The DTT Project and its impact on Italian industry

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on behalf of DTT group

Industrial Opportunity days 2022
9-10 June 2022
INAF Osservatorio Astronomico di Capodimonte

Outline

Company overview
DTT within the Roadmap to Fusion Energy
DTT procurement schedule
- Building and electrical distribution system
- Machine components
- Heating systems

DTT Company Overview

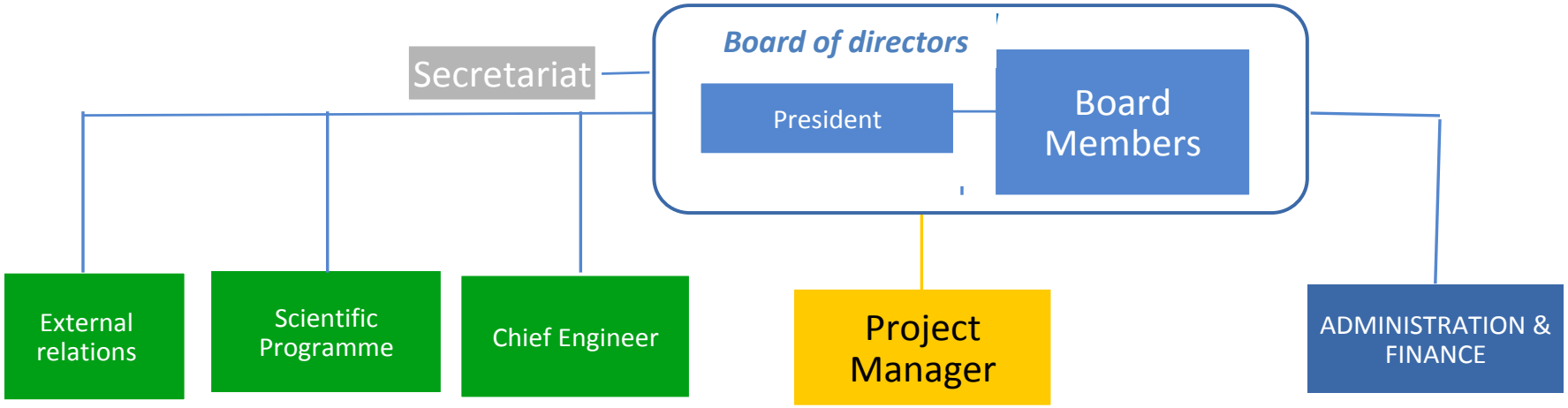
DTT scarl (Società Consortile a Responsabilità Limitata) is a legal entity created to build and operate the DTT

Capital investment: 500M€ already secured by ENEA, 100M€ part of ongoing negotiation.

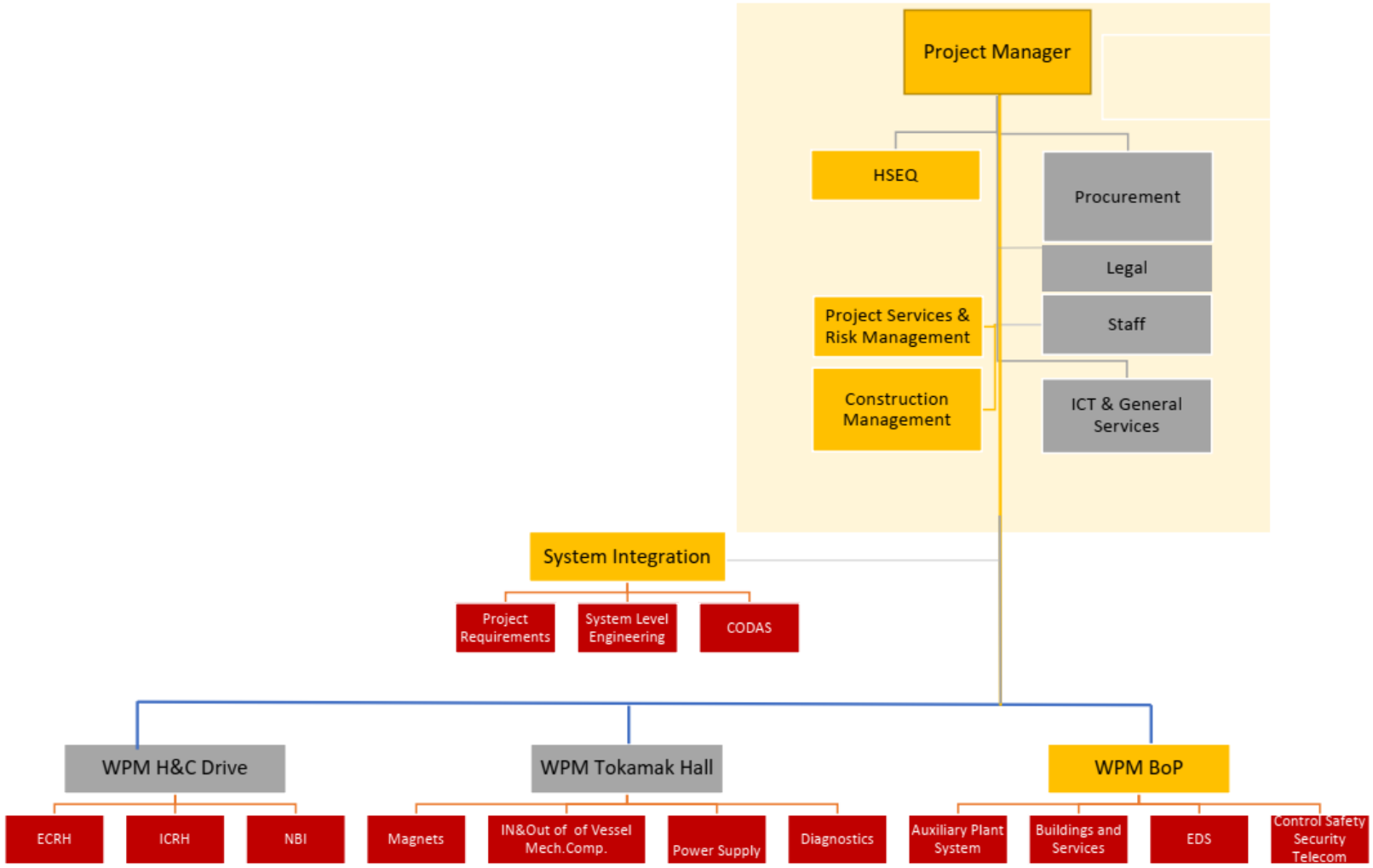
Operating costs: 130M€ shared pro-rata among the shareholders for engineering, research and operating costs

ENEA will remain owner of the facilities; DTT Scarl is configurated as a Public Company (under the Italian law “Codice Appalti”); the applicable scheme is inside “Settori Speciali”

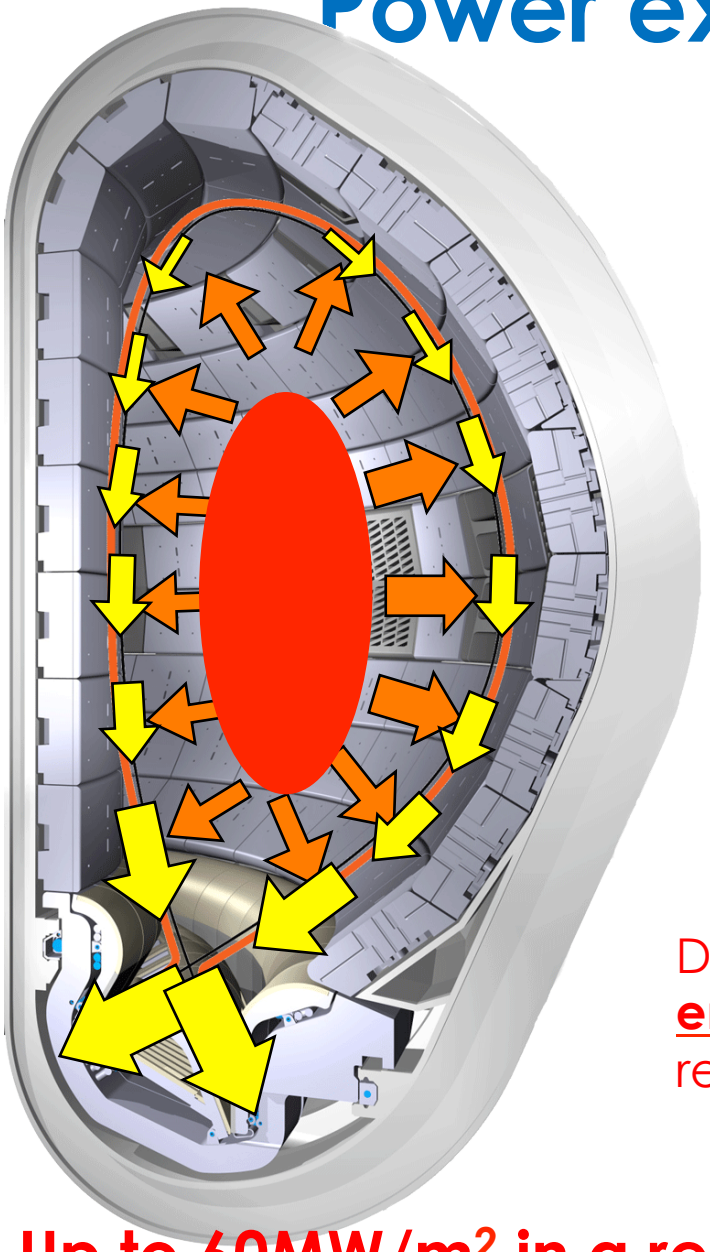
DTT Assetto macro-organizzativo



DTT organization



Power exhaust is one of the main challenges of fusion



Plasma facing components technology -> max heat flux presently limited to 10-20 MW/m^2

Power exhaust problem solved by:

1. Magnetic configurations that allow large divertor wetted areas
2. Partially detached plasma conditions
3. Plasma facing components technology
4. Impurity seeding to increase core radiation
5. Liquid metals for plasma facing components

DTT is aimed to provide a **unique integrated environment, relevant to DEMO**, where all the relevant approaches can be tested.

Up to 60MW/m^2 in a reactor

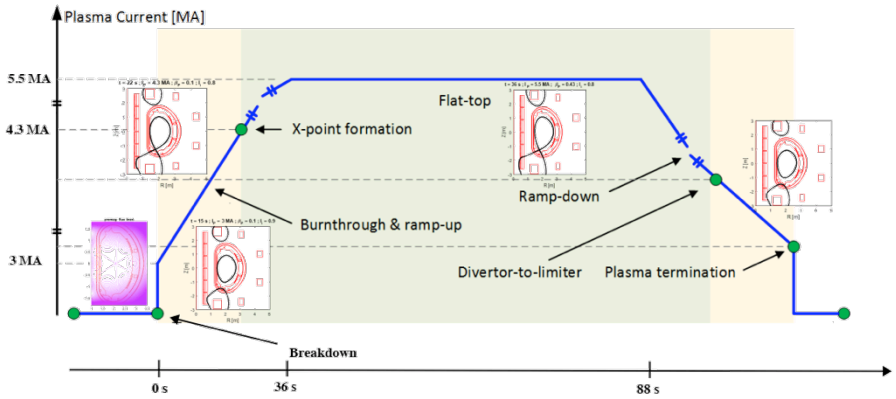
~ heat flux on the surface of the Sun!

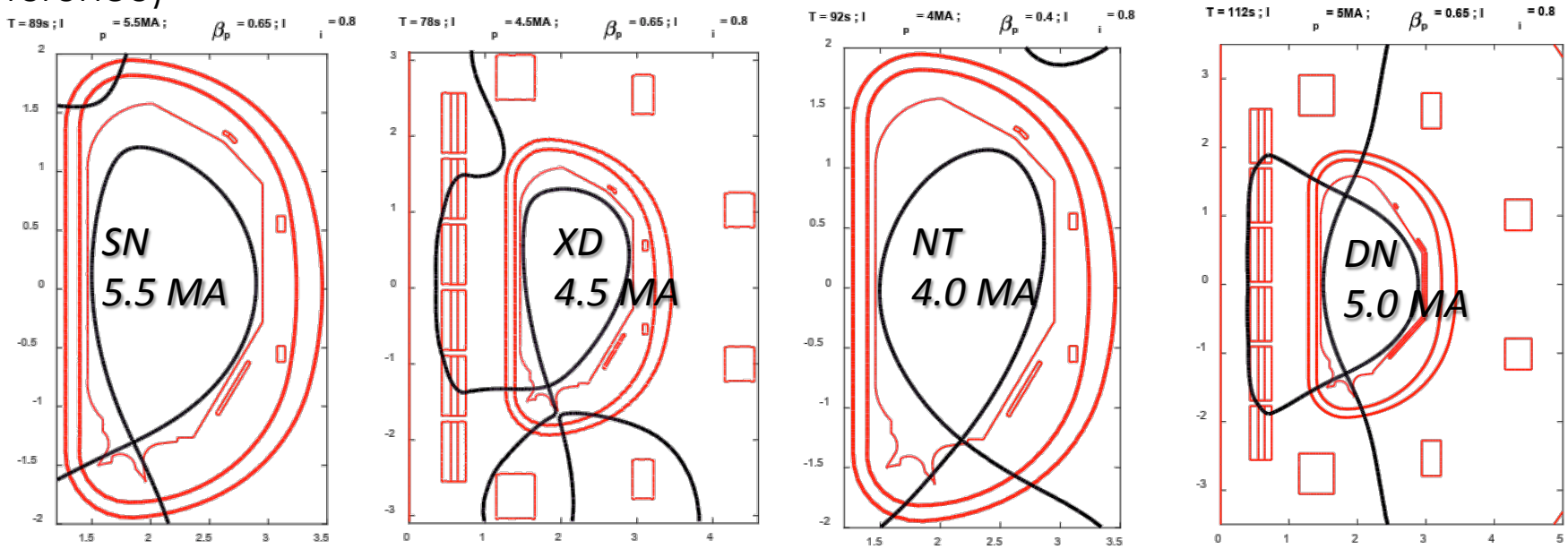
DTT flexibility as primary design requirement

The design of the different systems of DTT has been carried out with aim at insuring the **largest possible flexibility** in terms of:

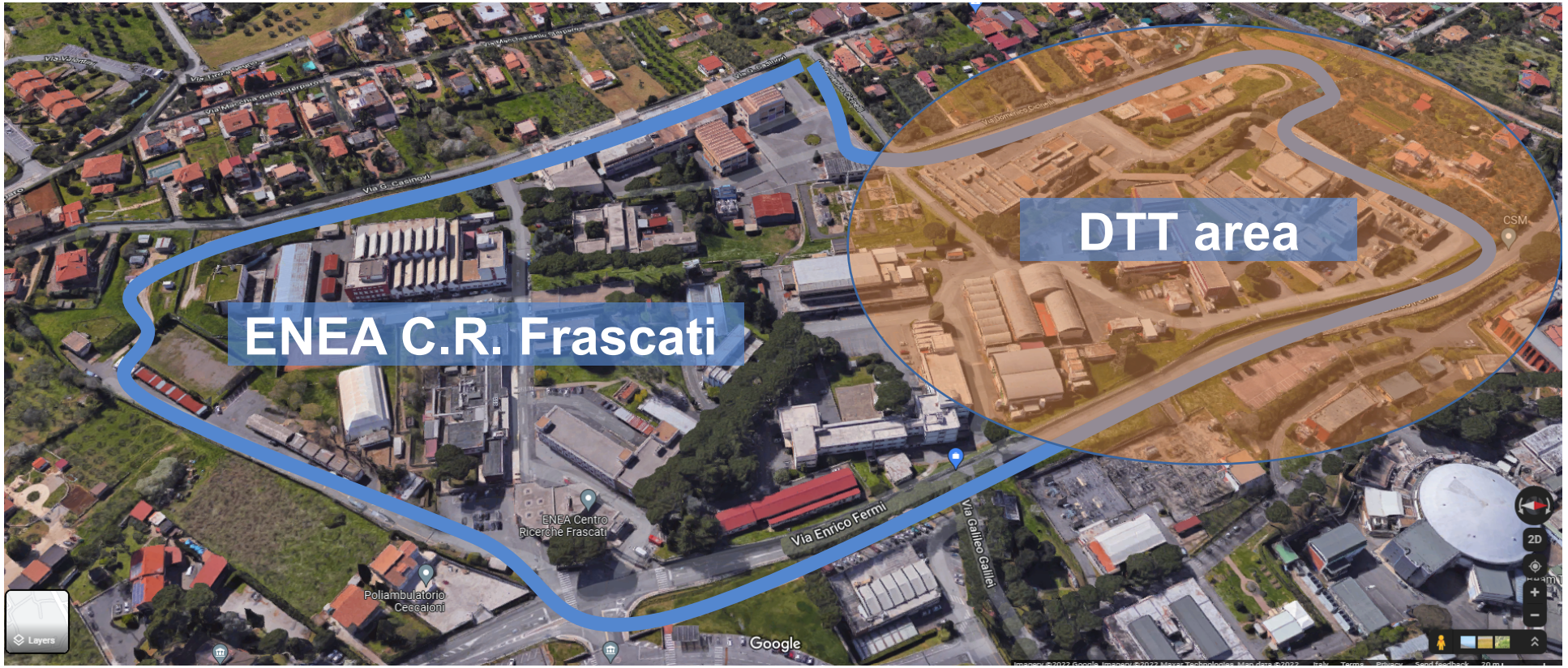
- Completeness of plasma scenarios;
- Space allocated for divertor;
- Power density on divertor;
- Mix of additional heating systems

At the same time **state of the art technology** has been considered (ITER and JT-60SA as reference)



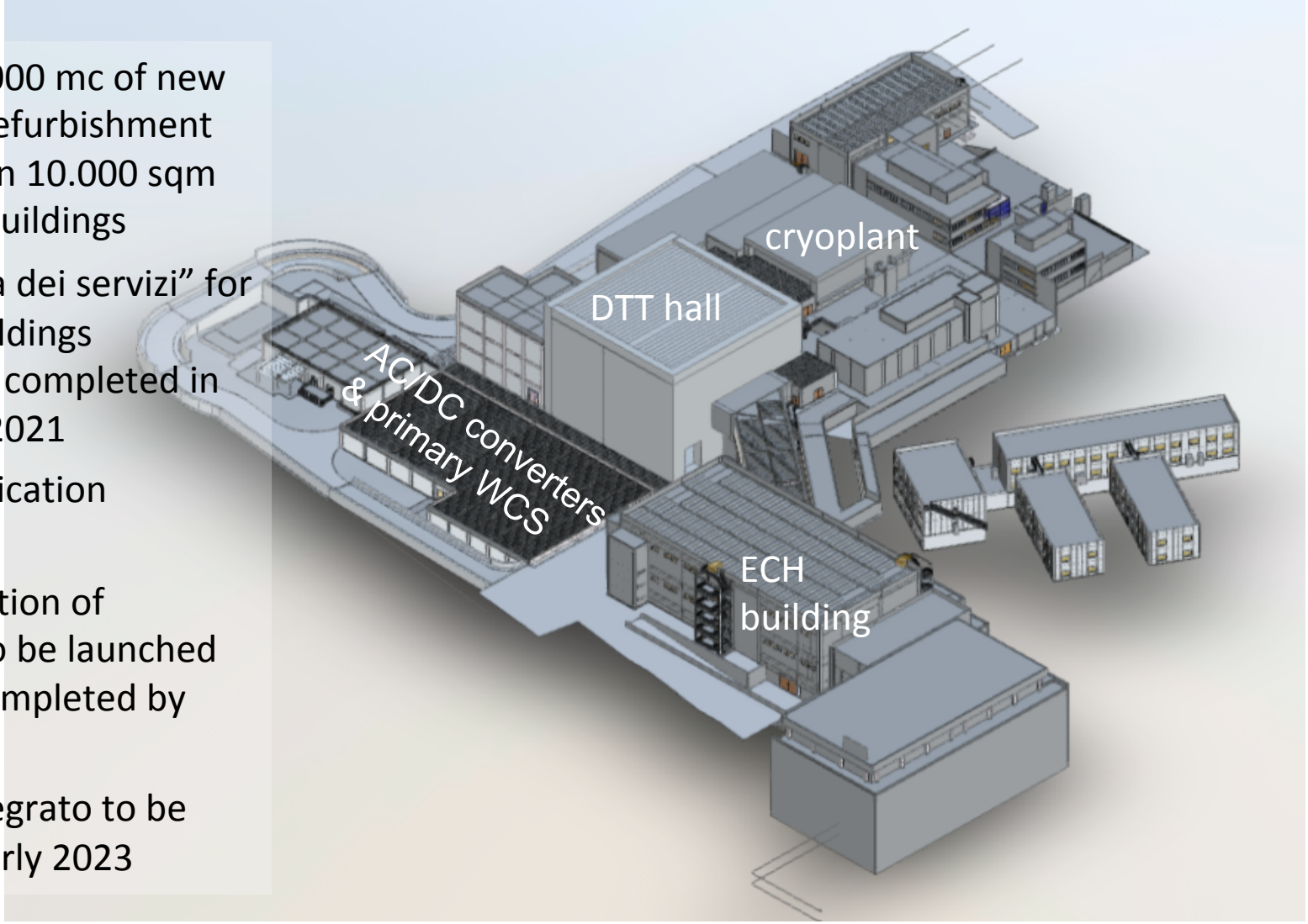


DTT being built at the Frascati research center



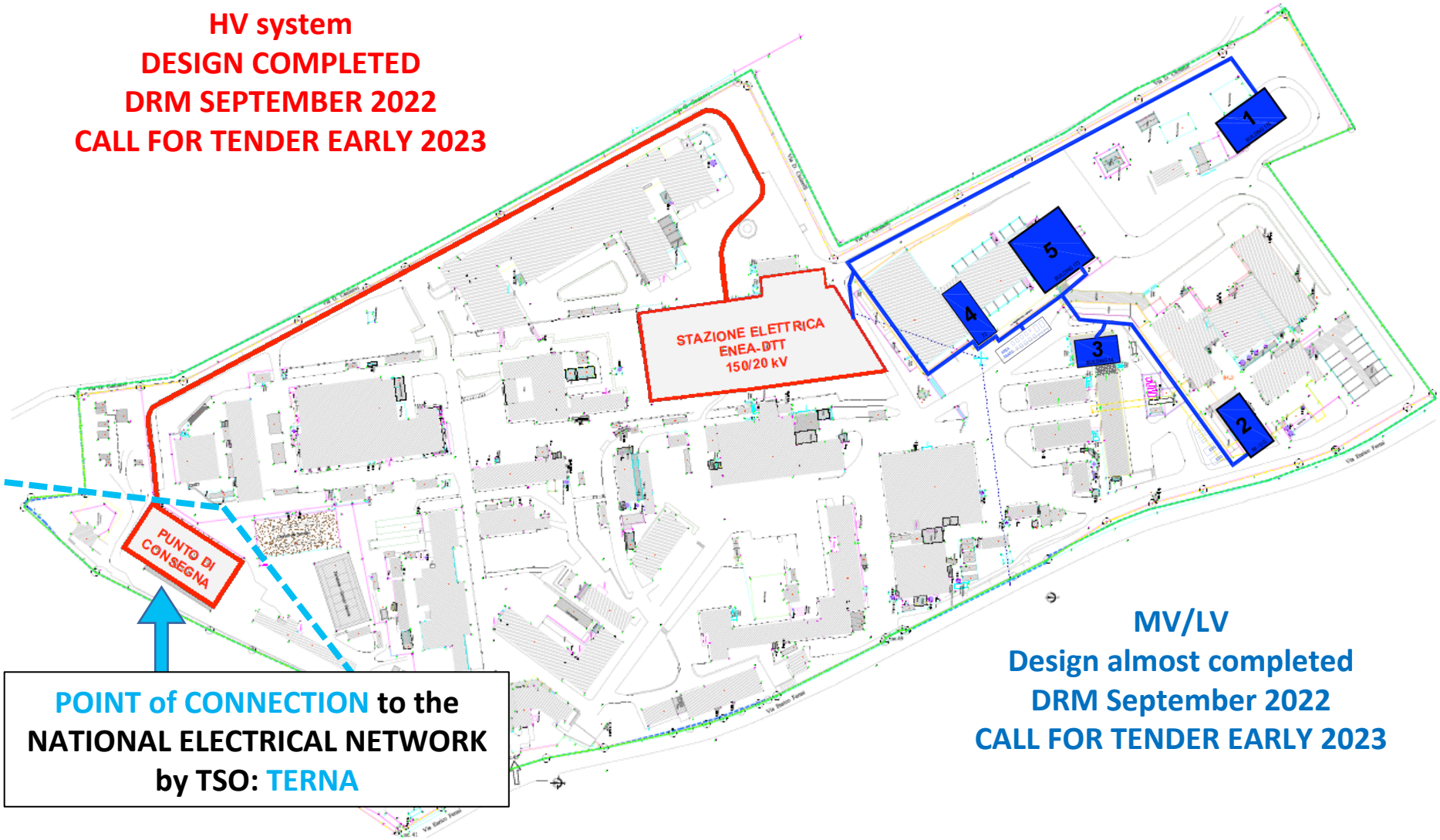
Render of new buildings layout

- ✓ About 150.000 mc of new buildings. Refurbishment of more than 10.000 sqm of existing buildings
- ✓ “Conferenza dei servizi” for the new buildings successfully completed in November 2021
- ✓ Design verification completed
- ✓ Prequalification of industries to be launched soon and completed by November
- ✓ Appalto integrato to be launched early 2023



Electrical Distribution Systems

HV system
DESIGN COMPLETED
DRM SEPTEMBER 2022
CALL FOR TENDER EARLY 2023



POINT of CONNECTION to the NATIONAL ELECTRICAL NETWORK by TSO: TERNA

MV/LV
Design almost completed
DRM September 2022
CALL FOR TENDER EARLY 2023

Auxiliary Plant System

Main scope of this task is to provide the cooling water to all equipment involved in the experiment (Gyrotron, Antenna, Neutral Beam, Vacuum Vessel, Diagnostic, Power Supply items, etc) in order to remove the heat load generated during the operation.

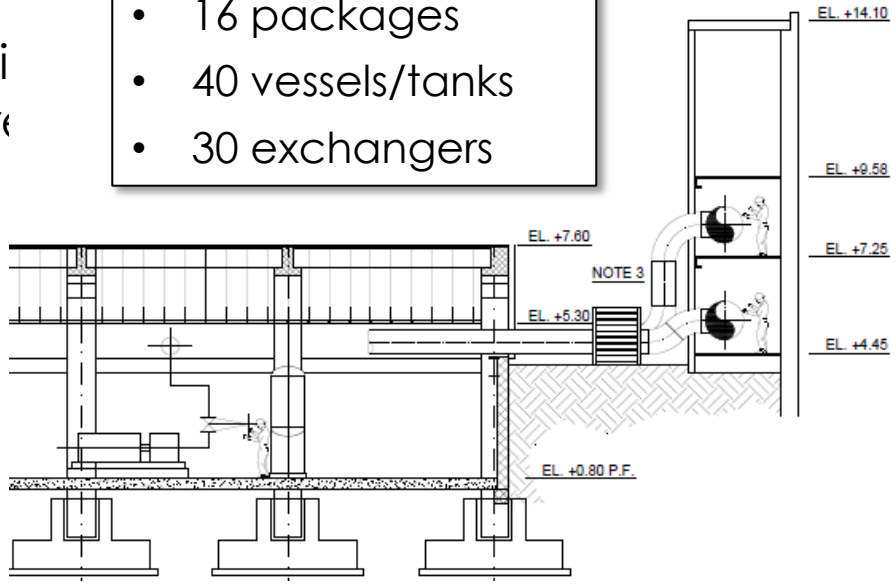
Auxiliary Systems includes:

- Water Demineralization System
- Chilling Units
- Primary and Secondary Circui
- Activated Exhausted Water Tre
- Nitrogen System
- Compressed Air System

Around 150 items:

- 60 pumps
- 16 packages
- 40 vessels/tanks
- 30 exchangers

About 1100 tons of piping and accessories (valves, fittings, supports)



DTT Design reviews/Call for Tender schedule

Present schedule foresees the first plasma in April 2028.

For each project component several internal design review meetings (DRM) foreseen

- preliminary (P-DRM)
- conceptual (C-DRM)
- engineering (E-DRM)
- specification (S-DRM)

External panels of international experts appointed to review the design.

Infodays for industry foreseen

Toroidal Field coil system: supply chain

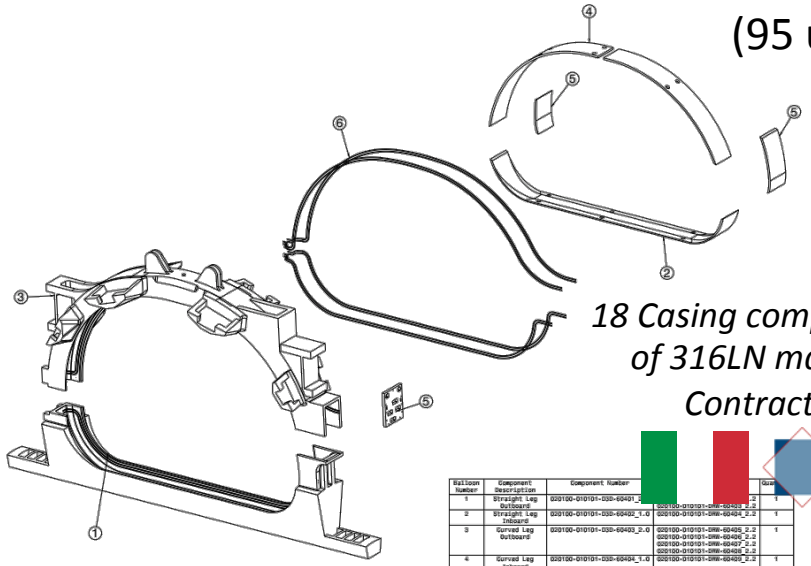
55 tons Nb_3Sn strands

31 tons Cr coated Cu strands

CICC

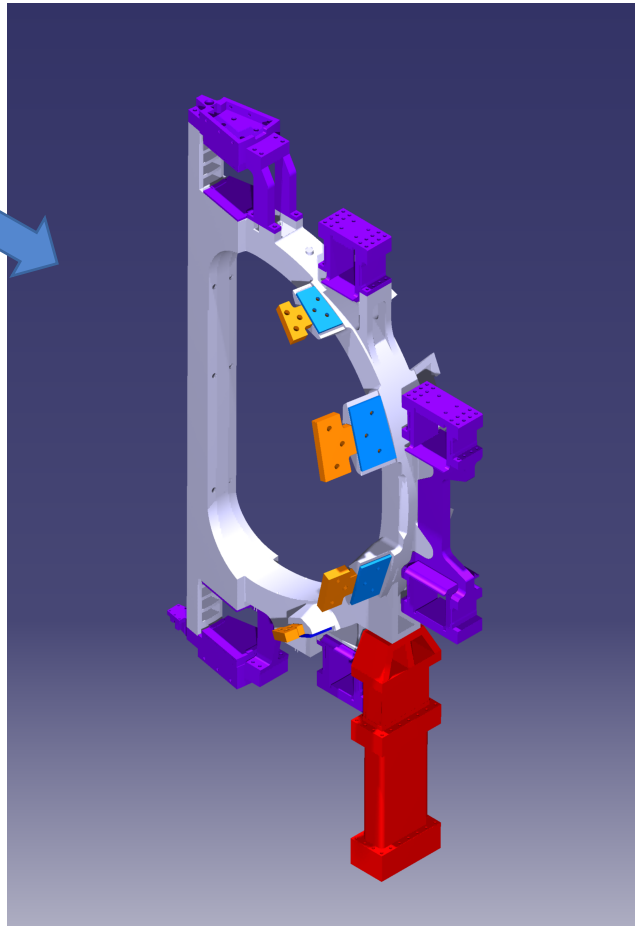
ICAS

20,4 km of conductors (95 unit lengths)



18 Casing components (~360 tons of 316LN material delivered)
Contract to be signed

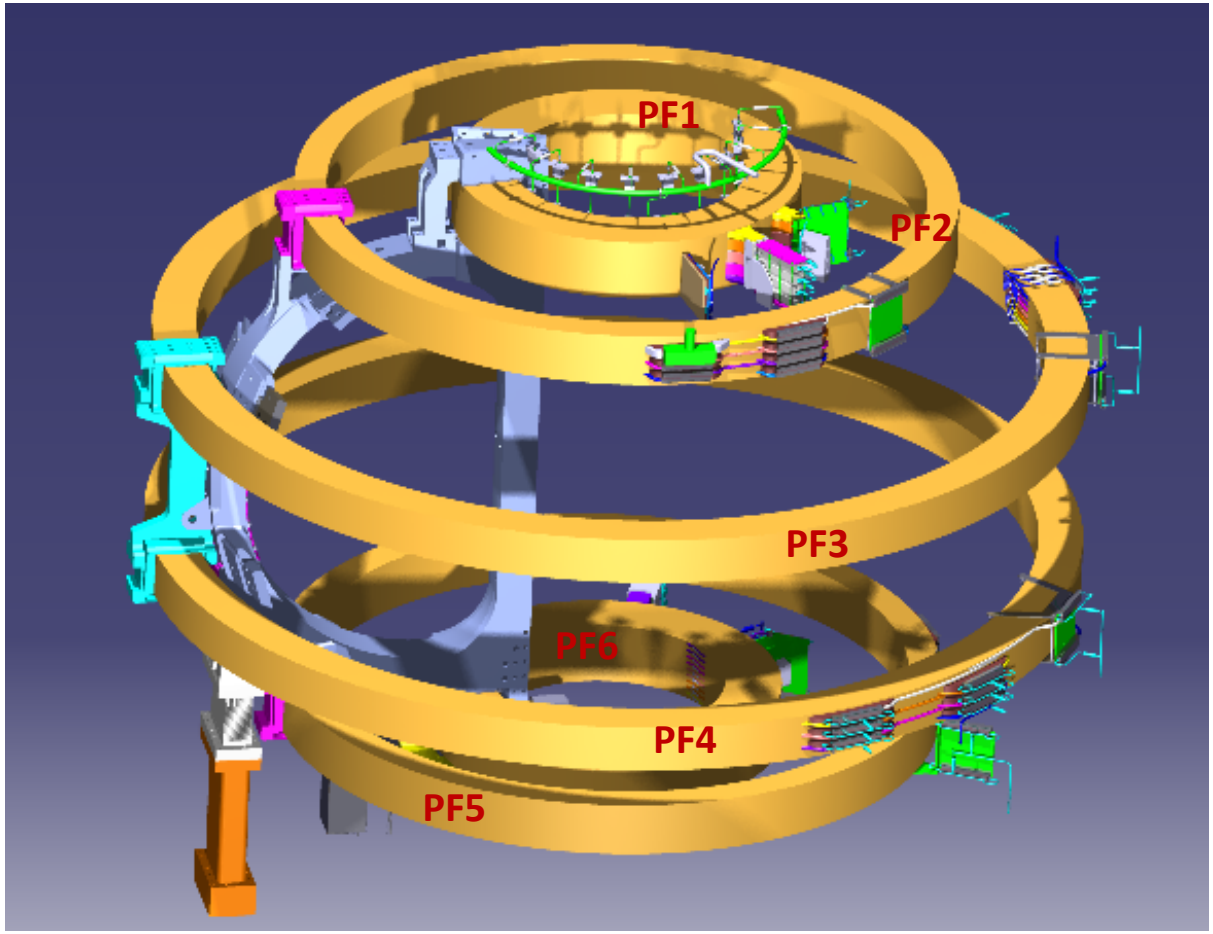
SIMIC Spa



18 TF modules

ASG SUPERCONDUCTORS

Poloidal Field coil system



PF1/6 – Nb_3Sn (Luvata):

- Bmax = 9,1 T
- I=10,2 MAt (Nt=360)
- M=15 ton
- D = 3,3 m

PF2/5 – NbTi (Furukawa):

- Bmax = 4,2 T
- I=4,3 MAt (Nt=160)
- M=16 ton

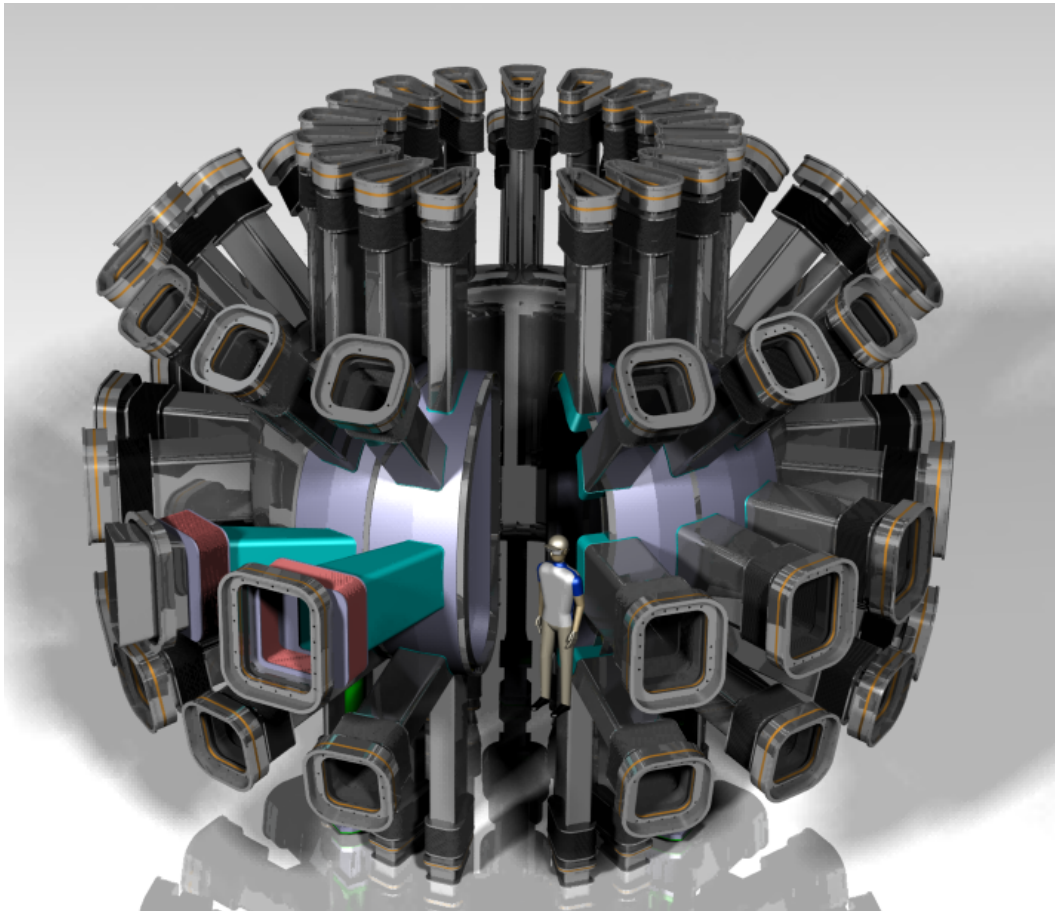
PF3/4 – NbTi (Furukawa):

- Bmax = 5,3 T
- I=5,6 MAt (Nt=196)
- M=28 ton

P-DRM -> 12-13/07/2018
C-DRM -> 19-20/02/2020
E-DRM -> 22/12/2020
Infoday fro industry -> 26/04/21

External Panel review -> 07-12/2021
S-DRM -> to be called in June 2022
Call for tender to follow in Autumn 2022

Vacuum vessel and ports



VVP:

- JT-60SA like double wall 316 lN
- Mass=37 ton (main vessel only, 175 ton all)
- Height = 3,9 m (main vessel only)
- Diameter = 2,5 m (inner) – 6.8 m (outer)
- Water in the interspace (borated later) as neutron moderator
- 14 x 20° + 2 x 30° + 1 x 20° special sector (including splice plates)
- 6 Gravity Supports + 82 ports (2 P3 inclined)

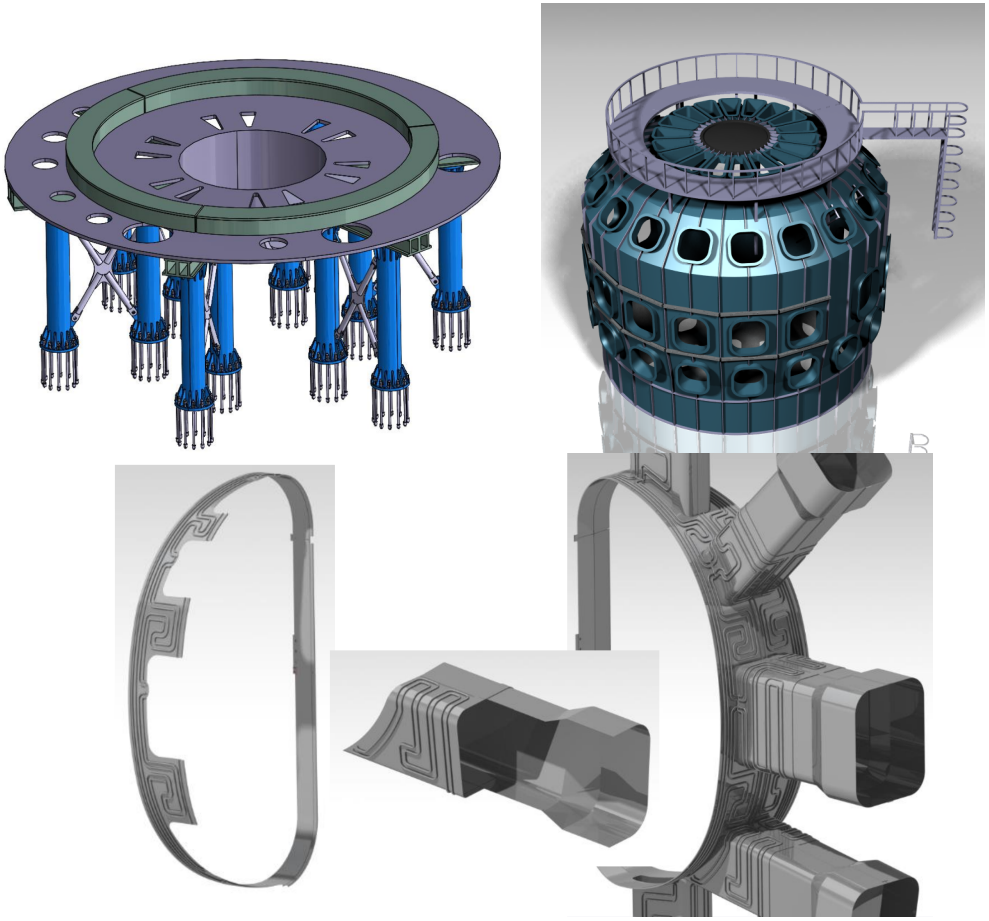
Procurement strategy:

- 12 months for engineering and prototype qualification
- 6 months for 1° sector
- 1 sector/month
- Sectors include P1, P3, P5
- Bellows, GS, P2 & P4 delivered a part
- Inner support structure for assembly

P-DRM -> 10/01/2019
C-DRM -> 13/03/2019
Infoday fro industry -> 09/12/21
E-DRM -> 20/12/2021

External Panel review -> 12/21-05/22
S-DRM -> to be called September 2022
Call for tender in Autumn 2022

Cryostat and Thermal shield



Cryostat:

- single-walled 304L(N) stainless steel
- Height = 9,4 m (cylindrical part)
- Diameter = 11,2 m (cylindrical part)

Cryostat base:

- 1° component to be assembled
- 12 columns
- Inner ring for TF support
- Inner depression for man-hole and He circuit

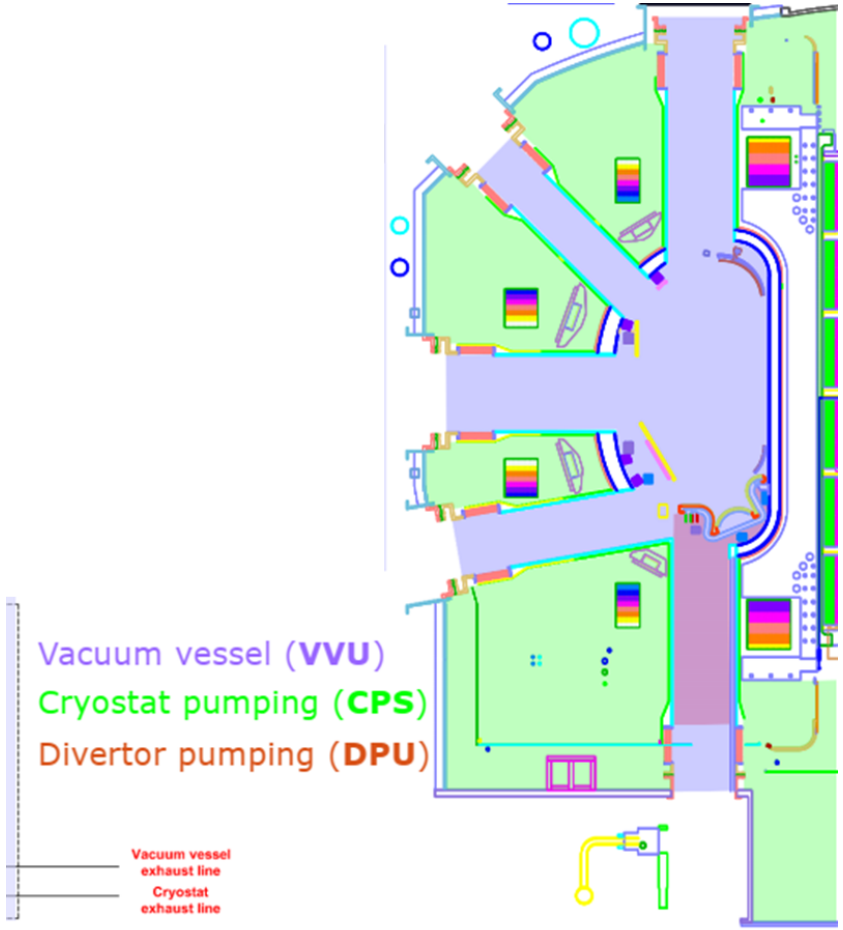
Thermal shield:

- Needed to start pre-assembly
- 316 lN
- K-STAR/ITER like
- Single shell with silver coating

Engineering design activities to be finalized in 2022

E/S-DRM-THS -> July 2022
E/S-DRM-CRS -> autumn 2022
Call for tender to follow soon

Vessel Auxiliaries



C-DRM-VAU -> mid ’22
E-DRM-VAU -> winter ’22
S-DRM-VAU -> spring ’23
Call for tender to follow later on

Pumping:
- Cryopump in 9 P5 (KIT design – JT60SA like)
- TMP + commercial cryo for VV & CRS

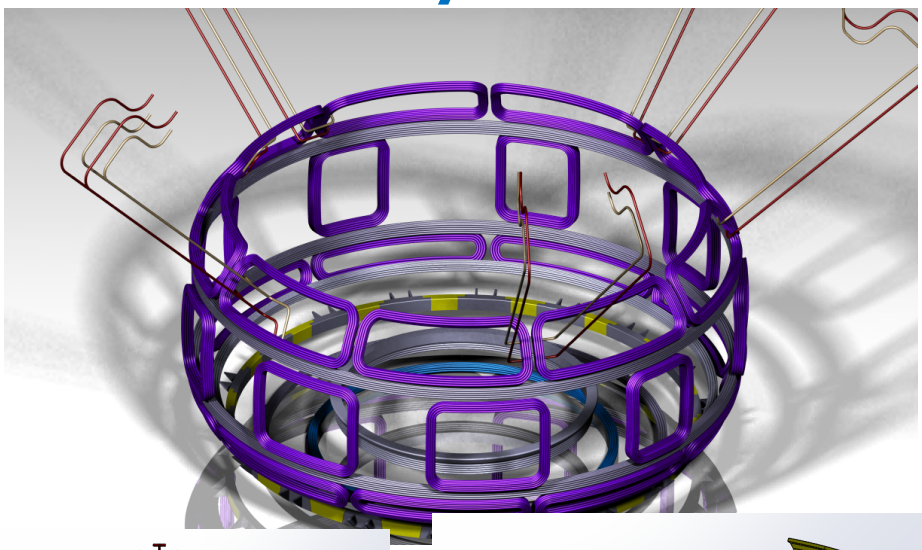
Fueling:
- Gas puffing for divertor
- Pellet from P3 to equatorial plane inner side
- MGI

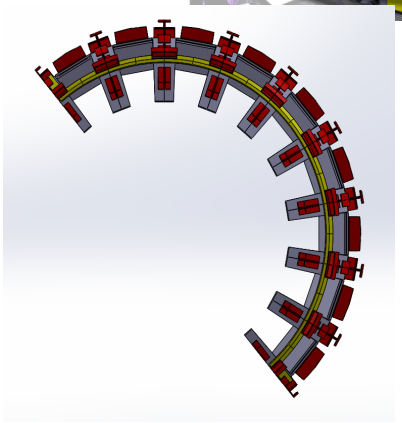
Cleaning & conditioning:
- Baking through heating of the vacuum vessel;
- Glow discharge with the electrode to be inserted by port 1;
- Boronization of the PFCs;
- ECWC and ICWC

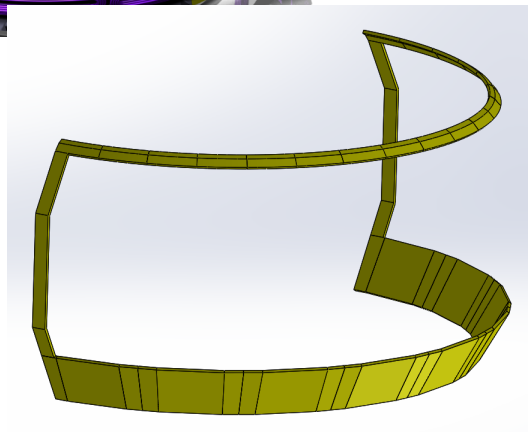
Only preliminary analyses to fix requirements have been carried out so far.

Support from KIT (C. Day) within Eurofusion

In-Vessel systems







In-vessel coils:

- 27 not-axial symmetric coils, devoted to control ELM events and to the error field correction (EFC)
- 2 axial symmetric in-vessel coils to stabilize plasma
- 4 axial symmetric in-vessel coils under the divertor, for the X-point sweeping
- 2 rails for divertor support (18 demountable segments one for each P4)

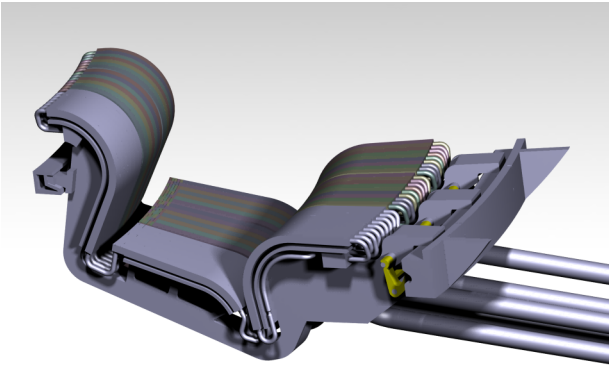
Stabilization plate:

- ASDEX-U like
- 30 mm thick

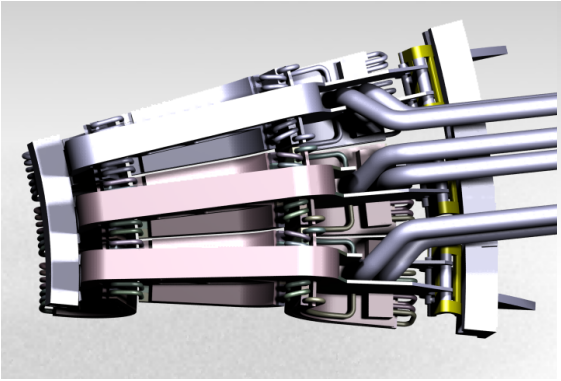
Engineering activities just started including EM and thermos structural analyses
Interface analyses with PFC and HCD completed

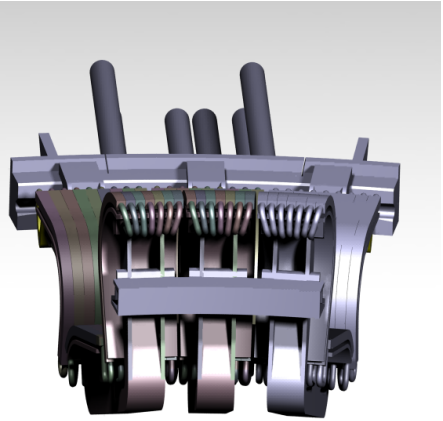
C-DRM-INV -> 12/21
E-DRM-INV -> autumn ‘22
S-DRM-VAU -> winter ‘22
Call for tender to follow later on

Divertor system



Conceptual design of carried out jointly with EUROFusion in WPDIV-IDTT: no showstoppers identified





Divertor

- 54 cassette
- > 20 MW/m^2 steady state
- M< 400 kg (max allowed weight)
- Hot Radial Pressing HRP with W monoblocks (ITER-like technology)
- Compatibility with SN – XD – NT scenarios
- RH compatibility checked
- Wide range of water parameters for flexibility (30°-130° C, up to 5 MPa)
- Pumping verified
- 4 central modules with additional flexiblity

Procurement strategy:

- R&D on small mock-up
- Prototype for manufacturing qualification
- 3 parallel lines for PFU (IVT, Dome, OVT)
- Integration into cassette
- Assembly in vessel

P-DRM -> 13/03/2019
C-DRM -> 07/01/2022
E-DRM -> autumn ‘22
Call for tender to follow for:

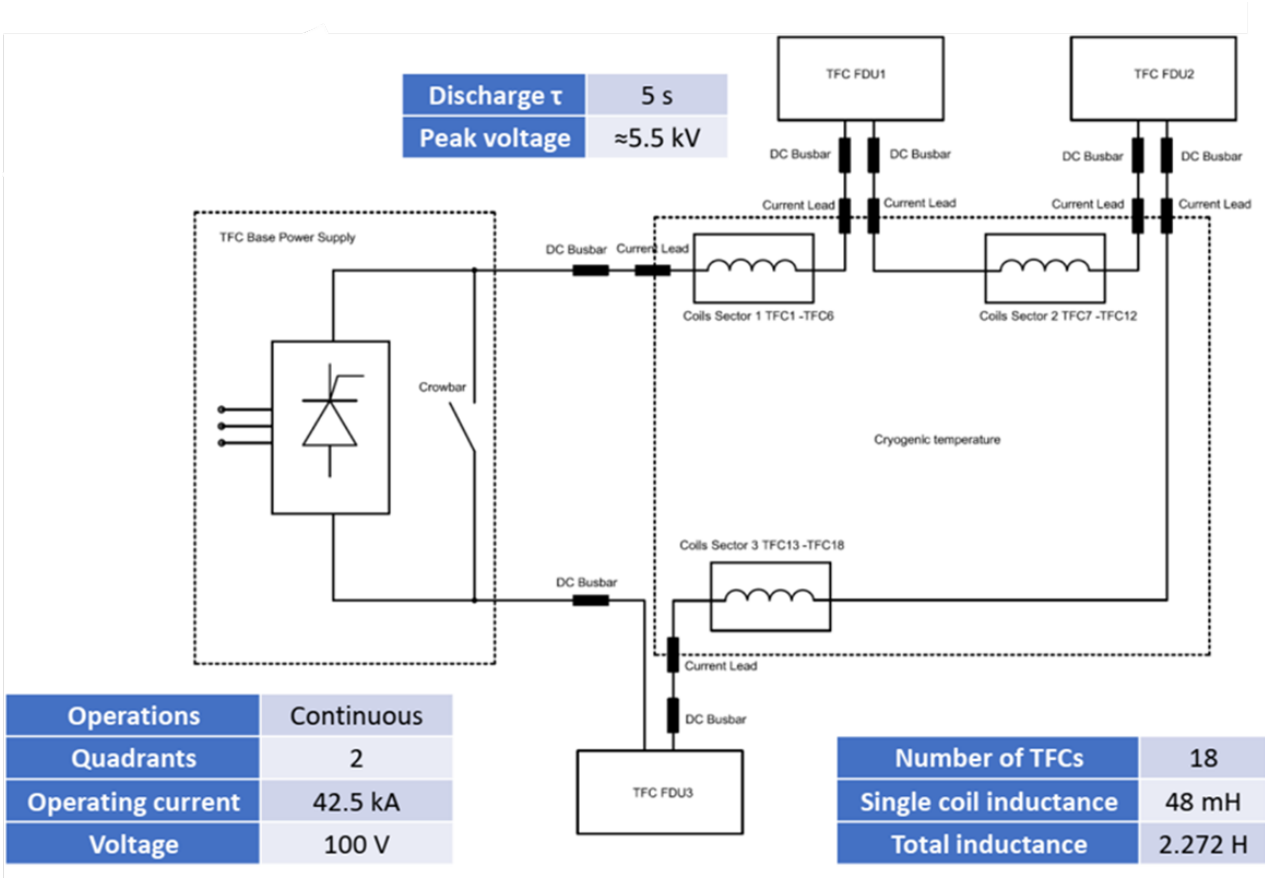
- W monoblocks
- Ovens for PFU
- Cassette manufacturing

Toroidal field coil power supply

Tender for TFC power supply has been awarded to **JEMA Energy**. KoM took place on 22/03/22. Delivery expected within 18 months from KoM in time for the cold test facility commissioning. TFS will be located in building 184 close to the Torus Hall.

Tender for FDU awarded to **OCEM**. KoM to Delivery on 25/5/22. First delivery within 18 months from KoM in time for the cold test facility commissioning.
The design introduced some novelties wrt to JT-60SA:

- 25.7 kA -> 42.5 kA
- <2.8 kV -> >5.5 kV
- Quasi linear discharge



Other power supply systems

Poloidal field power supplies

- Suggestions of the External Panel review being integrated
- Call for Tender immediately after the CfT for PF coils

Central Solenoid power supplies

- Under review following new CS design
- Call for Tender March 2023

In vessel coils power supply

- Design being finalized
- Call for tender linked to PNRR

Other machine systems

Diagnostics

- Assets from JET and FTU shall be recovered and adapted for DTT initial operations.
- Call for tender for magnetics most urgent

Remote Handling

- Two systems for the RH of the in-vessel components:
  - Hyrman (Hyper Reduntant Manipulator)
  - CMM & CTM (Cassette multifunctional and Toroidal Mover)
- Cut and welding tooling are under evaluation.
- Call for tender linked to PNRR

Assembly

- Assembly strategy under re-evaluation.
- Call for tender in 2023

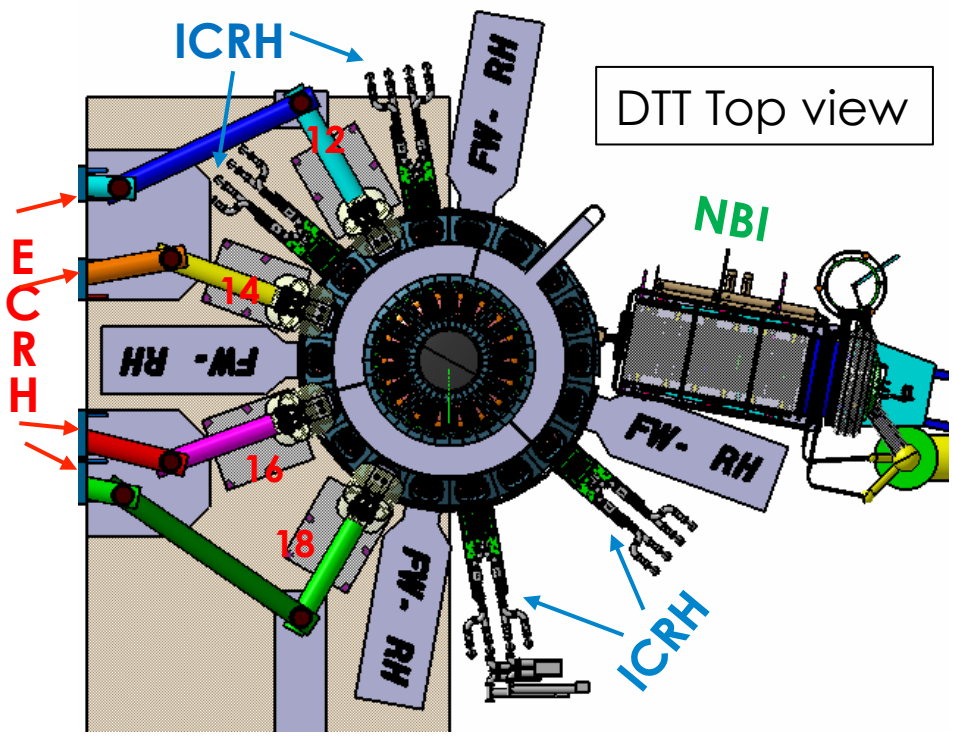
Heating systems

Up to **45 MW** of additional heating power to DTT

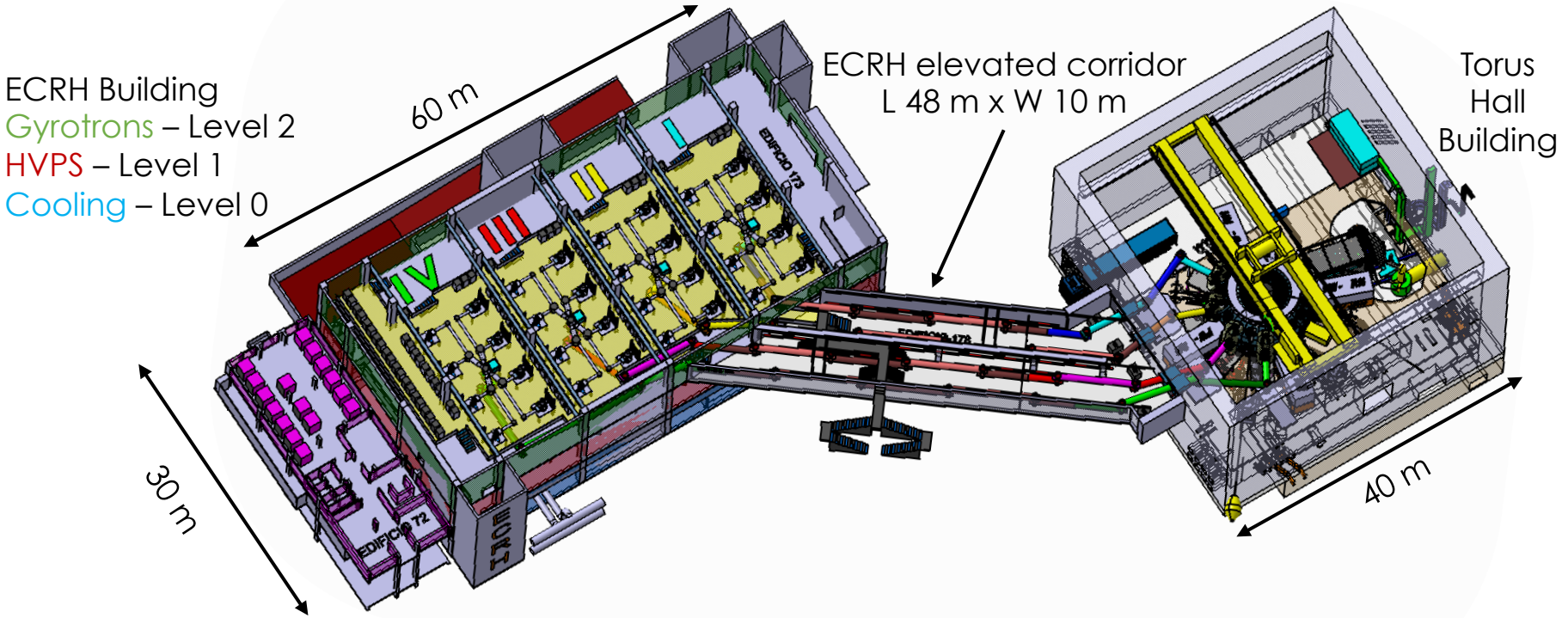
ECRH
- 16MW first phase
- 32MW second phase
- Gy. Joint proc. with F4E

ICRH
- 4MW first phase
- Solid state transmitter

NBI
- 10MW 500keV
- Procurement on hold



ECRH general layout



The ECRH system is organised in 4 Clusters, connected to the DTT sectors 12, 14, 16, 18, each one composed by:

- **8 Gyrotron sources** fed in pairs by **4 Main High Voltage Power Supply**.
- **1** Evacuated Quasi-Optical Single/Multi-Beam **Transmission Line** delivering the 8 microwave beams from gyrotrons to one tokamak sector.
- **8** Independent pairs of **launching mirrors** located in the equatorial (6 lines) and upper port (2 lines).

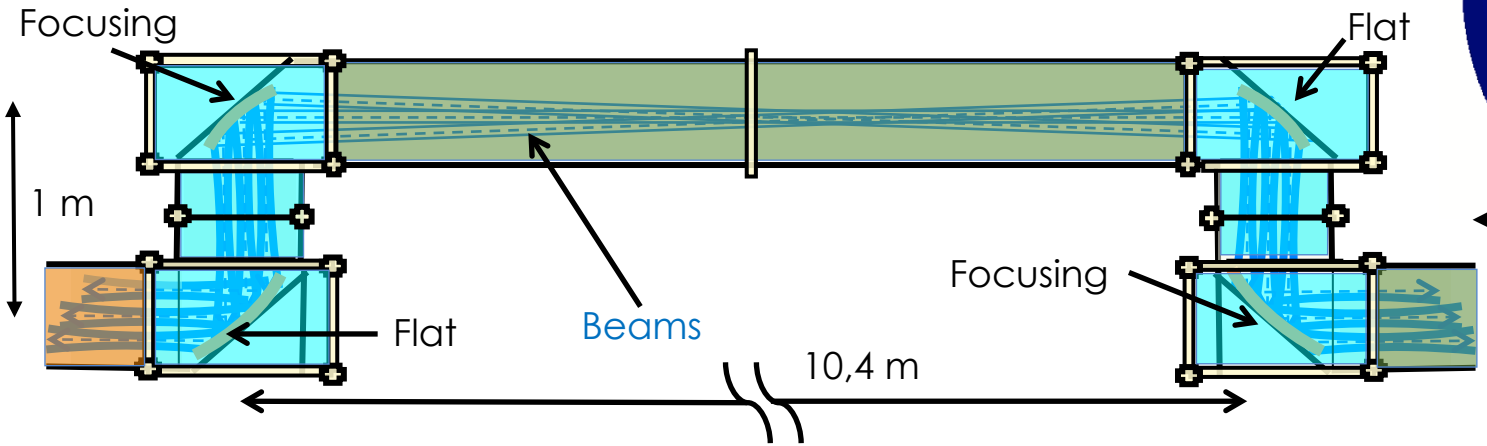
Transmission Line (TL)

Quasi-Optical **Gaussian** beam **propagation** produced by focusing **mirrors** in a confocal arrangement.

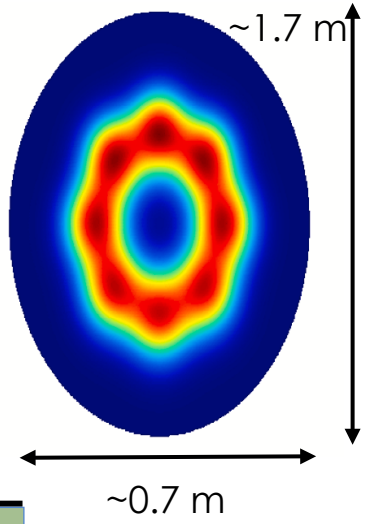
Novelty: TL mirrors embodied in a vacuum enclosure using large metal seals, to avoid losses due to air absorption and microwave leaks

- Efficiency target > 90%
- Designed for up to 1.5 MW per single beam

Multi-Beam TL: 8 Gaussian beams share a set of oversized ellipsoidal focusing and flat mirrors



Expected normalized heat load distribution of 8 overlap 1 MW beams on a MBTL mirror surface



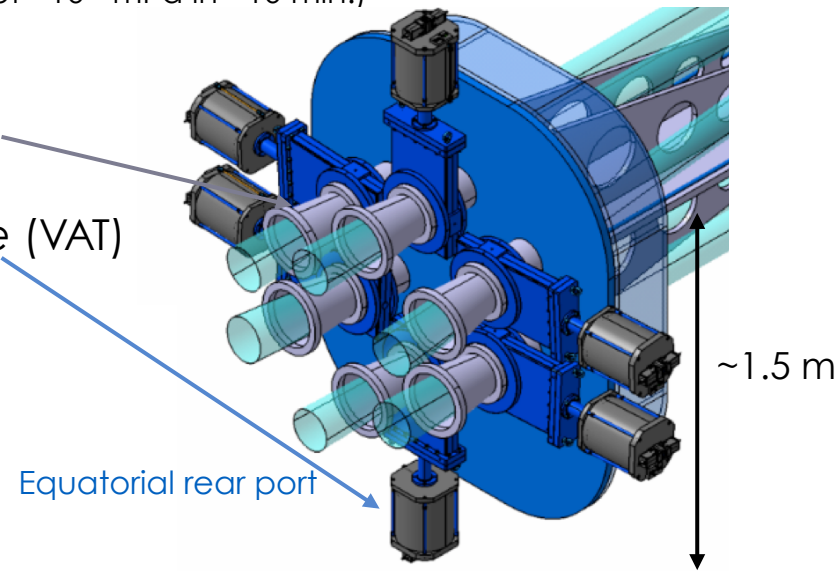
TL Vacuum pumping system

Vacuum envelope
Material: **SS** (lighter option in **Al** to be evaluated)
Target pressure: **~1 mPa**
Volume: from **68** m^3 to **87** m^3
Bellows to accommodate thermal expansion

Line	Diameter [mm]	Thickness [mm]	$Length_{MAX}$ [m]
SBTL	300	3	5
MBTL	800	6	10

Preliminary design:
- Two pumping systems at the ends of each TL (1 near gyrotrons , 1 close to the DTT Hall)
- **Primary vacuum**: Dry fore vacuum pump with roots pump (from atm. to ~10^2 Pa)
- **High vacuum**: TurboVAC pump or NEG (to get ~10^{-1} mPa in ~10 min.)

Connection of TL with DTT vessel:
- Conical section **L=450mm, Dia=150mm**
- Gate valve to regulate the access
  Reference: *ITER RF all metal Gate Valve* (VAT)
- DTT Vacuum: **~10^{-2}-10^{-3} mPa**
  (**~10 mPa** during plasma discharge)
- DTT Plasma Volume: **~30 m^3**
- Valve normally closed
- No diamond window

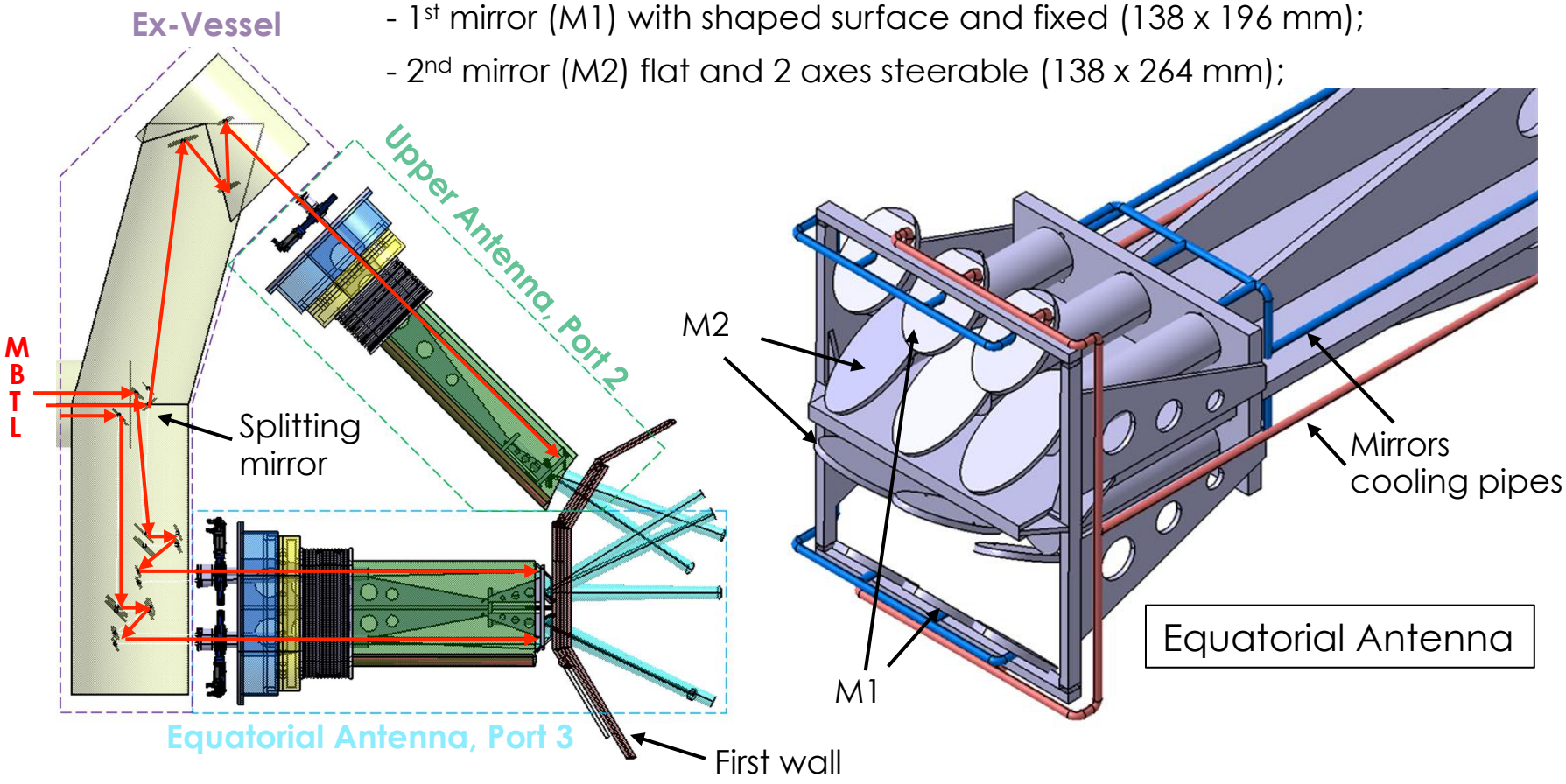


Launcher design

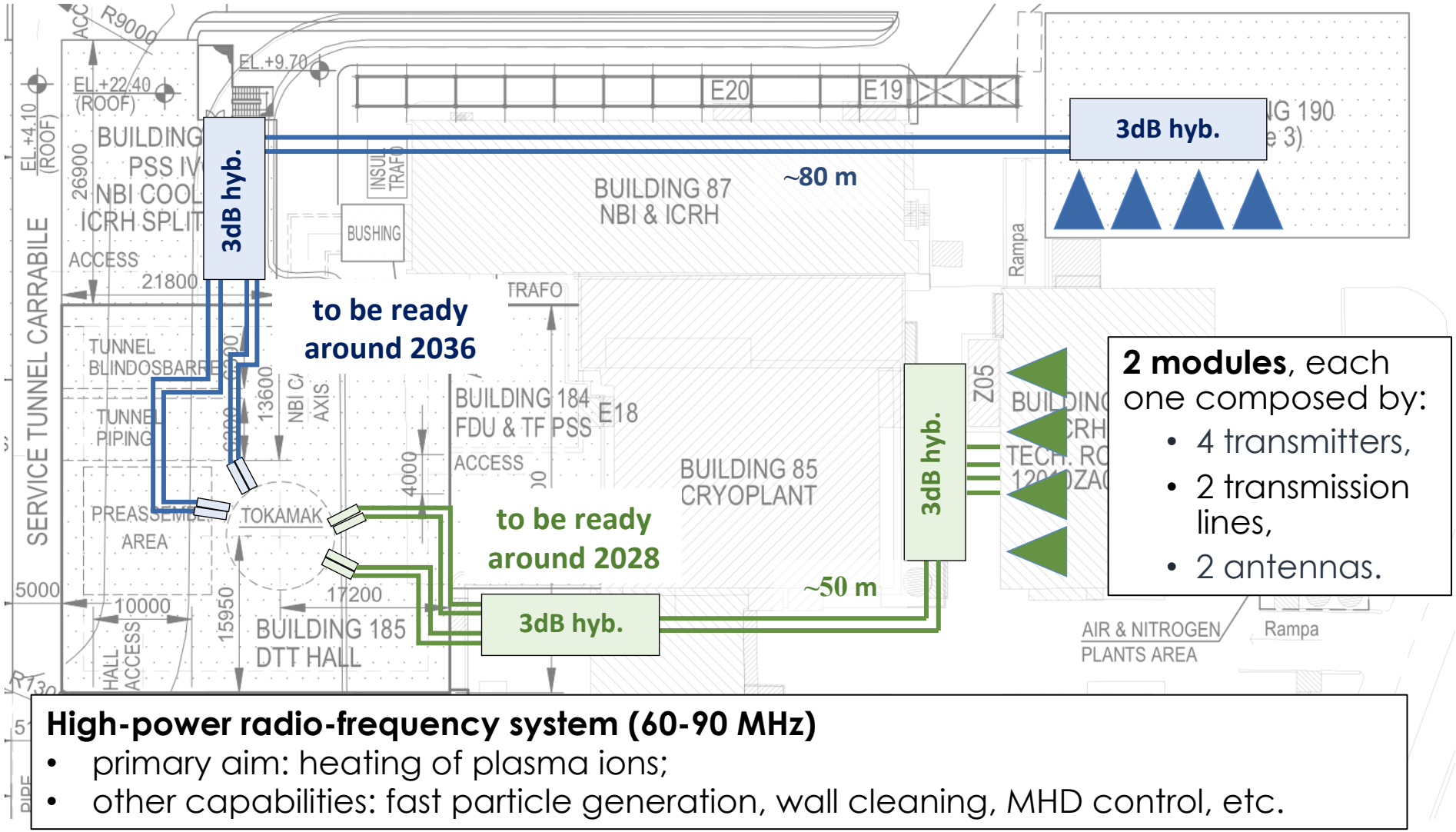
8 Independent beams <u>front steering concept</u> per DTT sectors (**6x** in *port 3* and **2x** in *port 2*) real time controlled.

Each launcher consists of 2 mirrors made of 12 mm CuCrZr alloy + 2 mm of copper, water cooled.

- 1st mirror (M1) with shaped surface and fixed (138 x 196 mm);
- 2nd mirror (M2) flat and 2 axes steerable (138 x 264 mm);



Ion cyclotron resonance heating



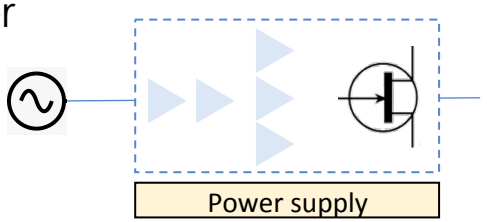
High-power radio-frequency system (60-90 MHz)

- primary aim: heating of plasma ions;
- other capabilities: fast particle generation, wall cleaning, MHD control, etc.

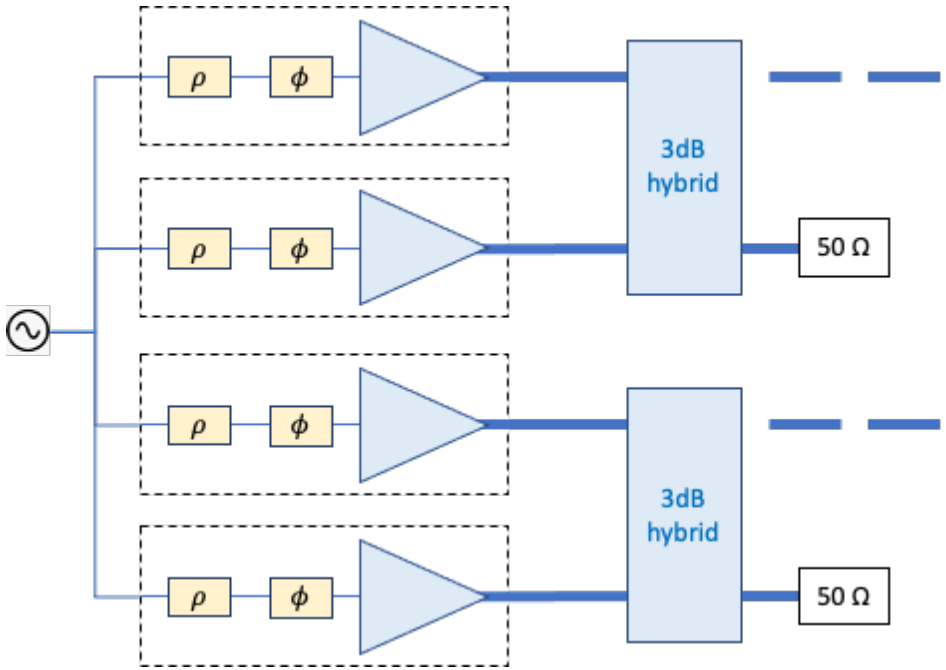
Transmitters

Broadband high-power solid-state amplifiers, capable to deliver

- 1200 kW for pulses of 50 s every hour
- close to 200 kW for long pulses (~ CW)
- ≤ 100 kW for short pulses with high accuracy (±2 kW)



1st system of this kind (~1000 LDMOS) => open nuclear fusion to solid-state technology



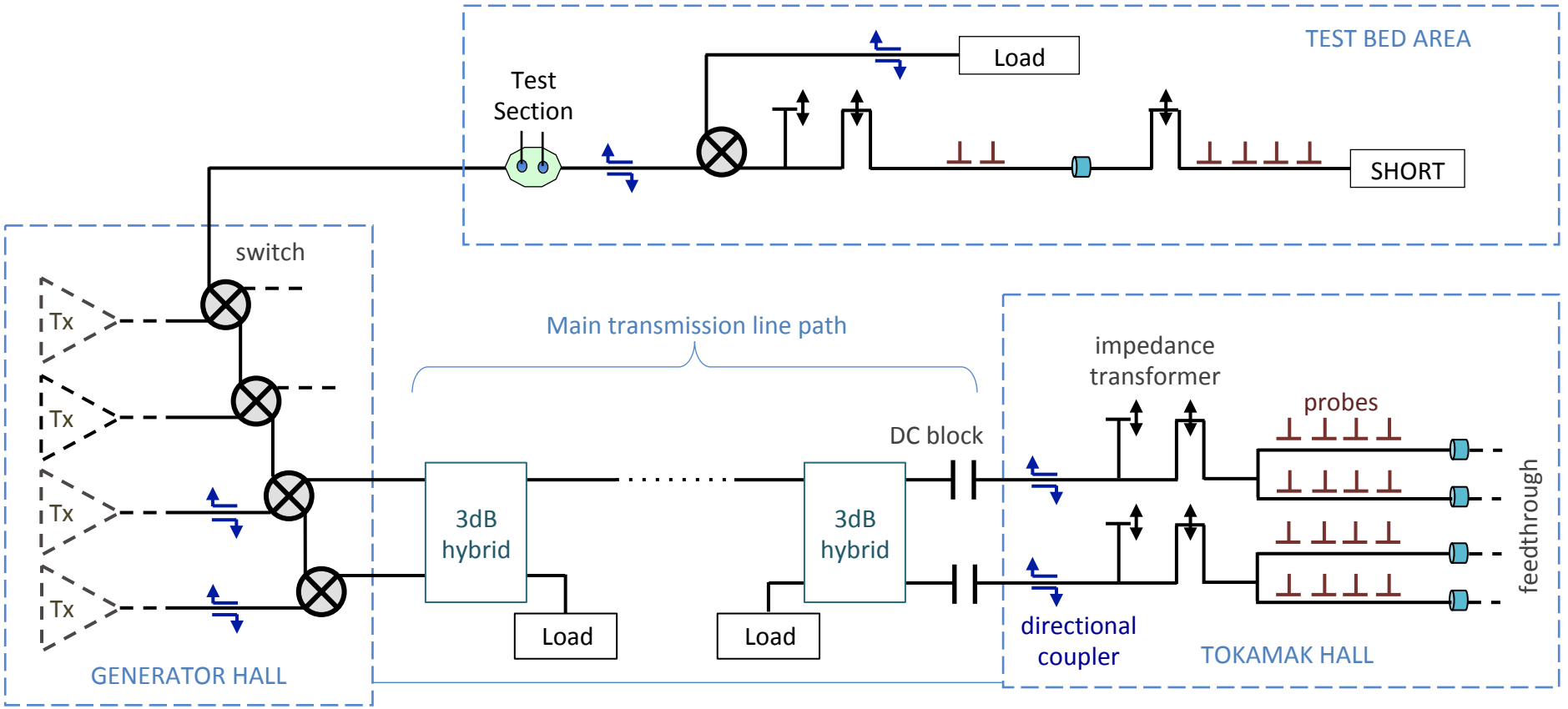
Procurement steps:

- Market survey completed
- Ongoing preparation of technical specs
- Call for tenders around end of 2022
- Tight schedule: prototype in 2023

- Modular system with easy maintenance.
- Need of proper amplitude and phase control of output waves.

Transmission line & matching

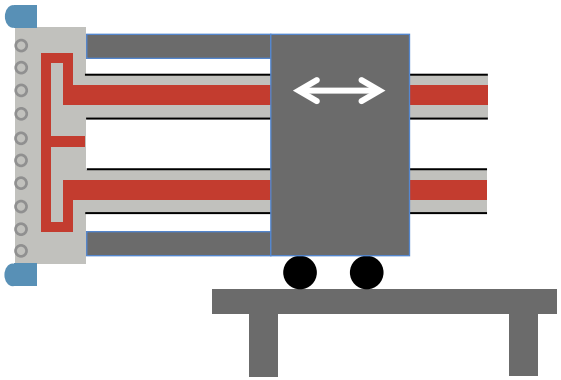
Hundreds of meters of rigid coaxial cable (EIA 9 3/16'') and associated components.
Call for tender to be issued in 2022, at least for the test bed components.

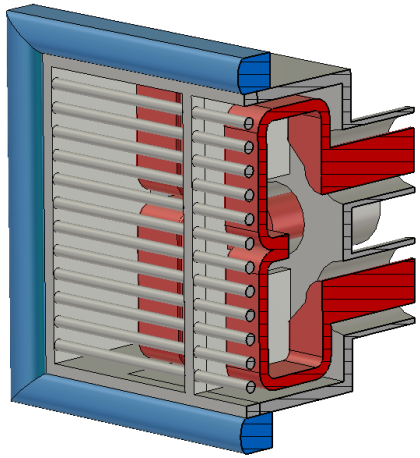


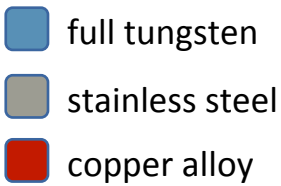
Antenna

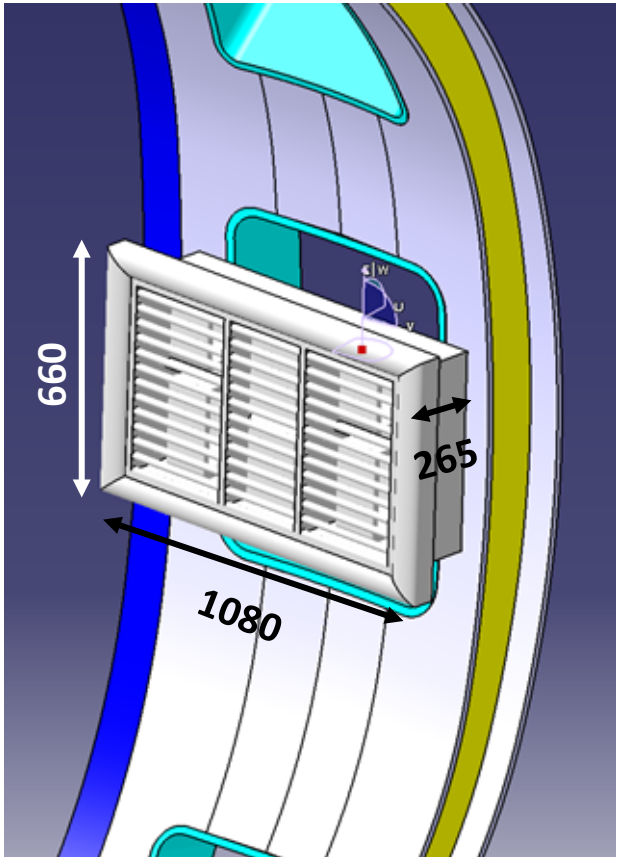
Some tasks to be outsourced

- detailed design of cooling circuit,
- detailed mechanical design,
- antenna manufacturing (precision mechanics, many internal cooling channels, difficult brazings, …),
- development of moving system to radially shift the antenna ~10 cm.









Other needs: km of cables (twisted pair, RG-59, optical fibres, …), instrumentation and control (PLC, FPGA, vector network analyser, low-power RF components, …)

Schedule of the auxilairy heating CfT

ECRH:

Gyrotron tender assigned: completion 2027

HVPS + AUX for gyrotron:

S-DRM Sept. 2022

Market Survey Sept. 2022

Call for Tender: Nov . 2022

T**L Vacuum System**:

C-DRM Dec. 2022

E-DRM Dec. 2023

Call for Tenders 2024

Launcher :

C-DRM June. 2023

E-DRM June. 2024

Call for Tenders 2025

ICRH:

Solid State Transmitter

Market Survey completed

Cal for Tender Sep. 2022

TL components:

C-DRM Dec. 2022

S-DRM: Apr . 2023

Cal for Tender Sep. 2022

Cal for Tender May. 2023

Antenna :

C-DRM Nov. 2022

S-DRM June. 2024

Call for Tenders July 2024

Concluding remarks

- ✓ DTT is progressing in the construction phase
- ✓ Contracts for a total of 170M€ are ongoing
- ✓ Over the next year contracts for a total amount of about 200M€ will be placed
- ✓ The construction of DTT is a challenge and an opportunity. Its success requires an adquate organization.

Aknowledgments

DTT community recently reached more than 200 members. The results shown in this presentation were obtained thanks to the efforts and commitments of a large number of researchers spread over several European laboratories. This testifies the role of largest Italian research infrastructure that DTT is going to play.

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