Design of the COMPASS Upgrade tokamak

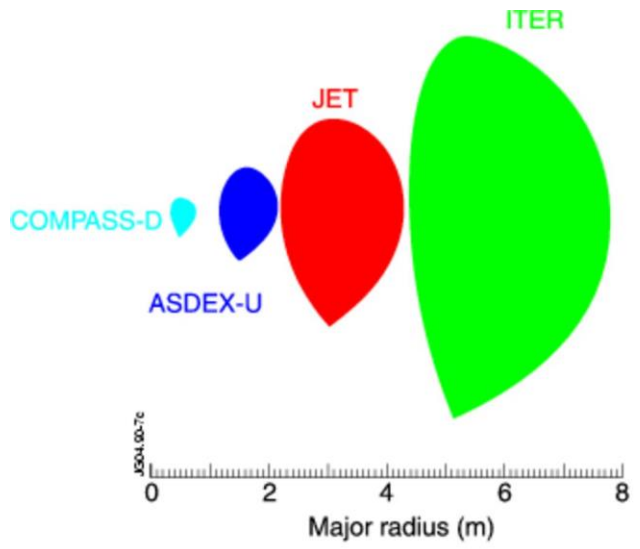
R. Panek and the COMPASS team

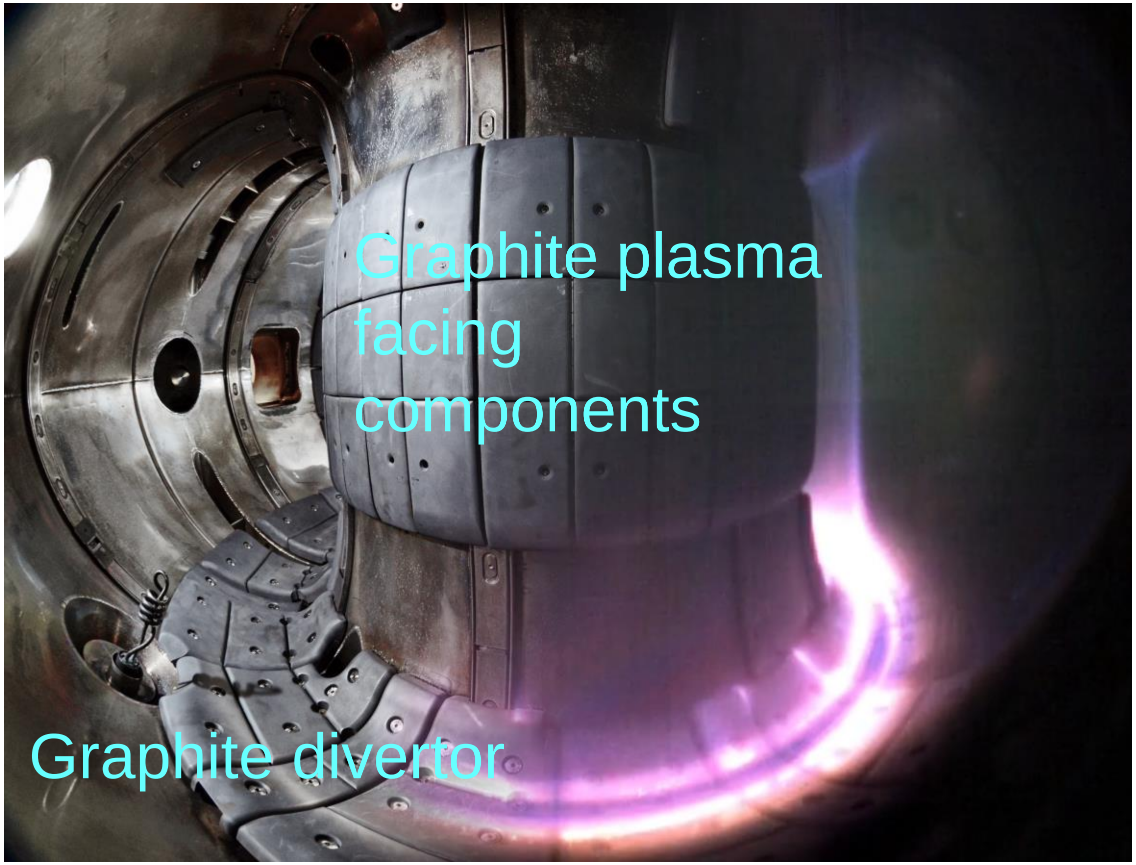
Institute of Plasma Physics of the Czech Academy of Sciences
Czech Republic

The COMPASS tokamak

Major radius [m]	0.56
Minor radius [m]	0.2
Plasma current [kA]	< 400
Magnetic field [T]	< 2,1
Triangularity	~ 0.5
Elongation	< 1.8
Pulse length [s]	< 0.5 (1)

- **ITER relevant geometry (1:10)**
- In full operation since 2012

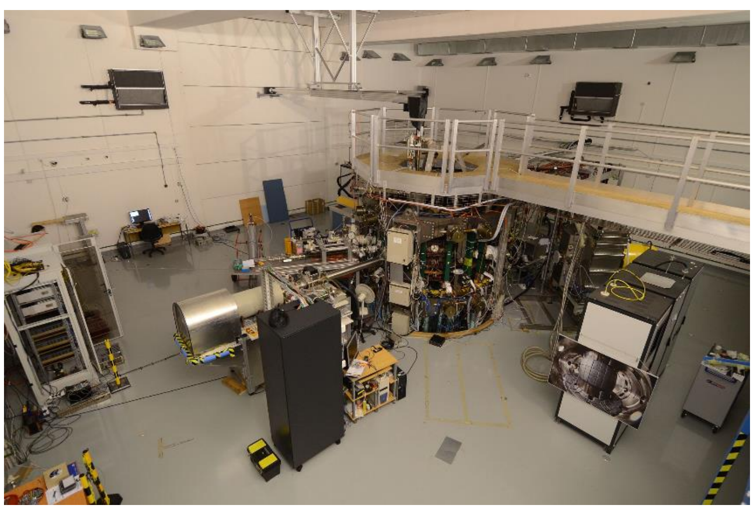




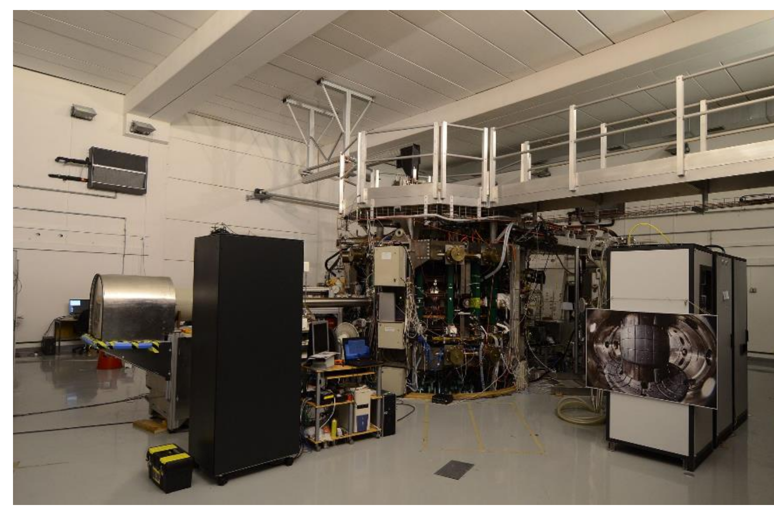
COMPASS infrastructure

Tokamak building

Tokamak building



View inside the COMPASS torus hall



View inside the COMPASS torus hall

Basic parametres of COMPASS-U

Basic dimensions and parameters:

R = 0,84 m

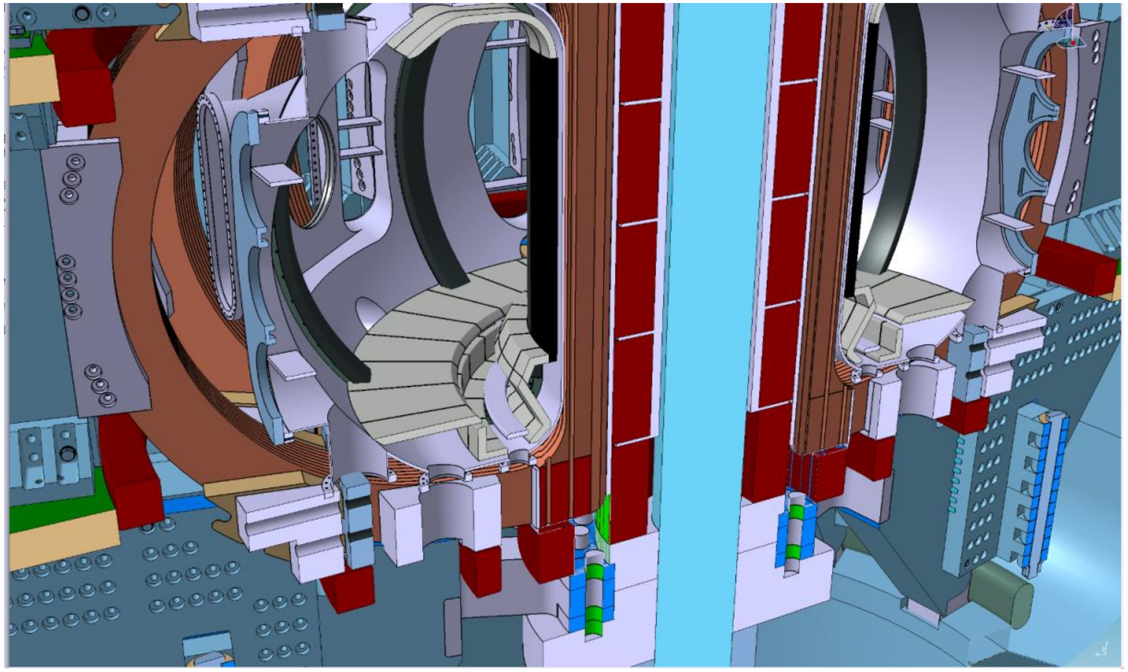
a = 0,28 m

B_T = 5 T

Ip = 2 MA

P_{NBI} = 4-5 MW

P_{ECRH} = 4 MW (170 GHZ)



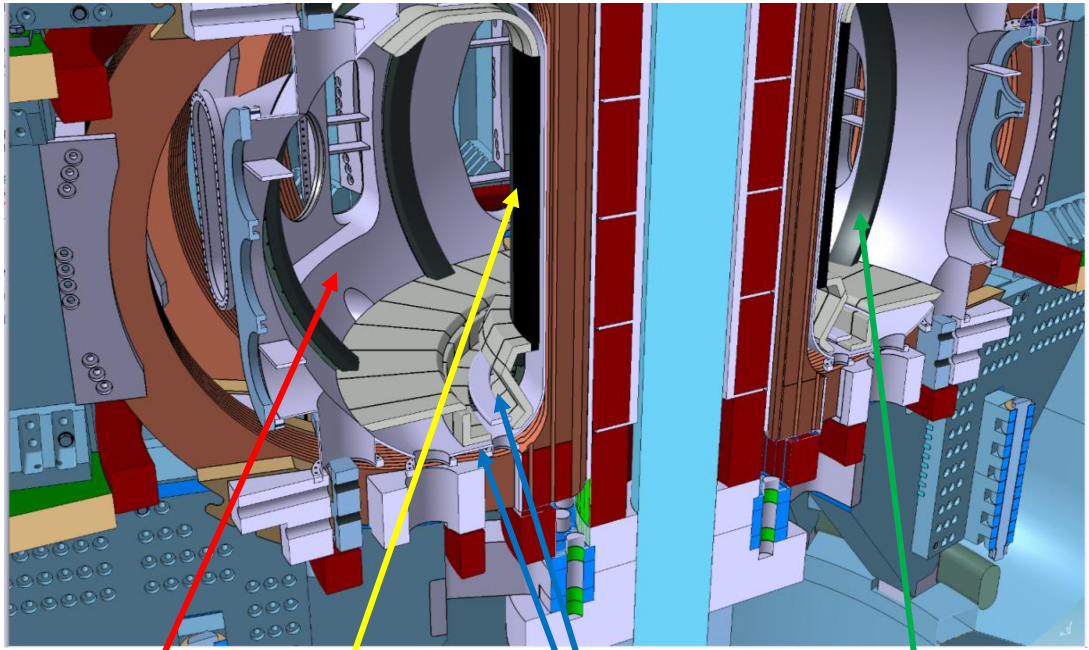
View inside COMPASS-U

- ITER shape and aspect ratio
- High magnetic field (5 T), high density operation (~ up to 4×10^{20} m^{-3})
- Single, double null + Advanced configurations - single and double snow-flake geometry
- Plasma volume ~ 2 m^3
- Metallic first wall device at high-temperature operation (~ 300°C)
- High Bt => physics of advanced H-modes (QH-mode, I-mode, EDA-mode, etc.)

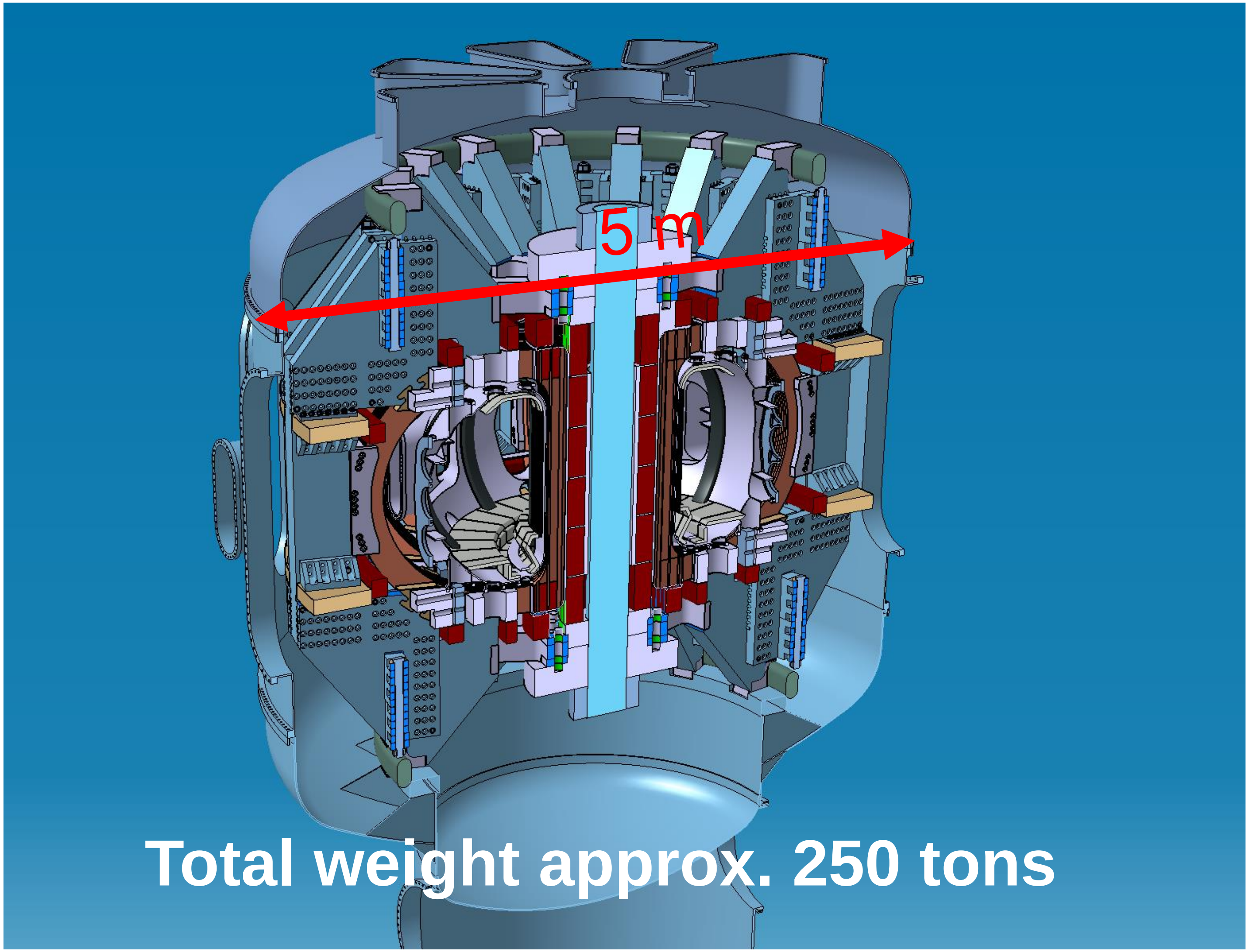
Plasma facing components

PFCs on the 1st Wall Material:

- COMPASS-U will be an all-metal device with stainless steel vacuum vessel.
- Full central column made of W-coated steel.
- 8 outer limiters with thick W-coating on steel.
- Divertor tiles will be W-coated on SS or Cu in a 1st stage -> flexibility for installing bulk W tiles in a later stage.



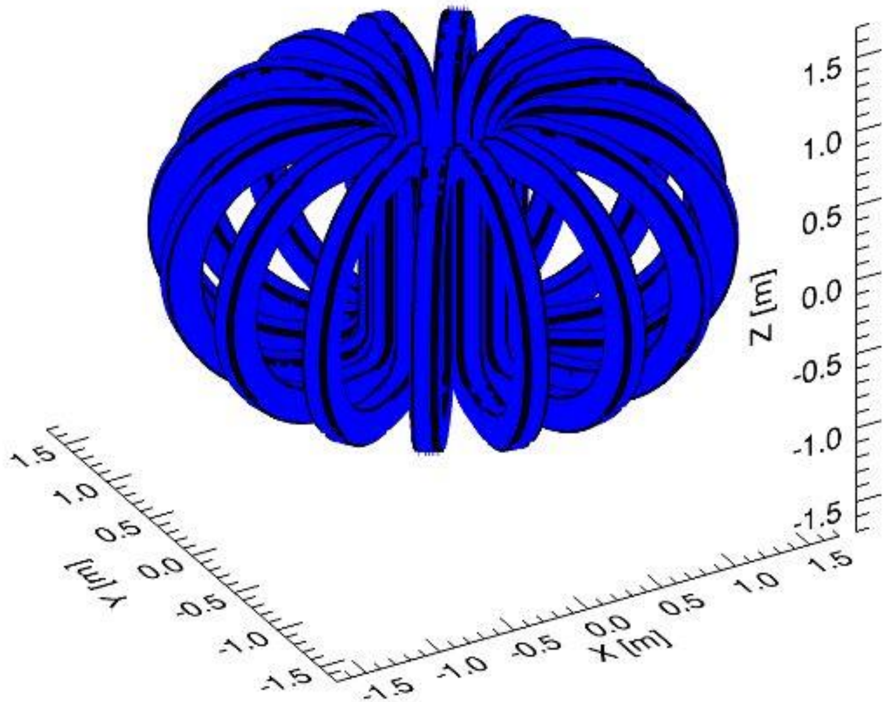
Cross-section and general dimensions



COMPASS-U cross-section and dimensions

Toroidal Field coils

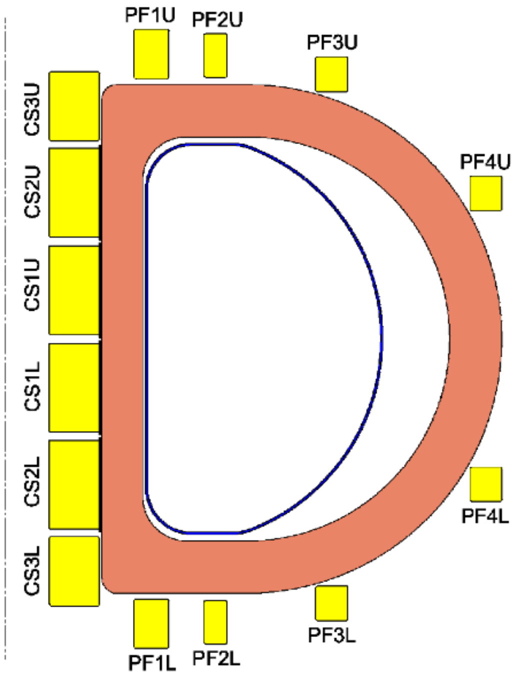
- 16 TF coils with 7 turns each and current 187.5 kA.
- toroidal ripple similar to ITER ($\delta < 0.5\%$).
- 9 T on the High Field Side
- total force acting on one TF coil is 6.5 MN, i.e. 650 tonnes.
- detailed stress analysis performed



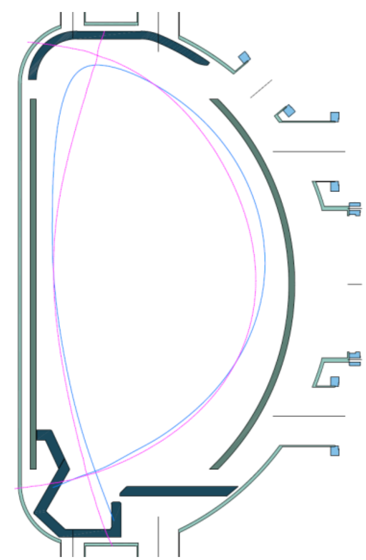
COMPASS-U tokamak TF coils reference design

Poloidal Field Coils System

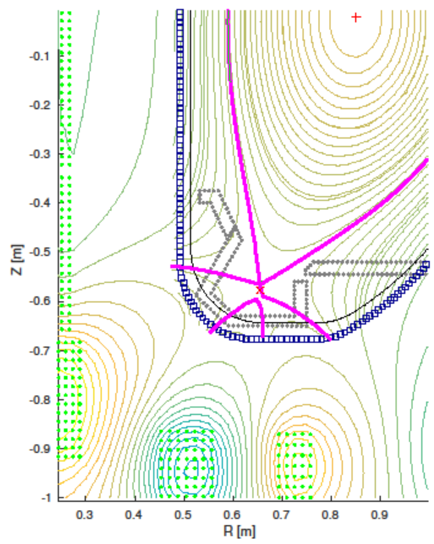
- possibility to create plasma with ITER-like shape (and higher triangularities)
- flexibility to create different plasma shapes, including double-null and double snowflake
- good access to the diagnostic ports
- spatial limitations given by the support structure.
- additional pair of PF coils at R = 0.725



System of PF coils



Single and double null configuration

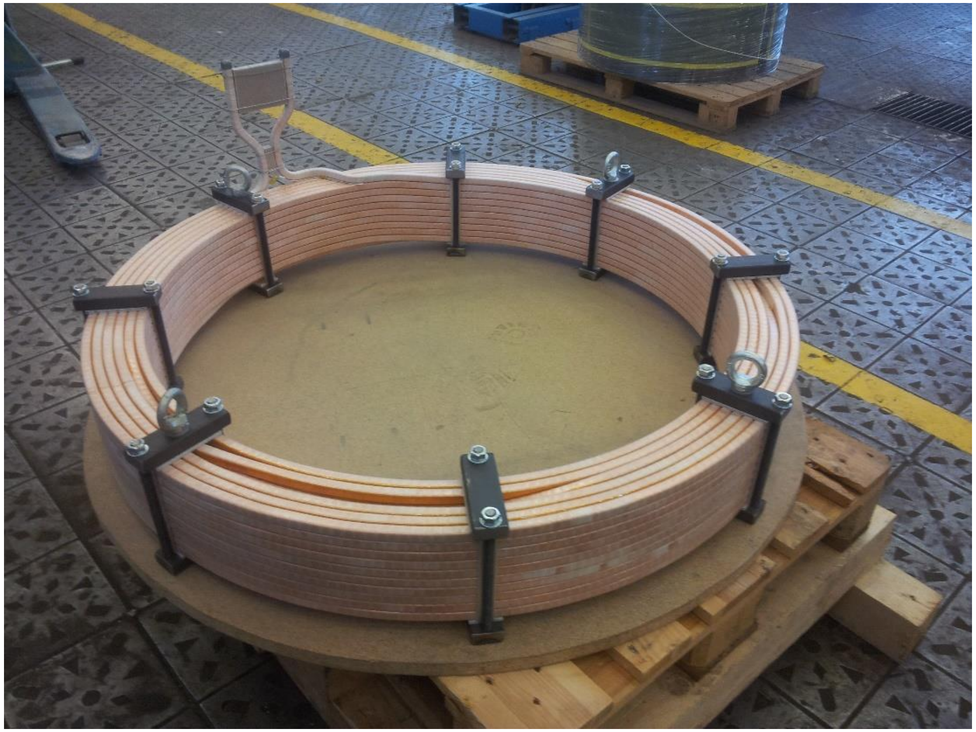


Snow-flake configuration

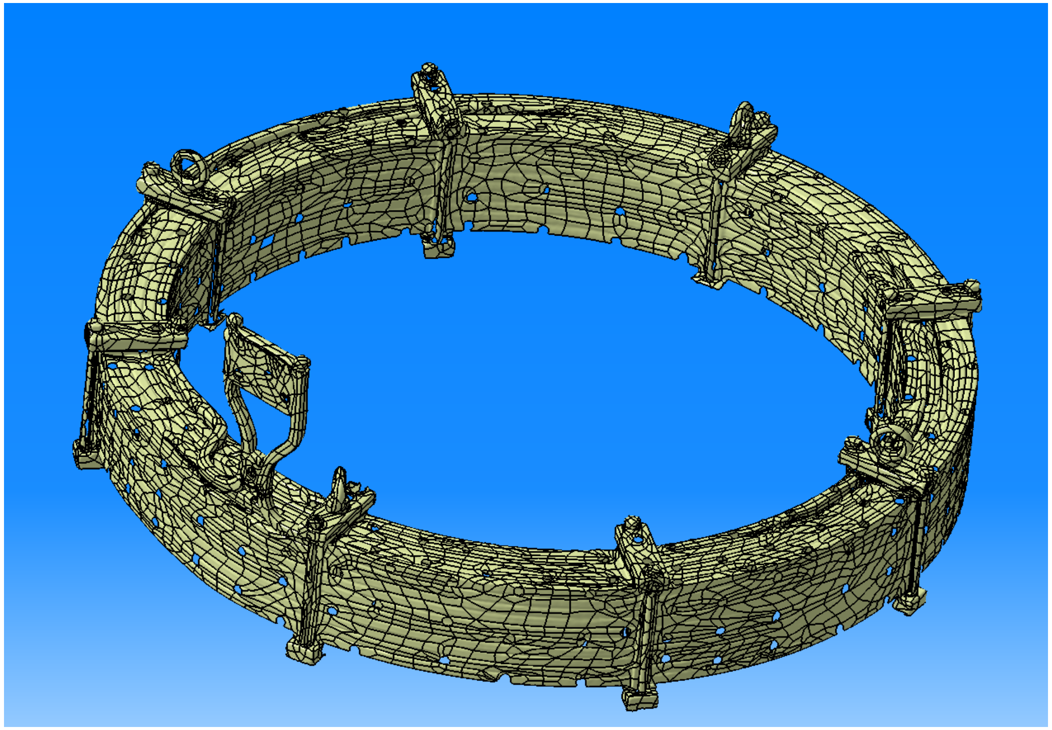
Passive stabilization coils are expected to be needed. These will be in-vessel.

Prototype of PF coils for COMPASS-U

- Full-size prototype of PFC has been manufactured
- Precision of winding measured by 3D mapping – within ~ 0,1%



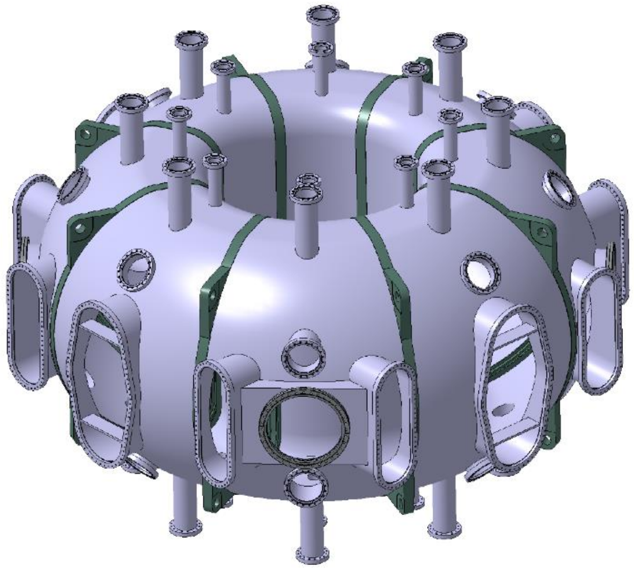
Coil before impregnation



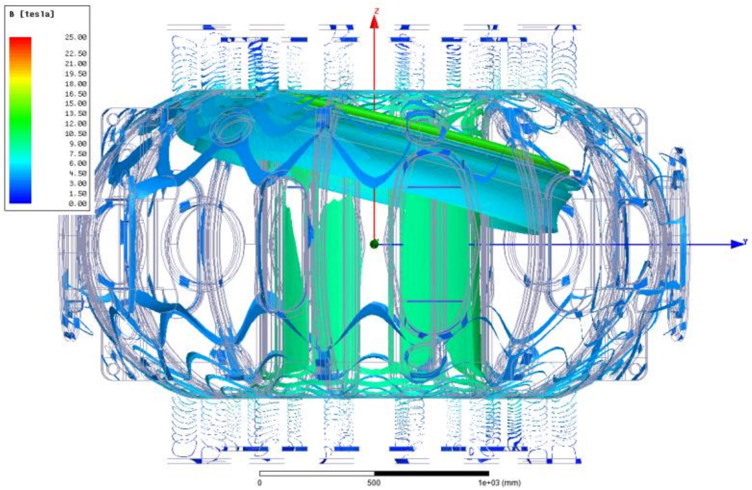
3D scan of the coil to assess manufacturing precision

Vacuum vessel

- Material – 10-12 mm AISI 316 L
- Large ports for
    - NBI access
    - human access
    - diagnostic access
    - Divertor part exchange
- Extreme EM forces
- Operation at least at 300°C
- First wall, limiter and divertor material – combination of W-coated stainless steel/copper and bulk tungsten



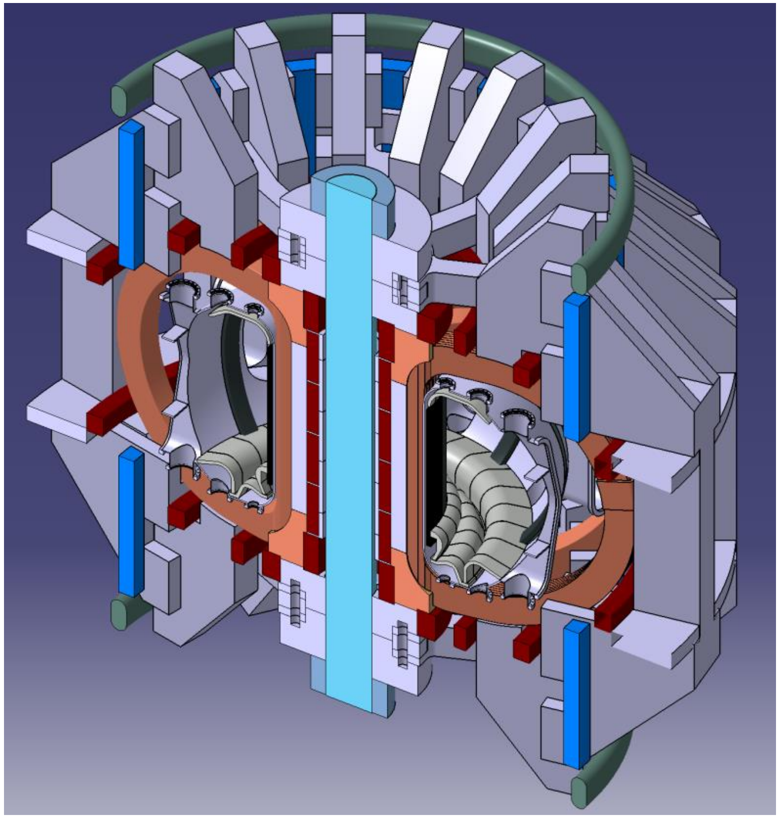
General view on the vacuum vessel.



Plasma disruption model

Support structure (1/3) Requirements

- Support Structure was designed taking into account the PF coils positions
- Needs to resist tremendous forces (650 tones from each TF coil)
- Industrially standard parts to keep the project cost as low as possible – e.g., steel plates with widths up to 200 mm
- Designed to accommodate tangential NBI access, other auxiliary heating systems and for the required diagnostics.



COMPASS-U support structure

Power supply system status and requirements

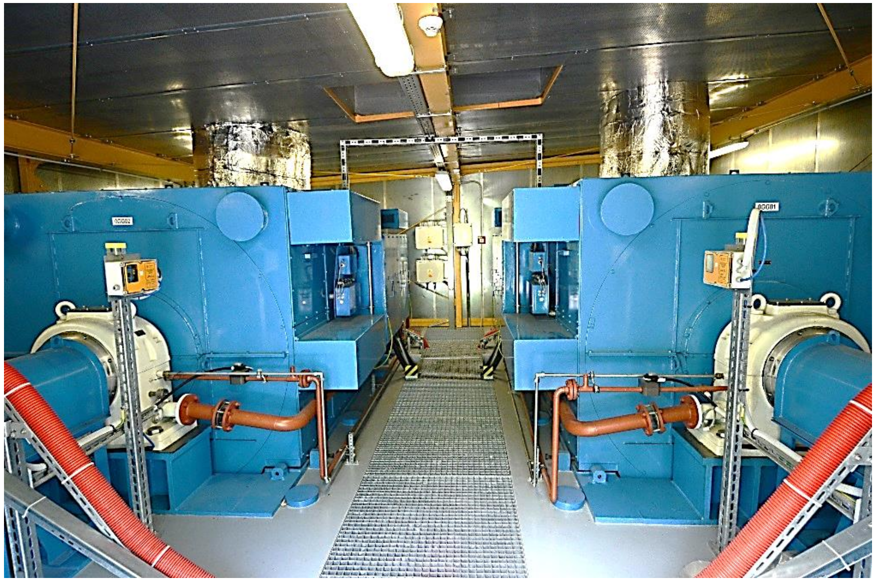
Current status (COMPASS):

- Public grid: 2 MW/22 kV
- Two flywheel generators: 2 x 35 MW, 2 x 40 MJ
- Switching station, transformers, …
- Thyristor converters, transistor based fast amplifiers

Requirements for COMPASS-U:

- TF coils: 70 MW, 130 MJ
- PF coils: < 90 MW, < 110 MJ
- Additional heating and reserves: 70 MW, 150 MJ
- In total: 180-230 MW, 300-400 MJ

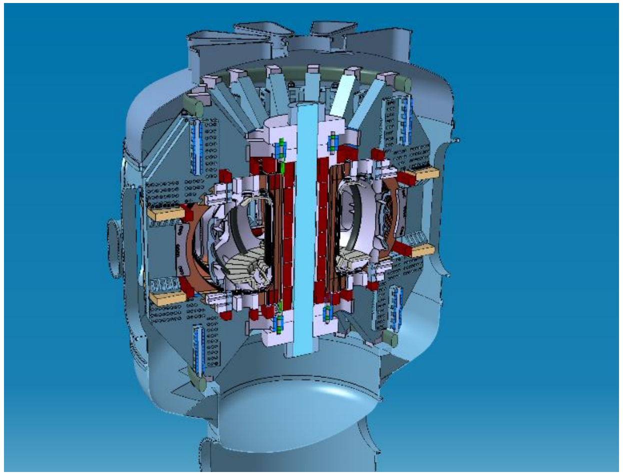
High-voltage switches



COMPASS fly-wheel generators

Cryostat and cryogenics

- high operational temperature of the plasma facing components and simultaneously achieved cryogenic temperatures of the rest of the tokamak.
- a large amount of energy (~120 MJ) will be deposited into the tokamak PF and TF coils during the discharge.
- A vacuum cryostat necessary
- The closed He loop will allow us to cool PF coils below liquid nitrogen temperature if required.
- Heating of PF coils is the main parameters
- The cooling power is approximately 30 kW ~ approx. 2 shots at full parameters per hour.



Conceptual design of the cryostat

Stirling SPC-4 Helium Refrigeration System

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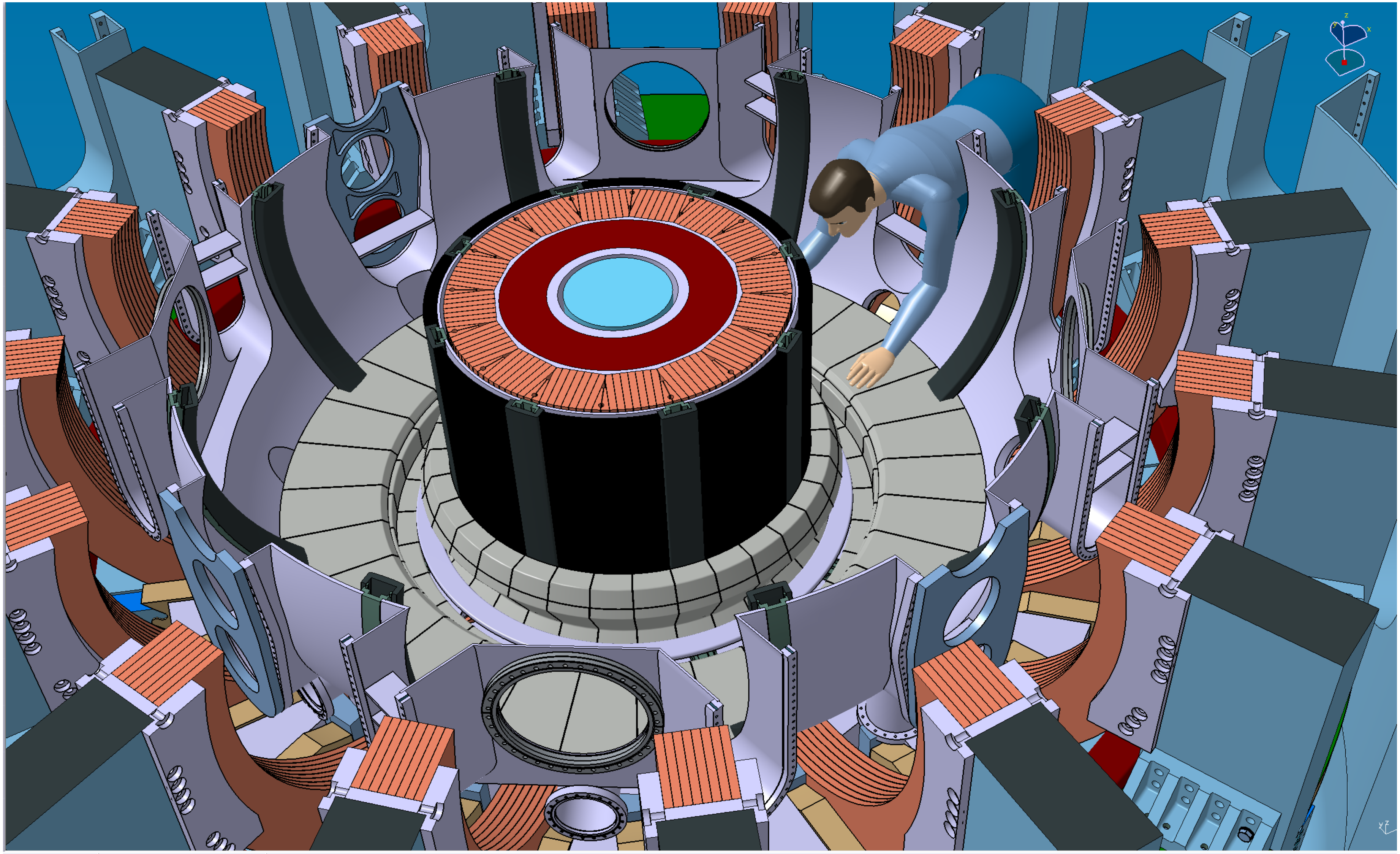
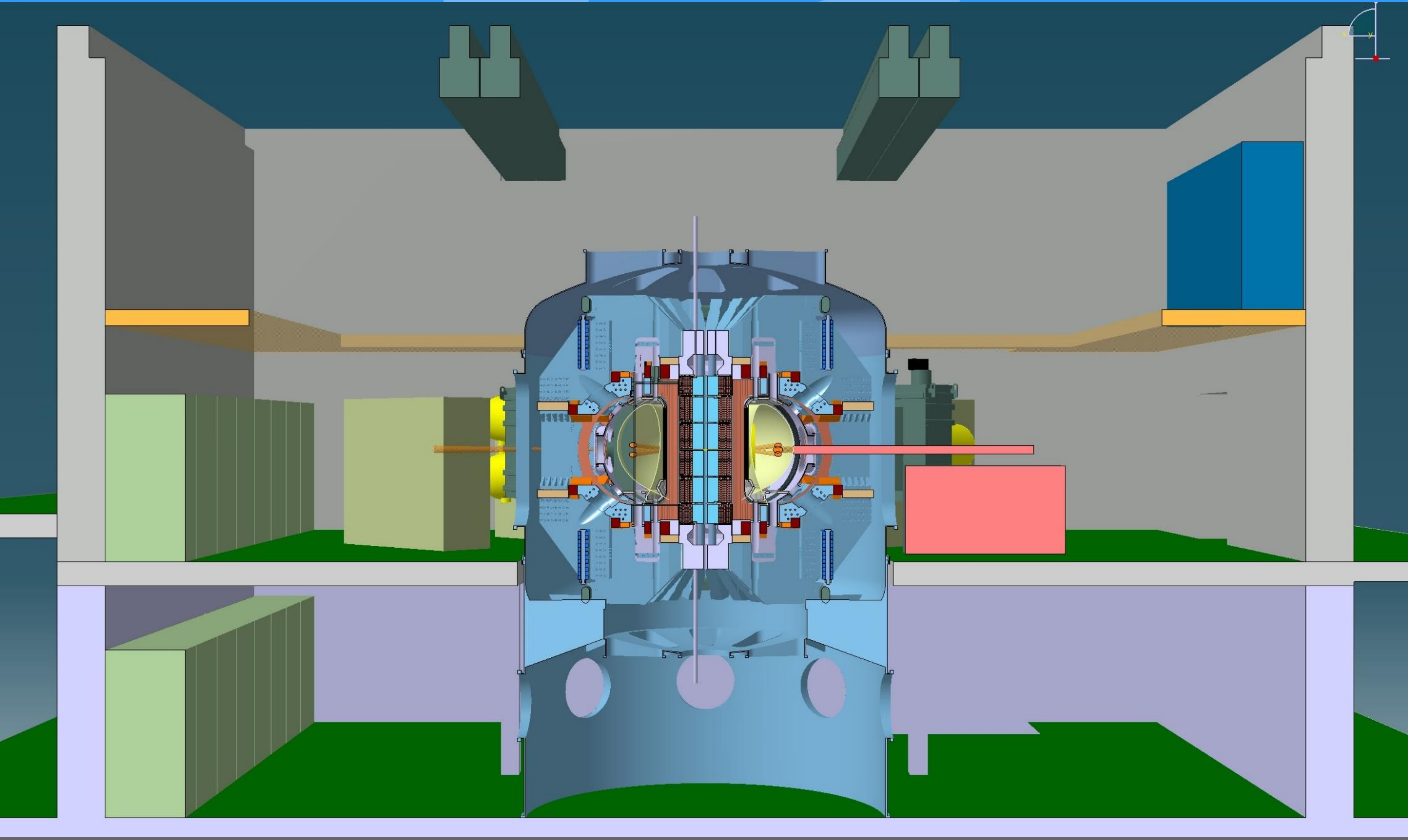
Man access into the tokamak



Occupation of the torus hall



Indicative timetable

Key milestones:

Conceptual design	2016 - 2017
Design of the components	2017 – 2018
Vessel, support structure manufacturing	2018 - 2019
PF and TF Coil manufacturing	2018 – 2019
NBIs manufacturing	2017 - 2020
Assembly and installation	2019 - 2020
Commissioning and start of operation	2021 - 2022

First plasma: 2021/2022

Time for full commissioned machine: **1.5 - 2 years**

Physical studies will start already from end-2022.

Operation at 5T / 2MA: **mid/end-2023**