The DTT project: status and opportunities for the Italian scientific community

Francesco Romanelli
University of Rome "Tor Vergata"
President DTT scarl

Conferenza Italiana Plasmi

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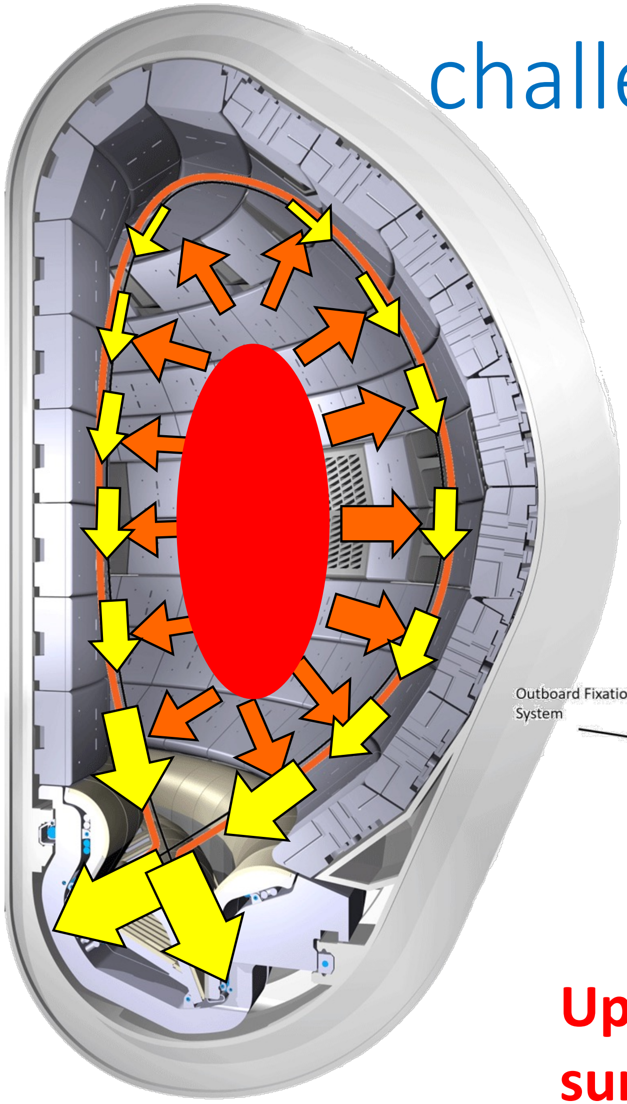
Acknoledgments: G.M. Polli, G. Granucci, N. D'Auria, M. de Sanctis, G. Giruzzi, F. Crisanti, P. Martin

Outline

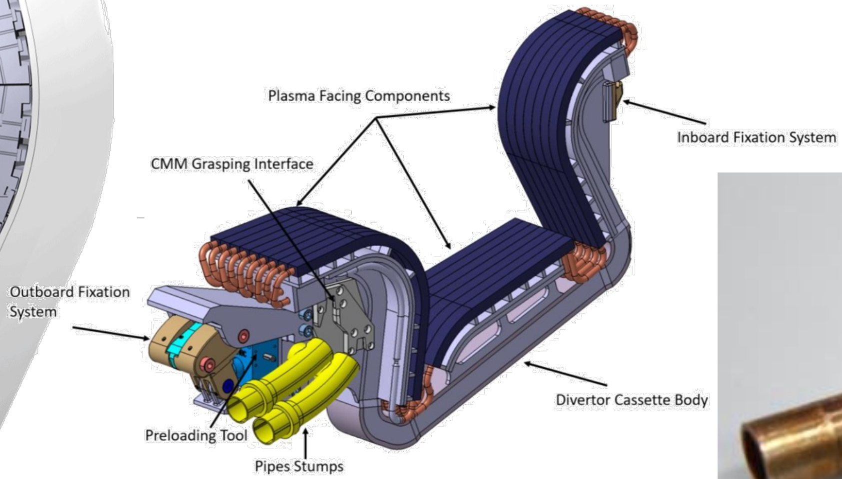
- How DTT can contribute to the solve the heat exhaust problem and support ITER development.
- Status of the construction
- DTT and the Italian scientific community

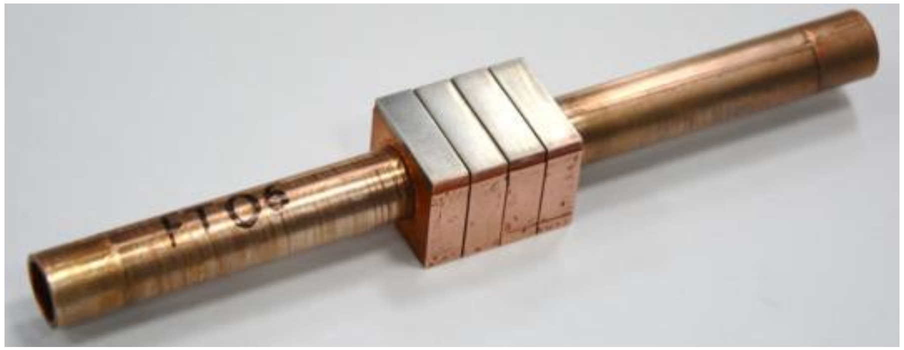
The heat exhaust is one of the main challenges for a fusion power plant



DTT goals:

Test innovative magnetic configurations for the divertor and advanced materials

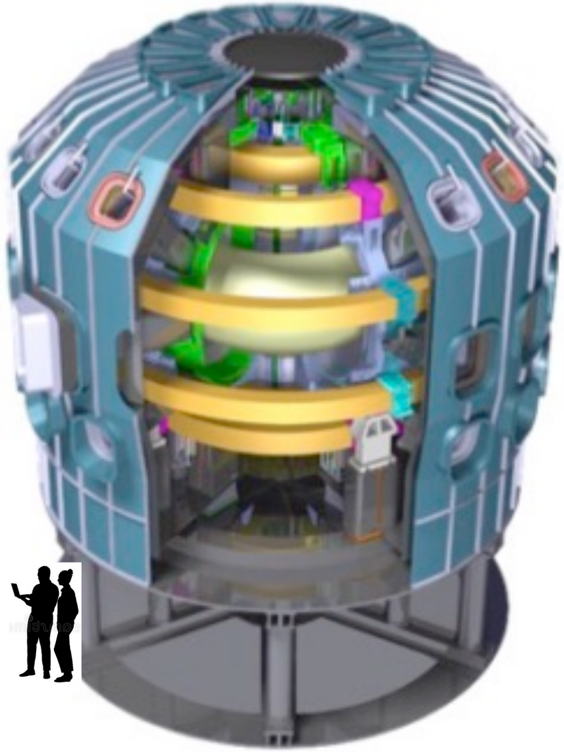




Up to 60MW/m^2 in fusion power plant = heat flux on the surface of the Sun!

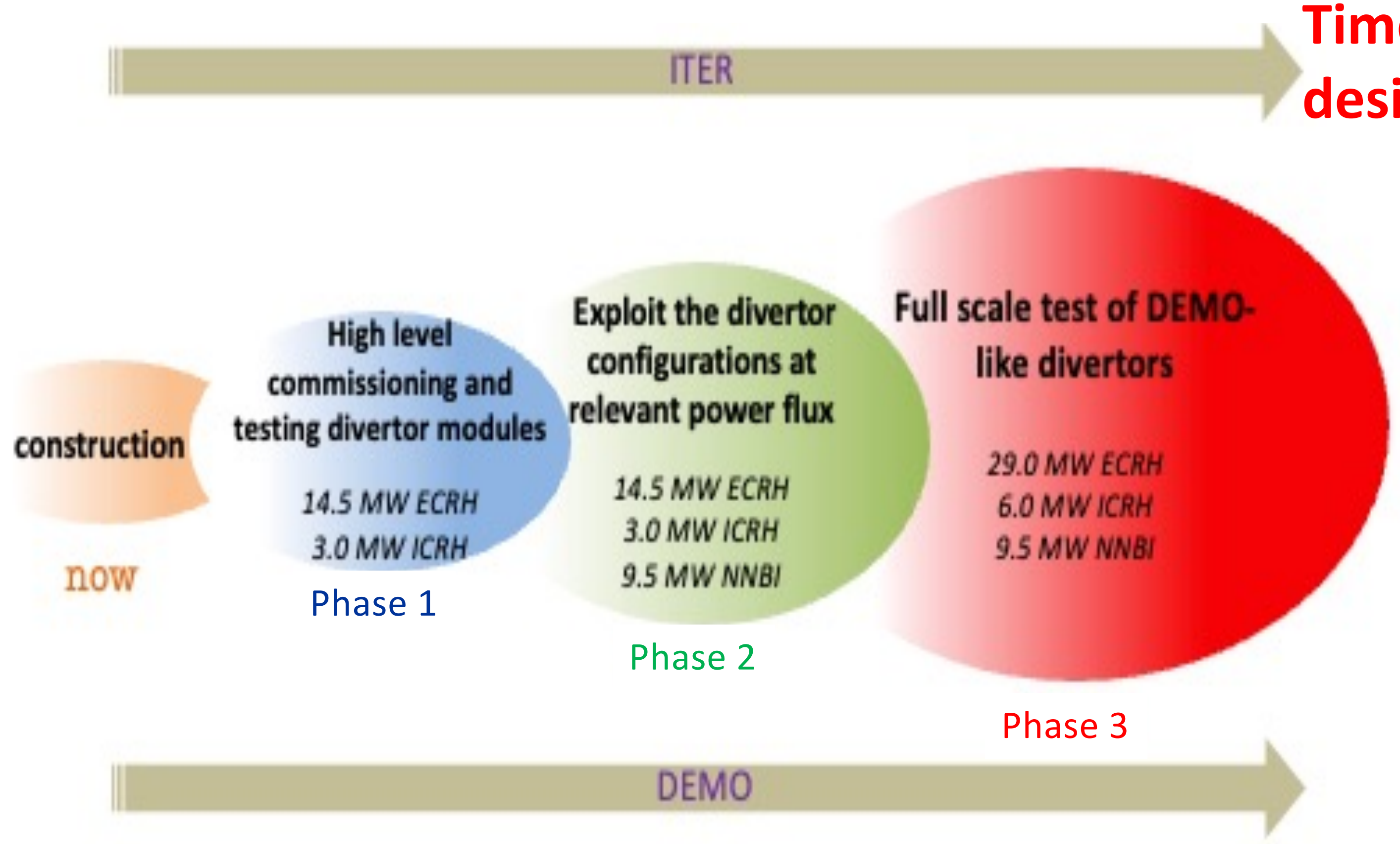
DTT main features

- **Breakeven class performance** (magnetic field B = 5.85 T, plasma current I_p = 5.5 MA) to produce ITER/DEMO relevant plasmas
- **Superconducting** magnetic field coils → **pulse length** in the range of several tens of sec.
- **Full-W actively cooled** plasma facing components, same material as DEMO and ITER.
- Capability of investigating **various divertor configurations**.
- Compact dimensions (**R = 2.19 m a = 0.7 m)** and large heating power (**P = 45MW**), to mimic reactor divertor heat loads

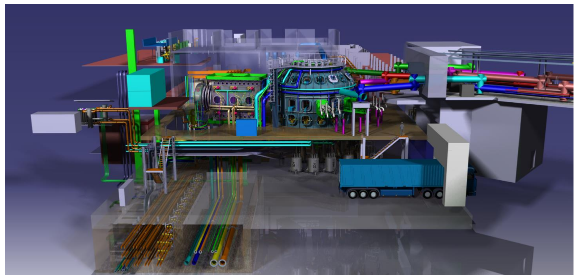


DTT scientific exploitation

Timeline coherent with EU DEMO design and ITER preparation



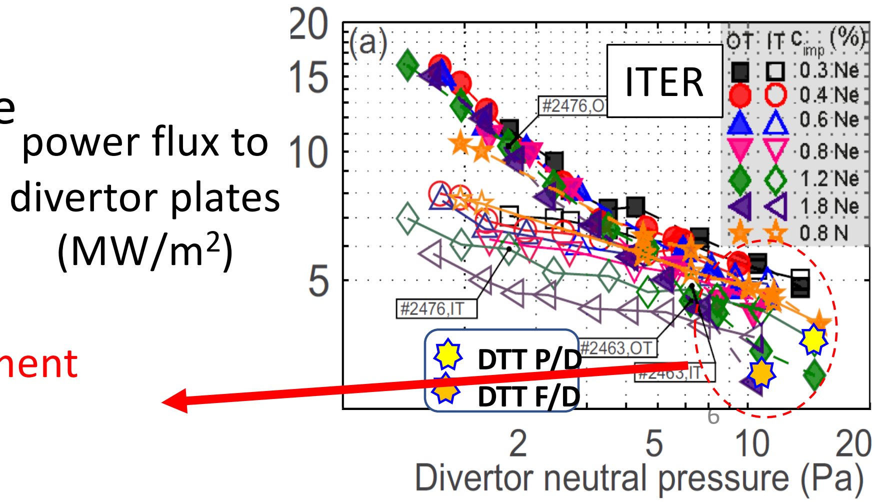
DTT
DIVERTOR TOKAMAK TEST facility
Research Plan
Version 1.0 - March 2024



DTT Research Plan released in 2024.
Letter of interest in participating received by US DoE

Core-edge integration

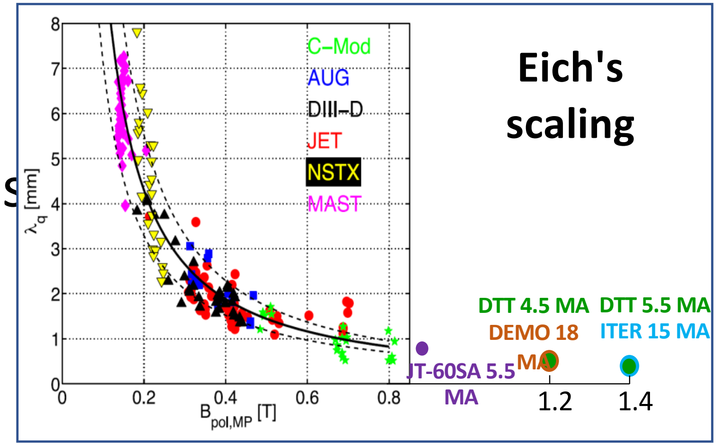
- The solution of the heat exhaust challenge requires the demonstration of regimes of operation that satisfy core (fusion power), edge (ELMs) and divertor (detachment) conditions.

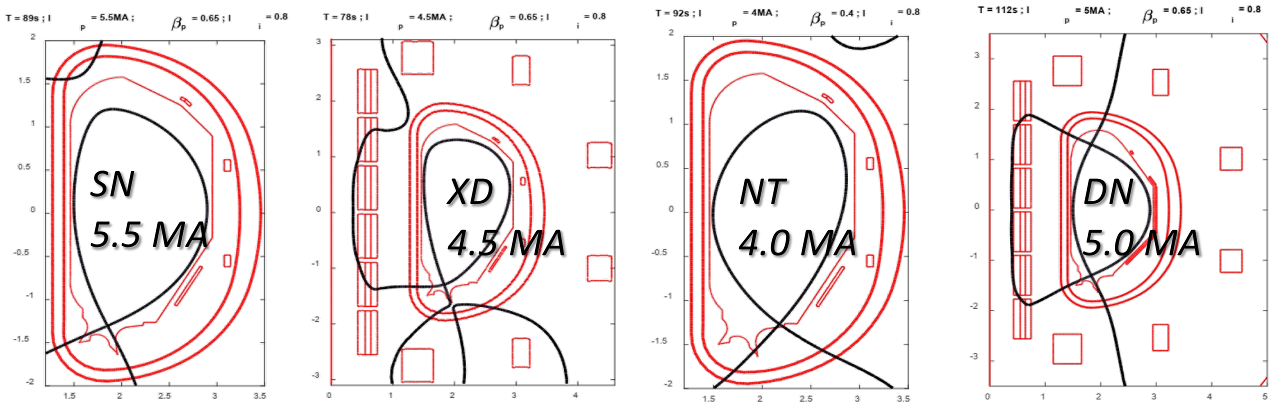


- Core-edge integration in a full-W device
  - High confinement / small ELM and ELM-free conditions at reactor relevant separatrix densities and pedestal collisionalities
  - High radiating fraction scenarios and impurity behaviour at reactor values of P_{sep}/R and neutral opaque edge
  - Access to full field / full current baseline scenarios for reactor relevant edge/SOL, and half field / half current advanced scenarios for reactor relevant normalized pressure
  - Advanced active control strategies and reaction to off-normal events (including disruptions)

Power exhaust and plasma operation with W PFC

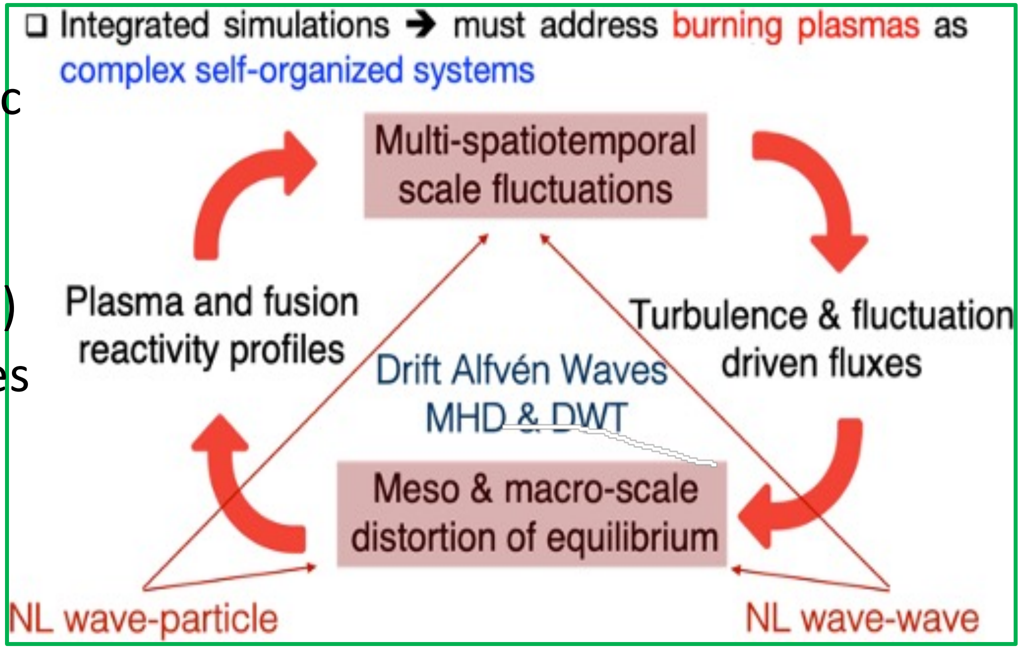
- Investigate power exhaust, with ITER/DEMO reactor relevant
  - core confinement properties
  - with ITER/DEMO relevant Scrape Off Layer (SOL) widths and exploring SOL width scaling with various plasma parameters
  - low pedestal collisionality at high density
  - high poloidal and toroidal magnetic fields
  - access to detachment in different divertor magnetic configurations





Energetic particle physics

- Energetic particle physics
  - Reactor relevant regimes with same energetic particles dimensionless parameters
  - Flexibility in the fast particle distribution thanks to ICRH + negative ion injection (NNBI)
  - New physics expected from energetic particles interacting with instabilities and turbulence
  - Unique capability of validation of physics based models

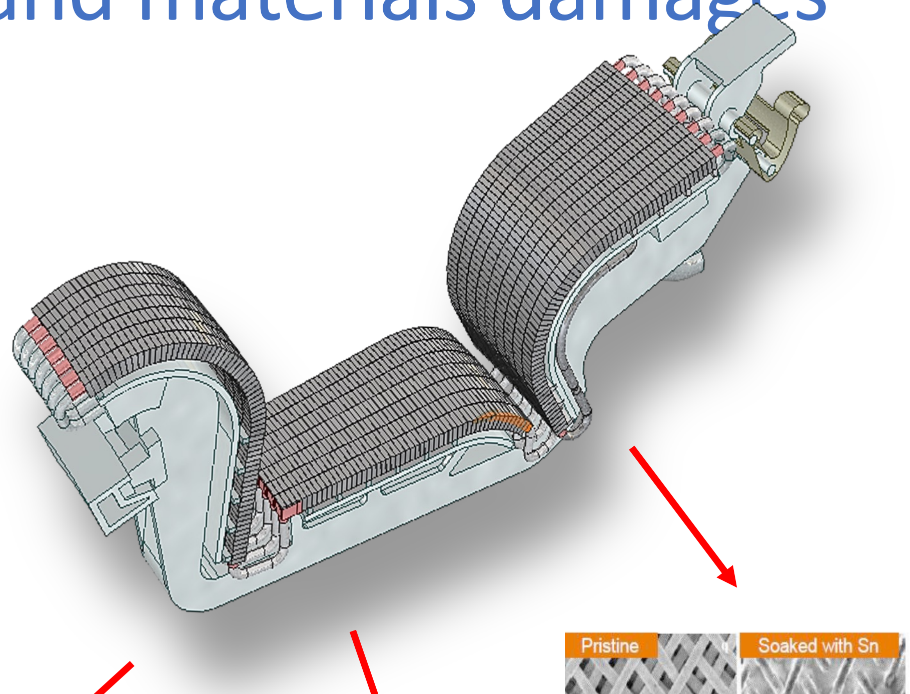


- DTT has the same heating mix as ITER
  - ECRH: (32 MW/170 GHz) (electron heating and current drive)
  - ICRH: (8 MW/60-90 MHz) (electron and ion heating; fast ion production)
  - NNBI: up to 10 MW at 512 keV (negative ion technology; dominant electron heating; current drive; fast ion production)

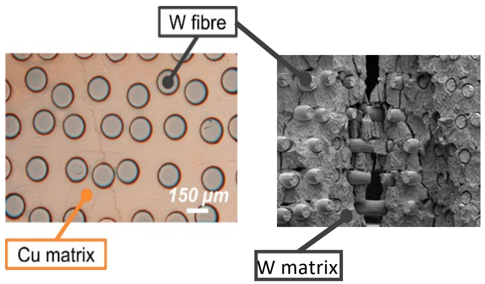
Alternative divertors materials and materials damages

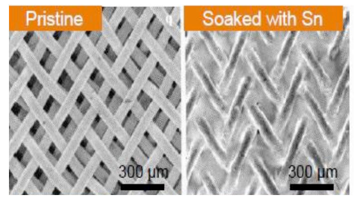
- Four DTT ports dedicated to advanced divertor material test (e.g. Wf/W, printed W, FGMs etc.)
- Liquid metal solution for divertor PFCs on basis of Sn technology (exploring EU programme solutions), assessing the impact on the global performances and the tritium retention
- Improving the understanding of the impact of material damage on the operations
- Runaway electron damage studies and PFC damage minimisation (e.g. use of W foam)

Divertor Test Module



3D Printed W





Liquid metals

Outline

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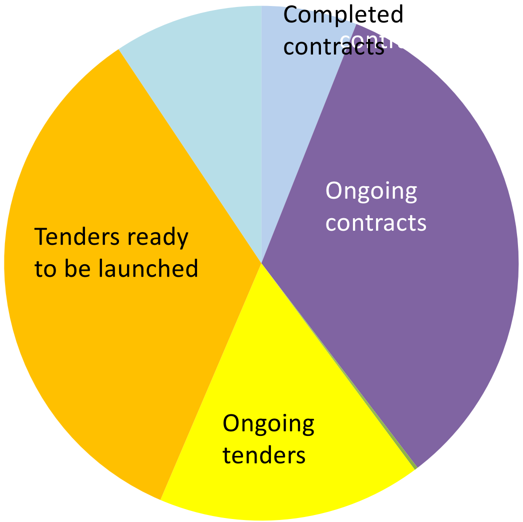
DTT construction status



- **About 40% of the budget already committed in industrial contracts:**
  - TF magnet and power supply
  - Strand and cables
  - Vacuum Vessel
  - Remote handling
  - In-vessel coils power supplies
  - 170GHz gyrotrons and loads
  - Ion cyclotron transmitters and test bed
- **About 17% of the budget in ongoing tenders**
  - Tender for the building under evaluation. Contract signature first half 2026. Excavation starting second half 2026.
  - Tender for the PF coil ongoing.
  - Tender for the divertor tiles outer target

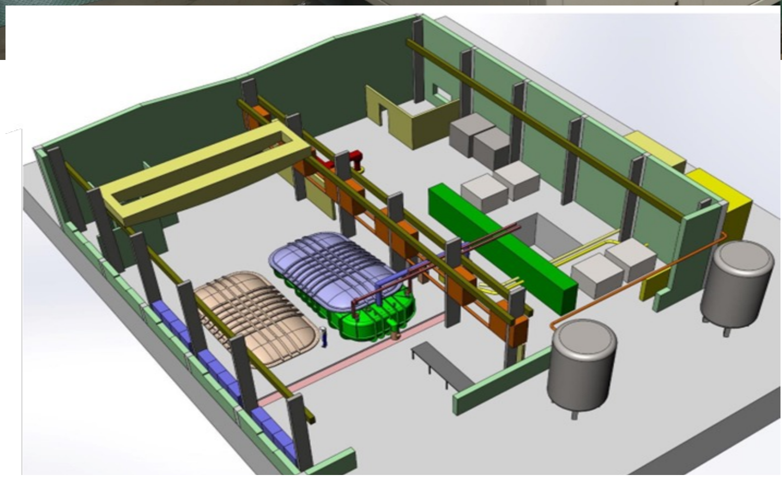
TF Winding Pack and integration

- ✓ All Winding Pack (WP) manufacturing qualifications completed
- ✓ Six WP completed and tested.
- ✓ All WP completed and tested by the

TF casing contract (De Pretto) ongoing

First casing expected early 2027

Toroidal Magnetic Field power supply



- The TF power supply has been delivered to DTT in 2024 and installed in the Frascati Cold Coil Test Facility.
- First Fast Discharge Unit (OCEM) arrived in Frascati end 2024

Strands for DTT superconducting coils

Strand for TF (Nb3Sn): procurement completed in 2021

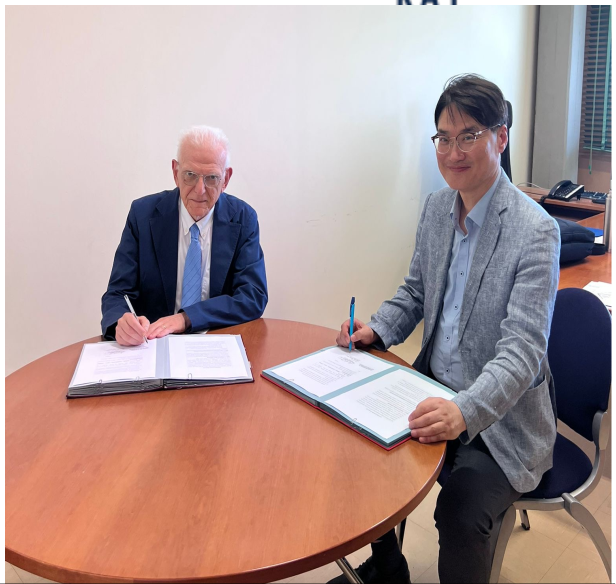
Strand for PF2-PF5 (NbTi): procurement completed in 2022

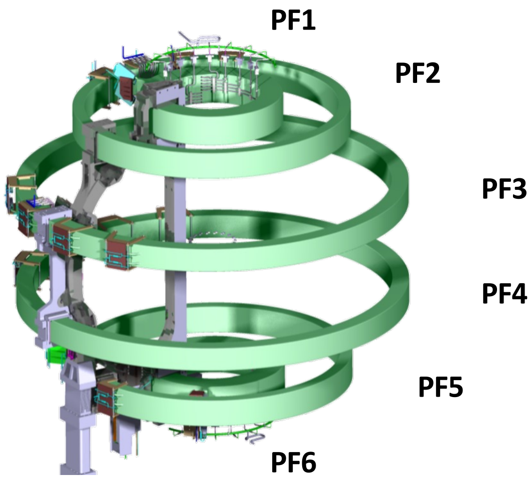
Strand for PF6 (Nb3Sn): procurement completed in 2024

Strand for CS and PF1: contract signed in 2025

- Strand delivery by the end 2027
- Strand performing better than requirement and offer!

  Impact on CS flux to be evaluated.





Parameter	Requirement	Offer	R&D results
Hysteresis loss (at 4.22 K over a ± 3 T cycle)	< 500 mJ/cm3	**< 450 mJ/cm3**	**247 mJ/cm3**
Minimum critical current (at 4.22 K and 12T)	> 270 A	**> 280 A**	**299 A**

Vacuum vessel and ports

First VVP call for tender (2023) went deserted:

- ✓ Tender documents revised
- ✓ Decision to allow offers higher than reference price

H3ES

EnF EnableFusion Inc. (주)인에이블퓨전

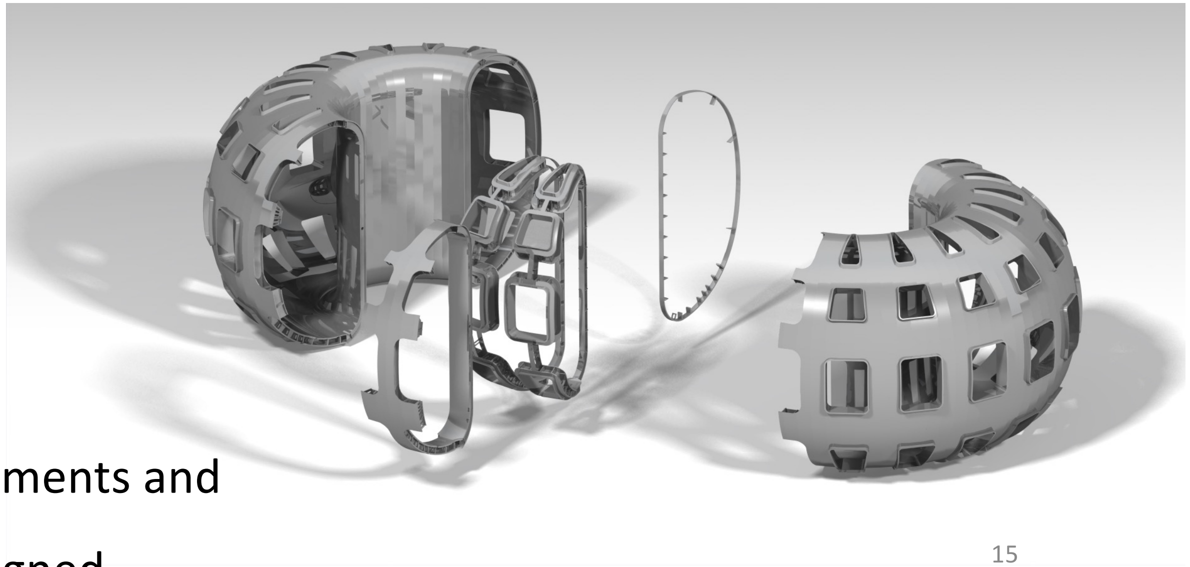
(주)한울이엔지

ENERGYEN

SamHong Machinery

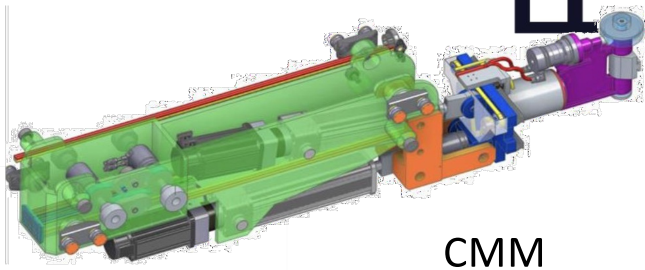
Second VVP tender main milestones:

- ✓ Tender published on started in July 2024
- ✓ Award on 09/05/2025
- ➢ Appeal from second-bidder on 09/06/25
- ➢ First court hearing on 02/07/25
- ➢ Final hearing on 17/12/25
- ➢ The judging panel accepts all of DTT arguments and rejects the appeal. The contract can be signed.

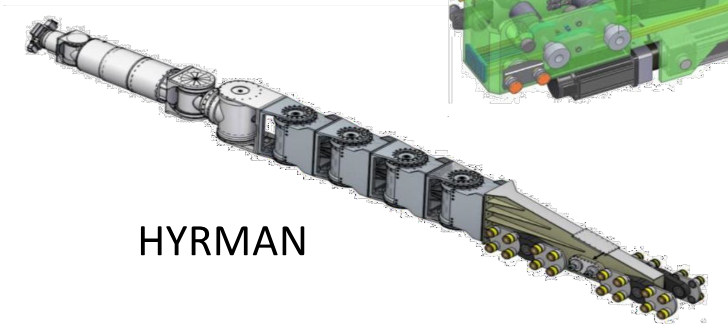


Remote Manipulation Systems

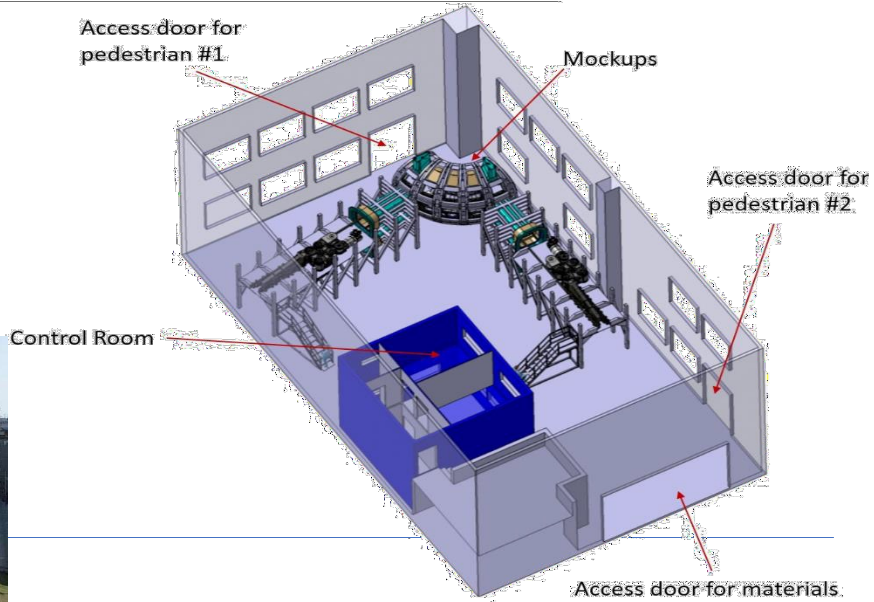
- Procured through Next GenerationEU funds.
- Delivery first half of 2026.
- Installation in the Remote Handling Training Facilit near Naples and ready for the use during the assembly.



CMM



HYRMAN



In-vessel coils and related power supplies

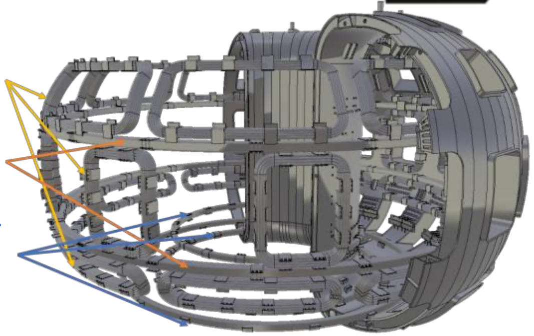
Power transformer   Protection coils

Parameter	DIV	VS	NAS
N.	3	2	27
Nominal current	±5 kA	±6 kA	±2.5 kA
Nominal voltage	±600 V	±4 kV	±550 V
Nominal duration	40 s	100 s	100 s

3x9 saddle coils

2 axisymmetric stabilization coils

3 divertor coils for fine sweeping of strike point

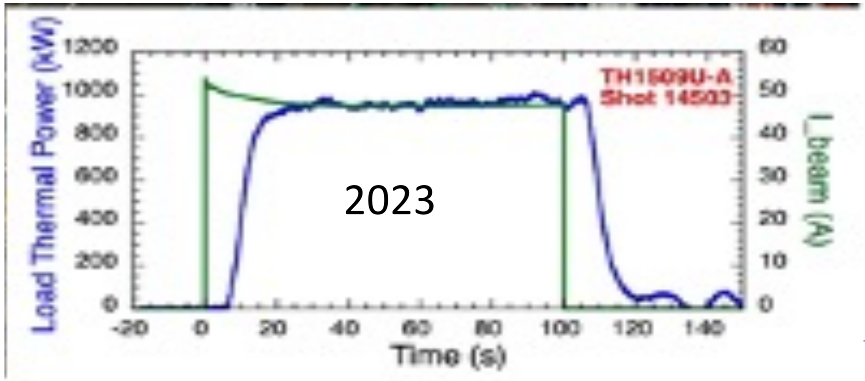


Imbalance inductor   Inverter module   Supercap cabinet   Output cabinet

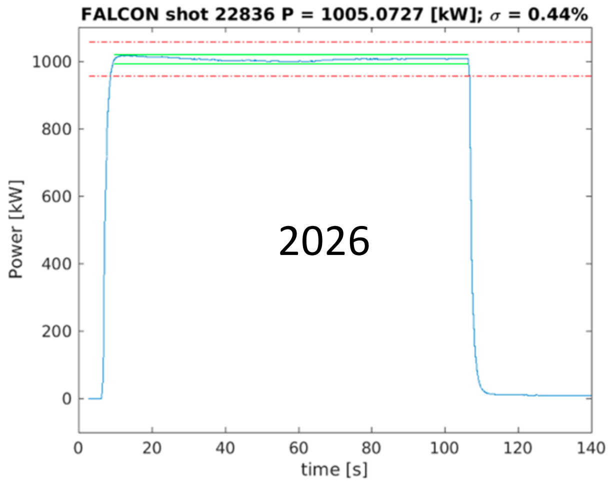

The 27 NAS inverter already completed by the EEI

ECH System: pre-series Gyrotron manufacturing

- Pre/series gyrotron successfully tested in 2023.
- Later problems emerged with the cavity cooling.
- Problems are now solved and the series prod. can start.
- Eight gyrotrons available by the end of 2028.



Call for tender of the gyrotron HVPS already approved.
To be published soon



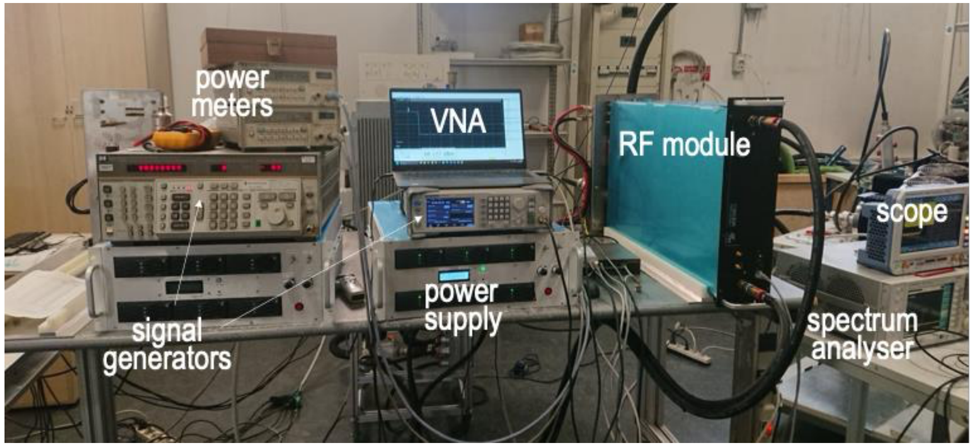
ICH Transmitter: Test results on RF module prototype

Tests with VSWR=1.5 for 50 s

Frequency	VSWR	Pout	Efficiency
90 MHz	1.54	11.3 kW	64.3%
60 MHz	1.53	11 kW	61.9%

- Spurious spectral content ≤-20 dB
- Power factor =1
- THD <2.2%

Water cooling at 10 l/min, but lower flow rates still acceptable. Vdc = 55 V. Efficiencies ≥ 65% with lower Vdc. Optimal Vdc will be tabled and automatically set by the transmitter control system.



Tests on matched load for 50 s emulating faulty pallets

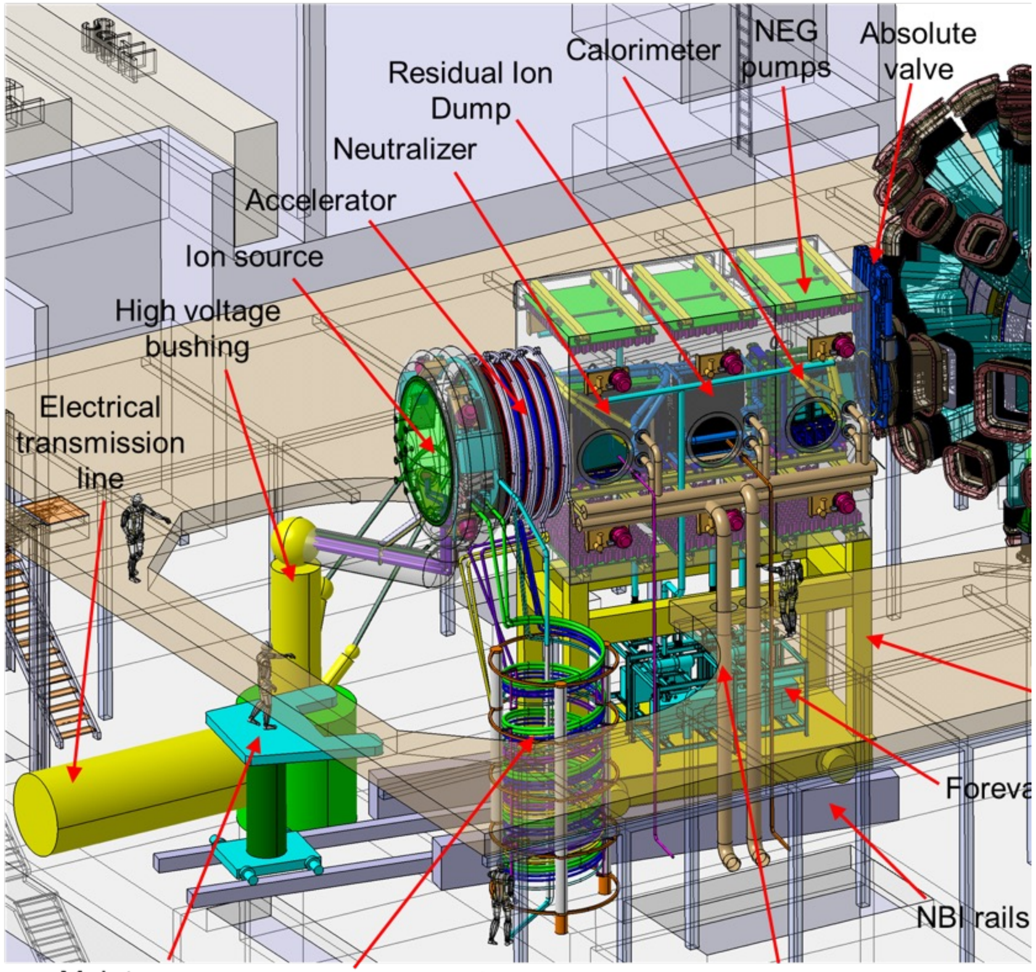
Setting	Pout	T_{max}	T_{max} position
All pallets on	11 kW	98 °C	On transistors
1 pallet off	9.5 kW	89.2 °C	On transistors
2 pallets off	7.7 kW	124 °C	On final load

Tests with VSWR=3.0 for 1 h

Frequency	VSWR	Pout	Efficiency
90 MHz	3.32	1.6 kW	58%

- Vdc = 21.3 V.
- Pout strongly limited with high VSWR constant in time. High Pout (~10 kW) achievable for temporary increase of VSWR, e.g., with duty cycle of 20%.

NBI Injector



Presently construction on hold.

Design activities progressing focussed on interface management and development of the solutions specific for DTT.

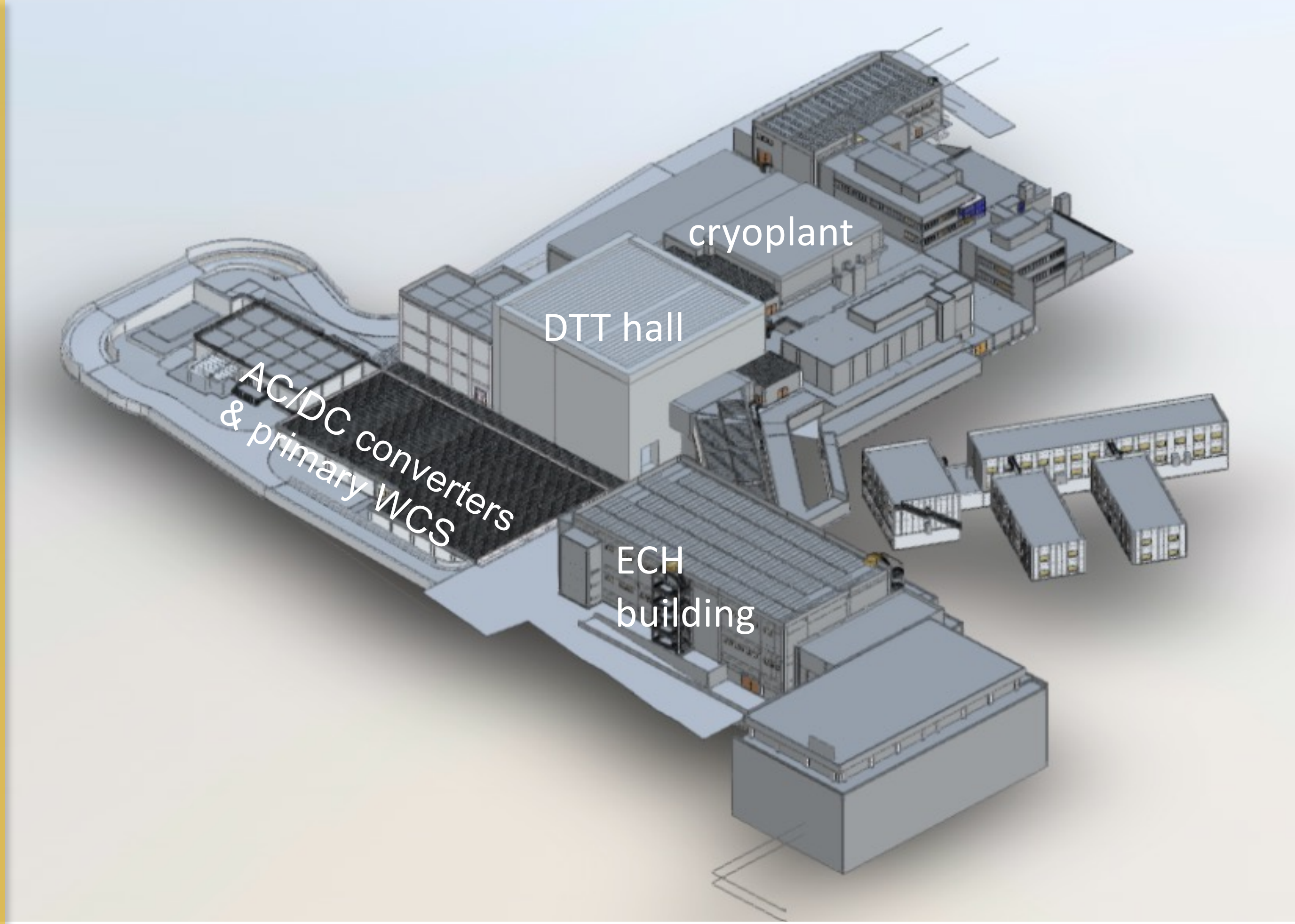
The experience of SPIDER & MITICA will be mainly used for the engineering phase of DTT NBI .

Design activities being carried out on:

- Stray Fields Shielding Structure to reduce the effects of the tokamak field on the beam
- Neutralizer optimization: panels with Cylindrical Sawtooth Structure with an expected 30% reduction in gas injection for the same neutralization effect → more efficiency
- Preliminary Design of the duct liner
- Acceleration Grid prototypes using additive manufacturing
- Size estimation of the Modular Multilevel Converter (MMC)-based Acceleration Grid Power Supplies (AGPS)

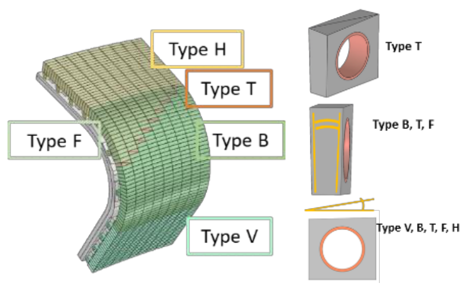
DTT buildings & Site Preparation

- ✓ About 150.000 mc of new buildings + 10.000 sqm of existing buildings
- ✓ Tender under evaluation for contract signature first half 2026
- ✓ Start of excavation second half 2026
- ✓ Construction area transferred to DTT January 2026.
- ✓ Demolition work started mid January 2026
- ✓ Clearing of existing buildings not completed by ENEA.



DTT first divertor

Outer target W monoblocks



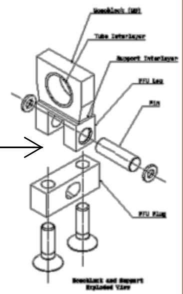
Outer Target 3D view

Order fo 47208 W mb
TS and tender documentation
-> link

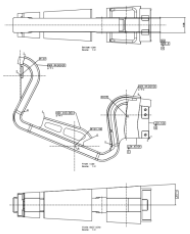
- ✓ Call for tender publication: 20/10/25
- Deadline: 03/12/2025

At the beginning of 2026 the tender for IT will be prepared

Item	Description	Notes
Type H + Type V	W monoblocks with parallel sides	Without stainless-steel support.
Type H (L) + Type V (L)	W monoblocks with parallel sides	With stainless steel support
Type B+Type F	W monoblocks with NO-parallel sides	Without stainless-steel support.
Type B (L)+Type F (L)	W monoblocks with NO-parallel sides	With stainless steel support
Type T	W monoblocks with NO-parallel sides and double Chamfered	Without stainless-steel support.
Type T (L)	W monoblocks with NO-parallel sides and double Chamfered	With stainless steel support



Cassette body



- Market survey (2° iteration almost completed)
- DRM called for 16/12/2025
- Schedule of deliveries discussed with Eurofusion to report first batch within 2027
- Call for tender in preparation to be launched at teh beginning of 2026

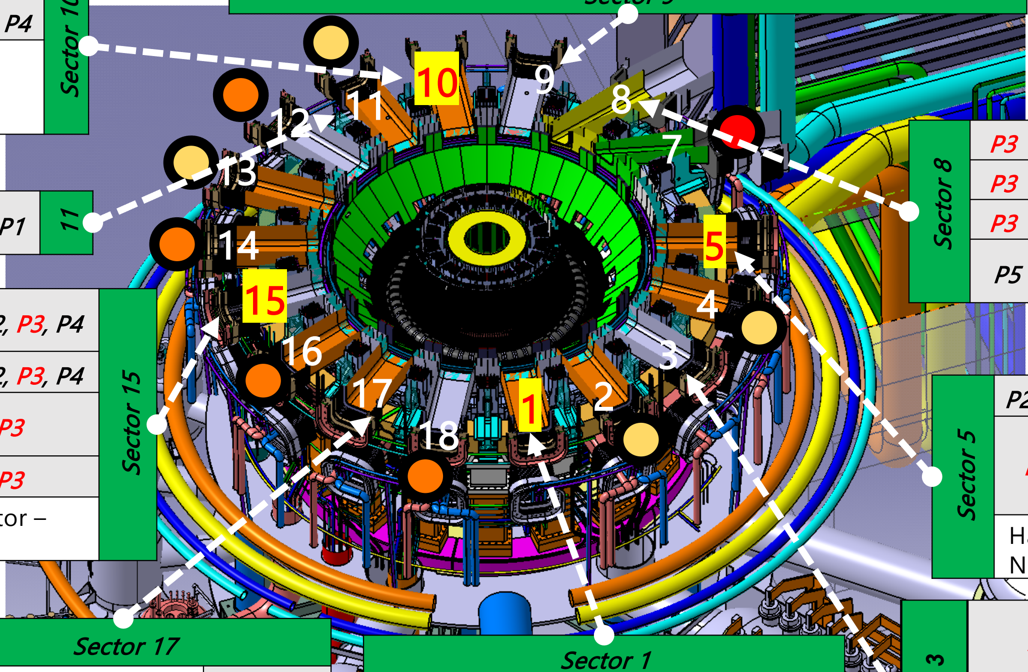
MATERIAL		COMPONENT	APPROX. WEIGHT (raw materials)
AISI 316l	Forged	Cassette body (inboard)	20 kg
		Cassette body (outboard)	20 kg
		Inboard manifold	3 kg
		Outboard manifolds	50 kg
		Inboard ribs	11 kg
		Outboard ribs	13 kg
	Plate	Side plates	6 kg
		IVT flanges	8 kg
		OVT flanges	8 kg
		Dome ribs	5 kg
			144 kg
XM-19	Forged	Cassette body (bottom)	40 kg
	Plate	Side plates	4 kg
			44 kg
TOTAL		Single divertor cassette	188 kg

DTT Diagnostics

DTT PHASE 1 Diagnostic Equipment Allocation

Equatorial Port Heating
Ion Cyclotron
Electron Cyclotron
Neutral Beam Inj.

Remote Handling Sectors



Sector 9

Interferometer Tangential	P3
IR/VIS Cameras	P3
REIS Spectrometer	P3
Neutral residual Gas Analyzer (NGA) & Optical gas Spectr.	P3

Sector 10

Interferometer Tangential	P3
Dα array & Divertor	P4
Hard-X & Gammas Rays Monitor – Neutron Yield Monitor	

Sector 11

Neutrons Activation Foils System	P1

Sector 15

Bolometer Tomography	P1, P2, P3, P4
SXR Tomography	P1, P2, P3, P4
Interferometer Tangential	P3
IR/VIS Cameras	P3
Hard-X & Gammas Rays Monitor – Neutron Yield Monitor	

Sector 17

VUV Spectrometer	P3
XUV Spectrometer	P3

Sector 1

Neutrons Activation Foils System	P1
Hard-X & Gammas Rays Monitor – Neutron Yield Monitor	

Sector 8

P3	Thomson Scattering LIDAR
P3	SXR imaging
P3	SXR Crystal Spectrometer
P5	Neutral residual Gas Analyzer (NGA) & Optical gas Spectroscopy

Sector 5

P2, P4	Dα array & Divertor
P3	ECE Michelson Spectrometer & Radiometer
	Hard-X & Gammas Rays Monitor – Neutron Yield Monitor

Sector 3

P3	IR/VIS Cameras
P3	Visible Z_{eff}-Bremmsthralung profile / Spectrometer Survey&Divertor

Conceptual design of DTT diagnostics completed and reviewed by an expert panel. Detailed design and construction responsibility transferred to ENEA that will manage also the related int. collaborations.

Next steps and main risks

- Tenders for assembly contract, gyrotron HVPS, and cryoplant already approved by the DTT CdA.
- Technical documents of the PF and CS power supplies ready. Call for tender to be published by ENEA.
- Electrical Distribution System design verification under completion (TERNA work for the 150kV line ongoing).

- Design of the Central Solenoid in an advanced state for the LTS part with the preliminary design ongoing of the HTSC insert to increase flux capability.
- Other components are under design but priority is given to the components closer to the critical path made by the availability of the new tokamak hall and the machine assembly and commissioning that at the moment are the main risks of delay.

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DTT and the Italian scientific community

The construction of DTT offers the scientists of the Italian Research Institutions an unprecedented opportunity of access to a first-class research infrastructure.

A large share of the experimental time (75%) will be devoted to Eurofusion. In this case the experimental programme will be defined by Eurofusion. The financial support is expected to come from EURATOM.

The remaining 25% will be devoted to the DTT shareholders and to private enterprises testing innovative solutions (see e.g. divertor test modules).

DTT and the Italian scientific community

"DTT scarl has the goal to promote, in the interest of the shareholders, scientific research, technology development and education/training."

At the moment, resources are provided by the shareholders (mainly ENEA) for the design and construction phase.

During this phase research activities will be limited to analyse the impact of specific design choices on the DTT scientific goals (see e.g. discussion on the central solenoid capabilities).

However, these activities produce research and innovation (to be protected) and training for PhD/Postdoc.

DTT and the Italian scientific community

The role of DTT scarl during the operation phase for the scientific exploitation will be defined in a operation contract with ENEA.

On the basis of the experience of other facilities, for the scientific exploitation the role of DTT scarl will be to provide the users (national and international) with

- a set of well validated experimental data
- a set of consistent numerical tools for the interpretation of the data
- in addition to the operation of the facility and the support for the installation and test of new equipment

Conclusions

- DTT is an unprecedented scientific opportunity for the Italian plasma physics community.
- DTT is also a challenge and an opportunity for the Italian country system.
- The construction is progressing and is entering a hot phase with the construction of civil infrastructures.
- The complexity of the project must not be underestimated but the national support is strong.