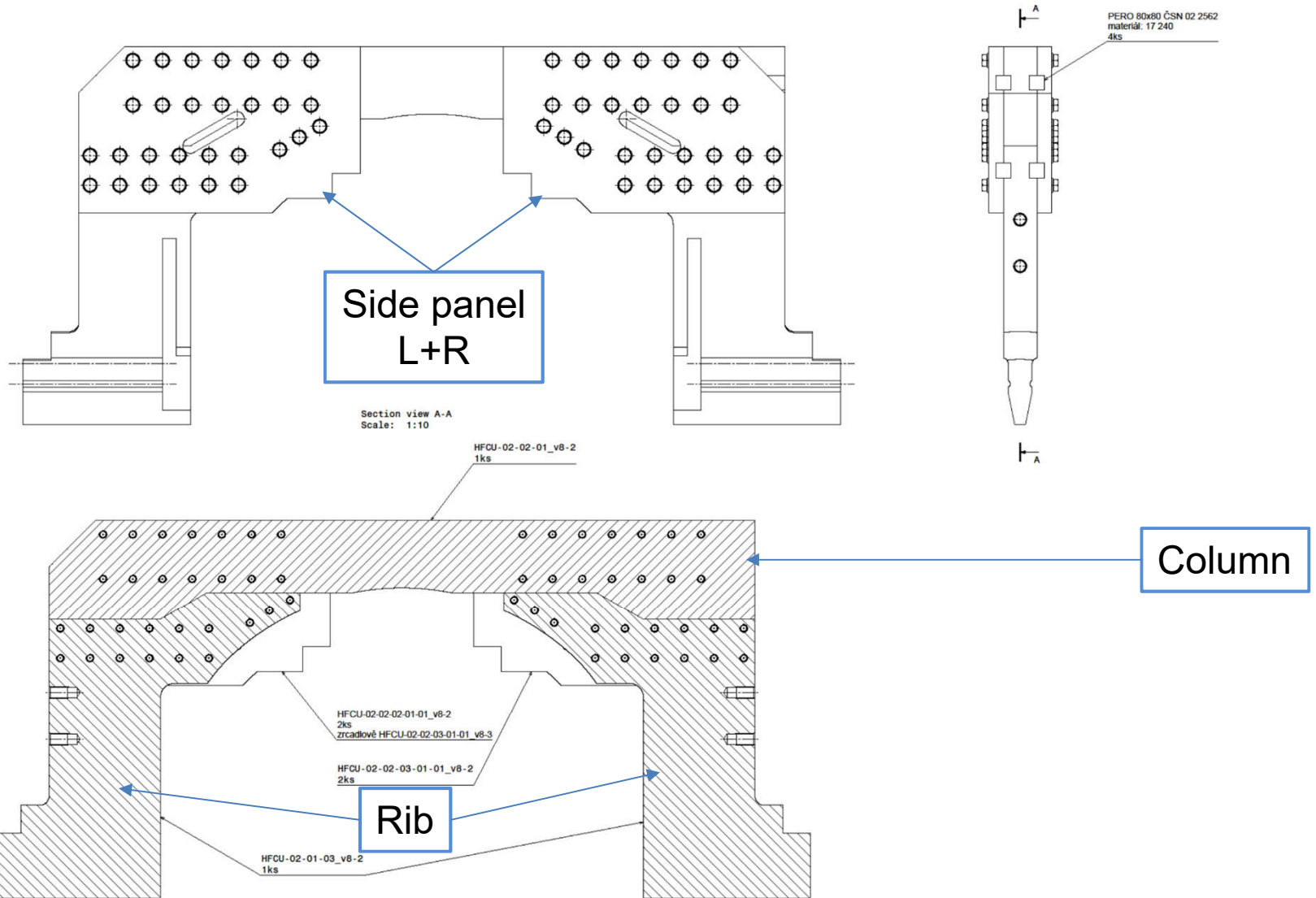




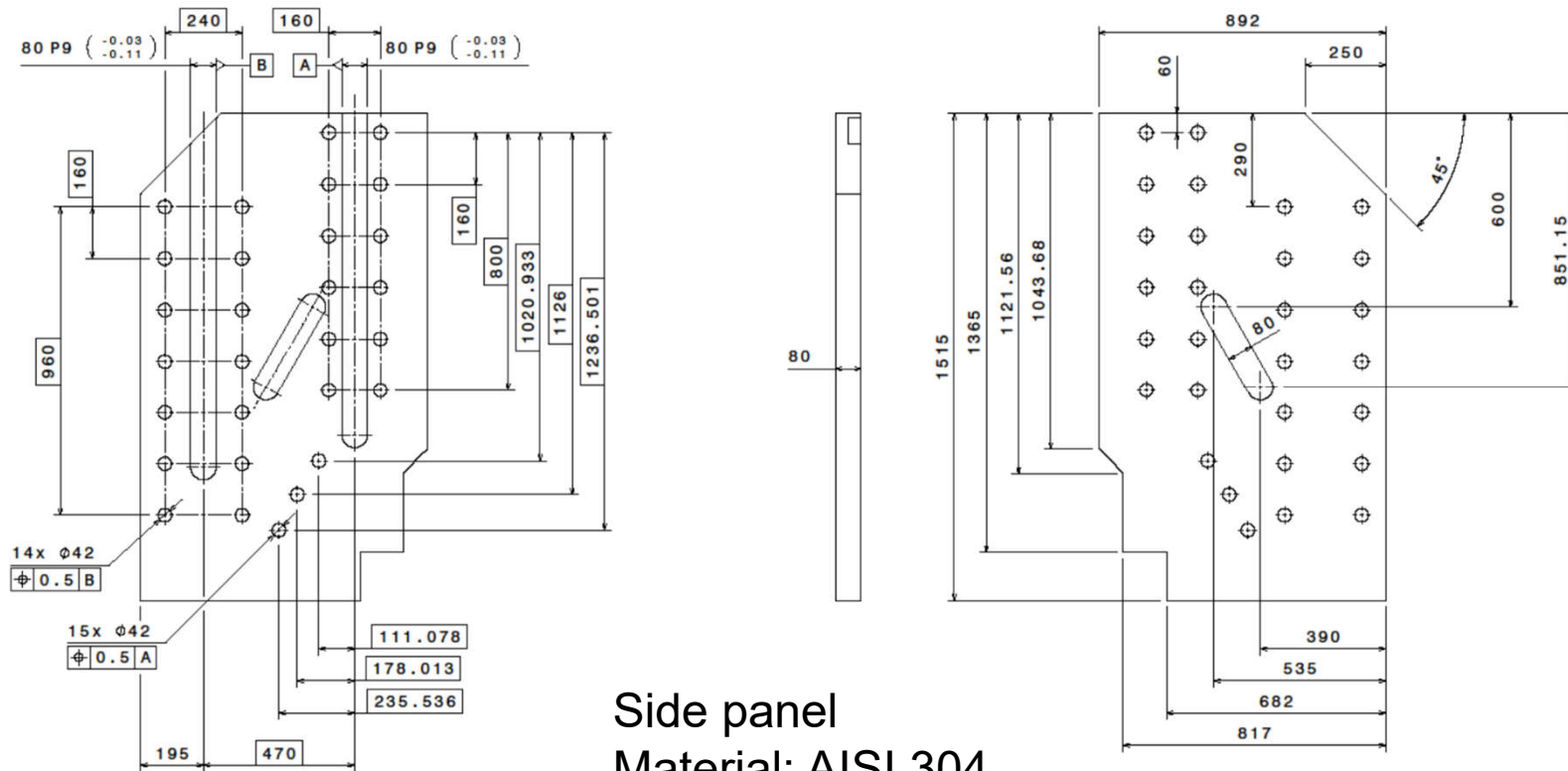
The COMPASS-U support structure should allow reasonable distribution of vacuum vessel ports to allow:

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

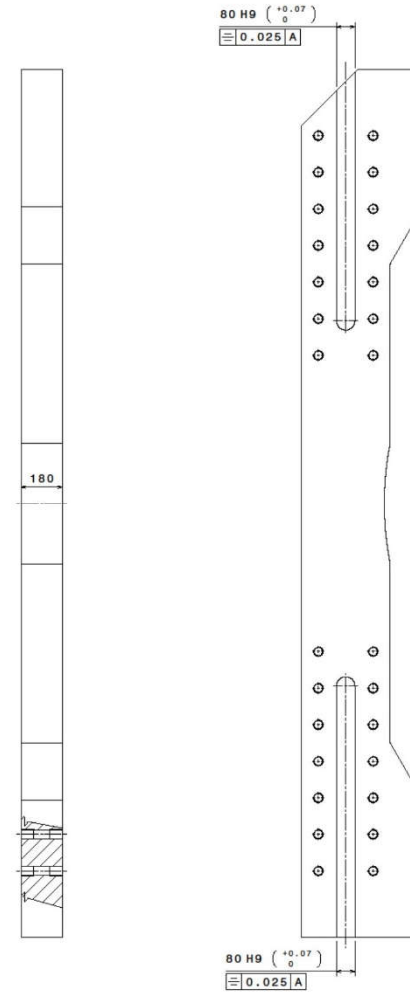
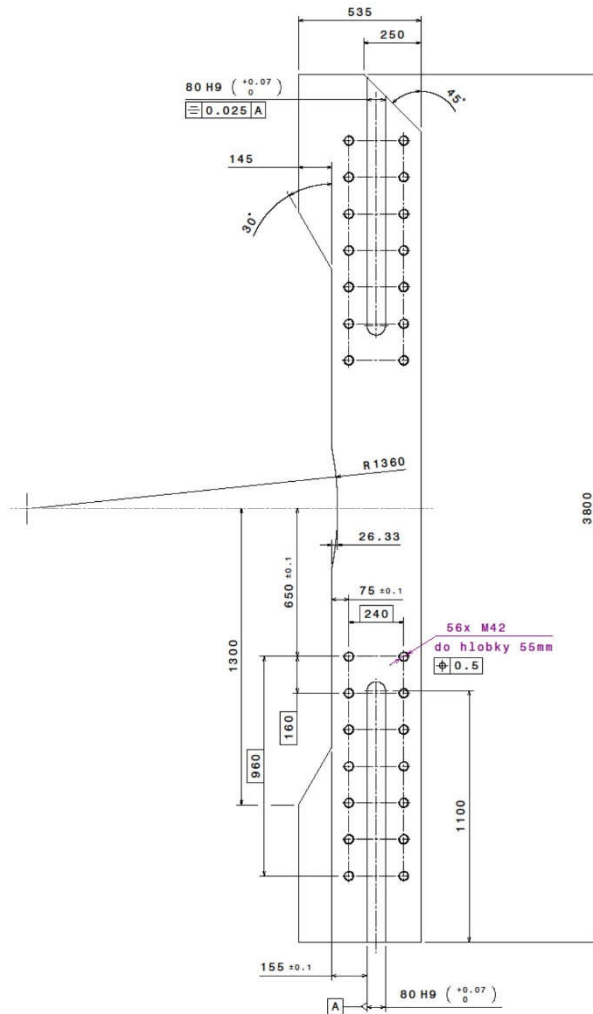
COMPASS-U support structure is under design process and can be modified later as per design requirements



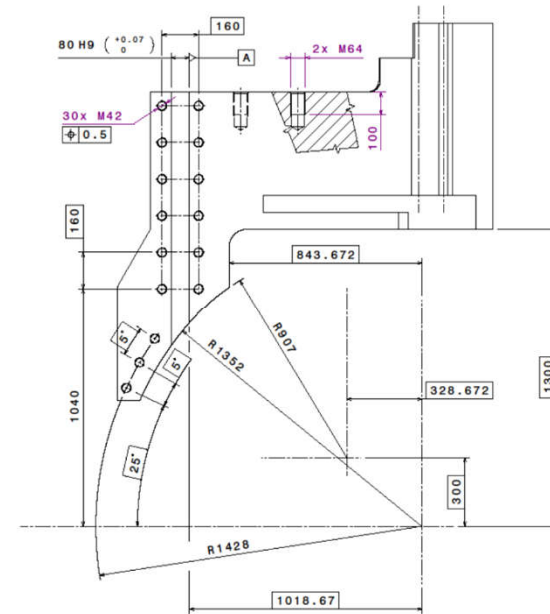
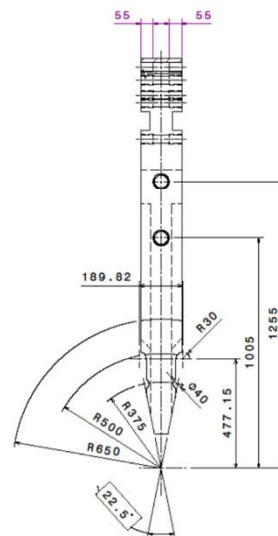
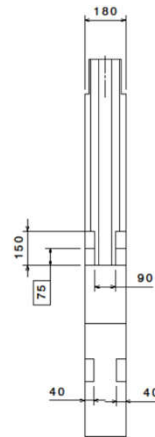
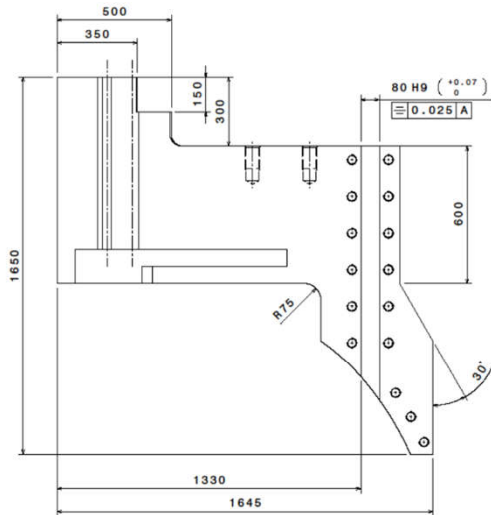




Side panel  
Material: AISI 304  
Weight: ~701 kg

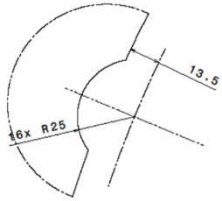


Column  
Material: AISI 304  
Weight: ~2 183 kg

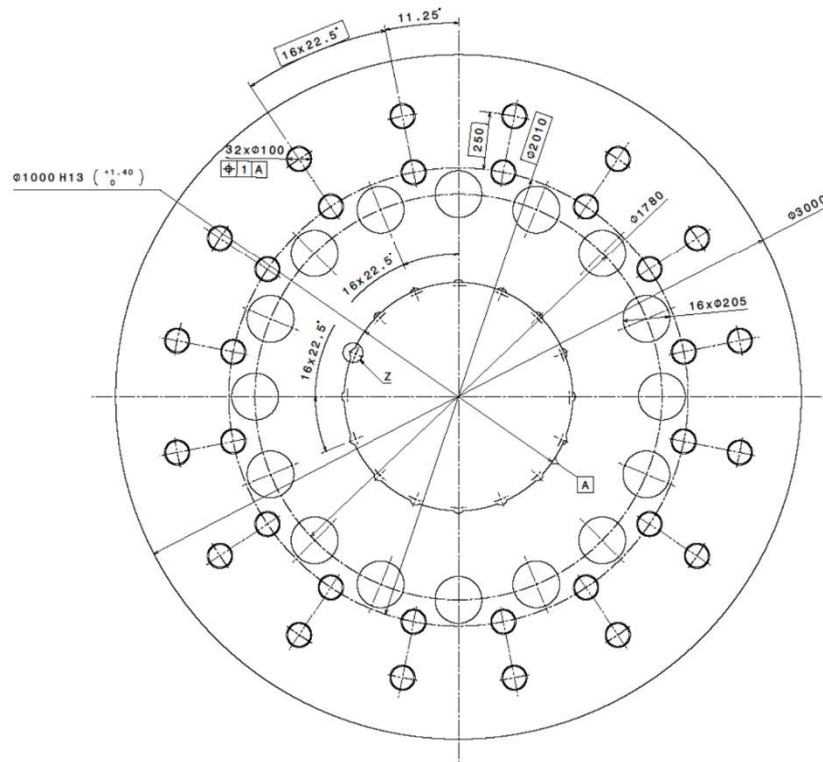


Rib  
Material: AISI 304  
Weight: ~1 486kg

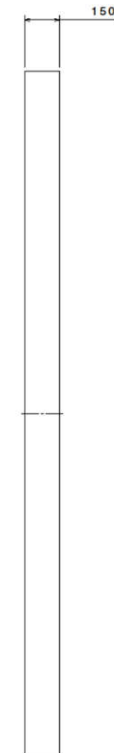
Detail Z  
Scale: 1:1



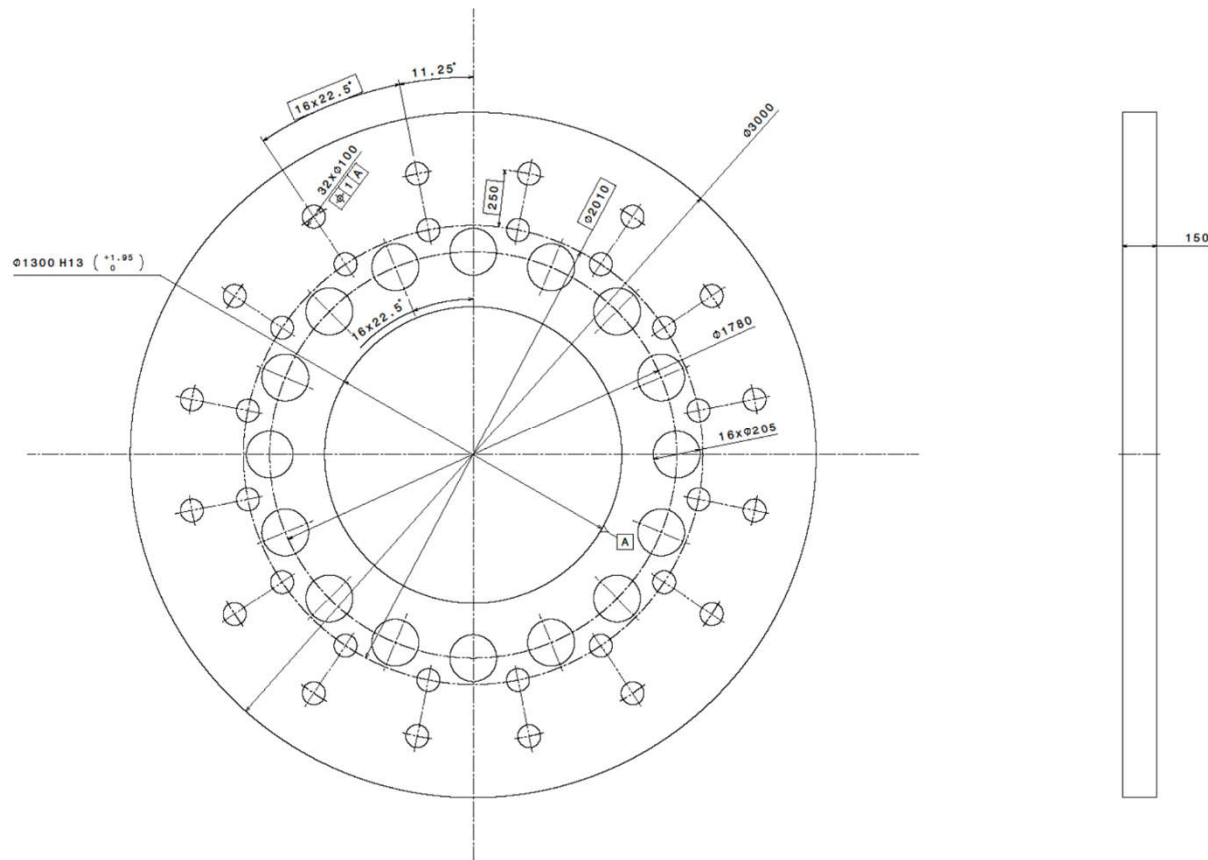
Front view  
Scale: 1:10



Left view  
Scale: 1:10

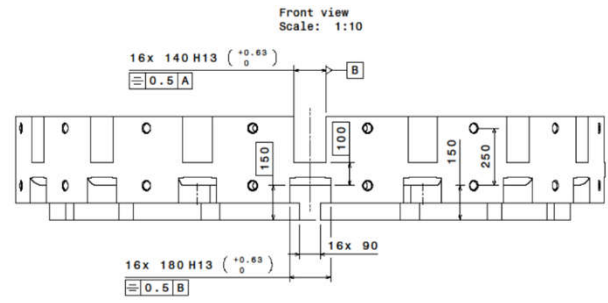
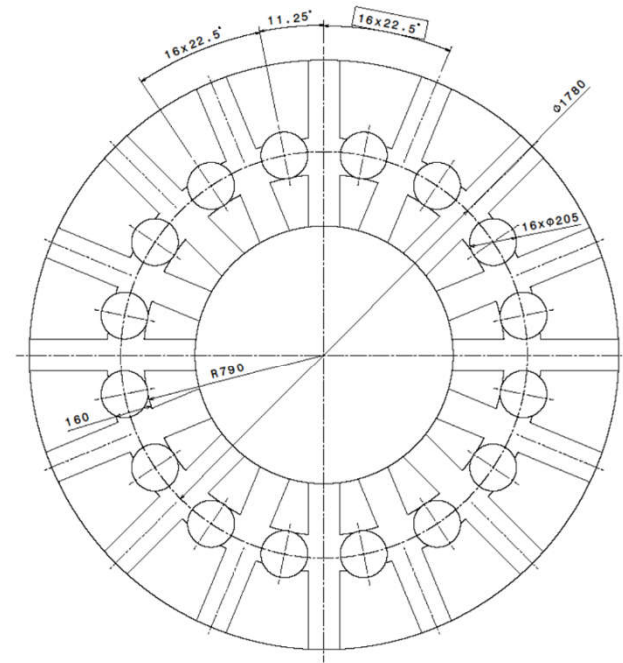
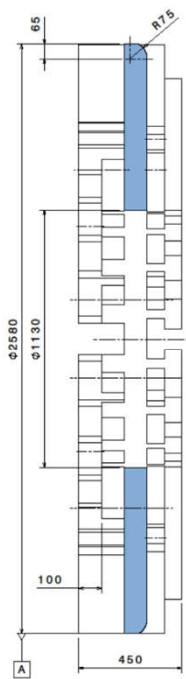
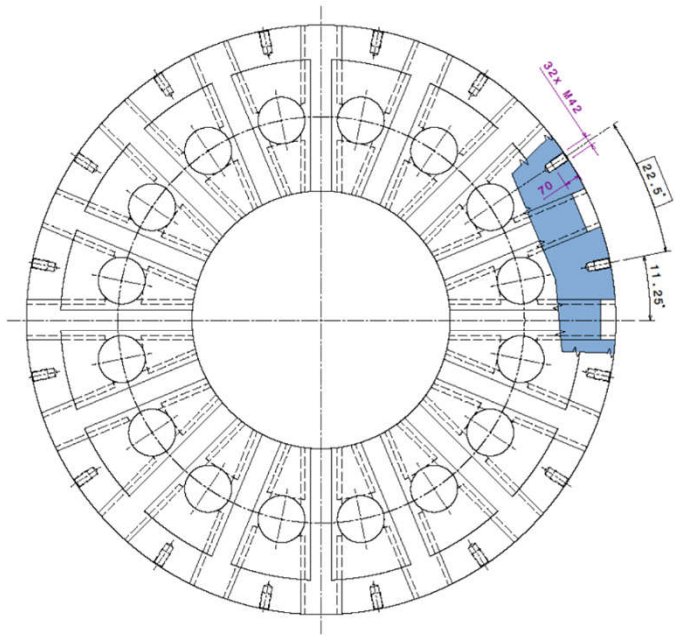


Disk 1  
Material: AISI 304  
Weight: ~8 500kg



Disk 2  
Material: AISI 304  
Weight: ~5 800kg





Disk 3  
Material: AISI 304  
Weight: ~7 641kg