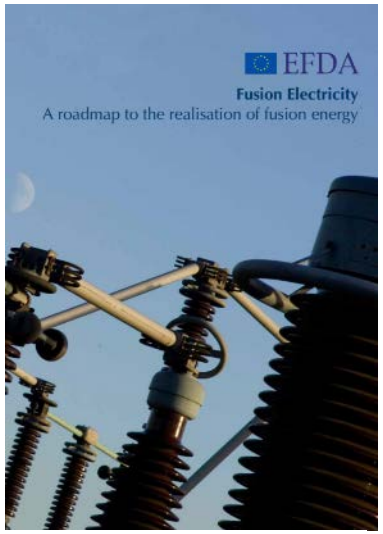
The Divertor Tokamak Test facility

Aldo Pizzuto

DTT-Scarl

Why DTT?



EFDA roadmap 2013:

A solution for the heat exhaust in the fusion power plant is needed.

[…] in parallel to the programme in support of the baseline strategy, an aggressive programme on alternative solutions for the divertor is necessary […] a dedicated test on specifically upgraded existing facilities or on a dedicated Divertor Tokamak Test (DTT) facility will be necessary.

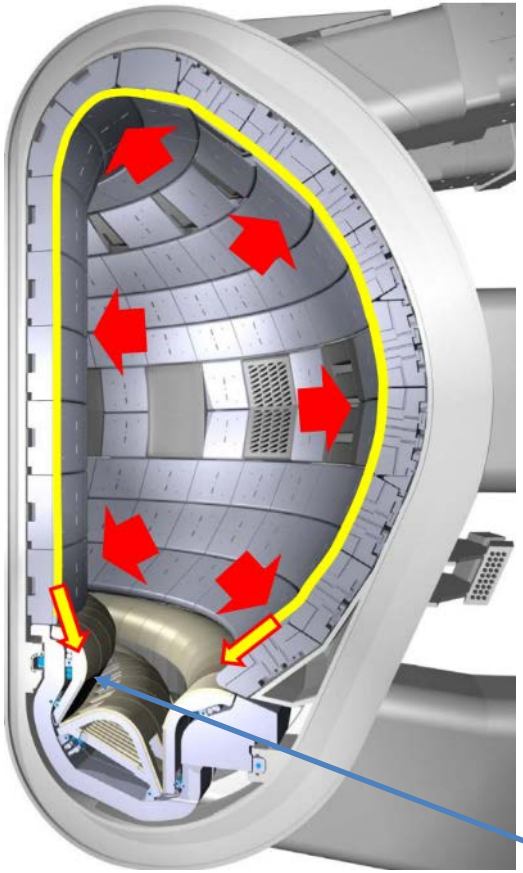
Eurofusion roadmap 2018:

[..] the extrapolation from proof-of-principle devices to DEMO based on modelling alone is considered too large. [..] a divertor optimised for the concept will be implemented in the Italian Divertor Test Tokamak (I-DTT) facility as a joint European collaboration.

EUROfusion

https://www.euro-fusion.org/fileadmin/user_upload/EUROfusion/Documents/Roadmap.pdf

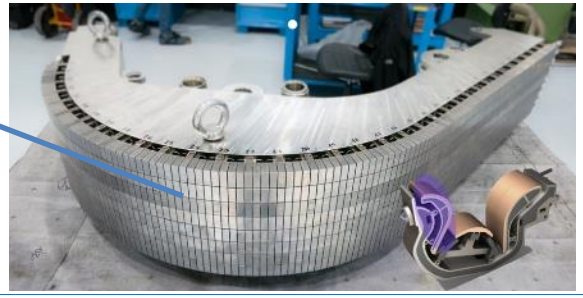
Why DTT?



Power exhaust problem solved by:

1. Magnetic configurations + Plasma shape
2. Plasma facing components technology -> max heat flux presently limited to 10-20 MW/m^2
3. Impurity seeding to increase radiation
4. Liquid metals

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



ITER Inner Vertical target full scale Prototype

How DTT? – the organization

The Consortium DTT scarl has been established to realise the facility. The shares hold are:

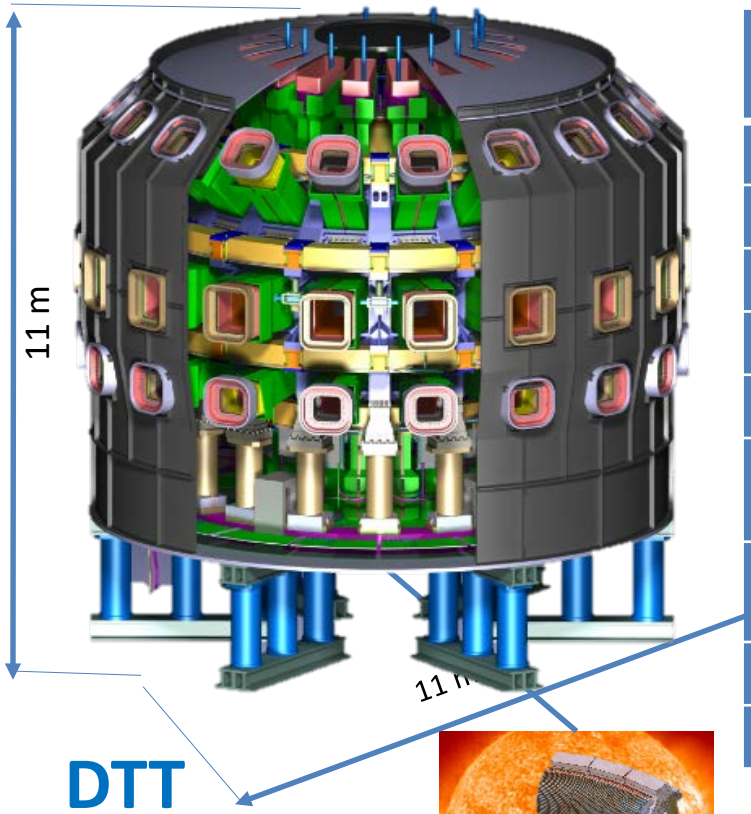
- ENEA
- ENI
- Consortium CREATE

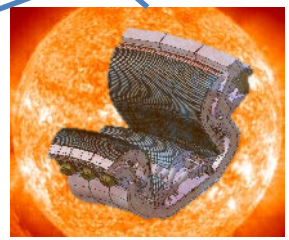
Other partners are going to take part of the DTT Consortium. Further to CNR, INFN and consortium RFX, to underline the DTT important role of training infrastructure, several Universities: PoliTo, Uni Bicocca, Uni Tuscia, Uni Tor Vergata.

The design is based upon the Project proposal and the first interim design report further elaborated during the last year.

https://www.dtt-project.it/index.php/about/who.html

How?: The DTT parameters



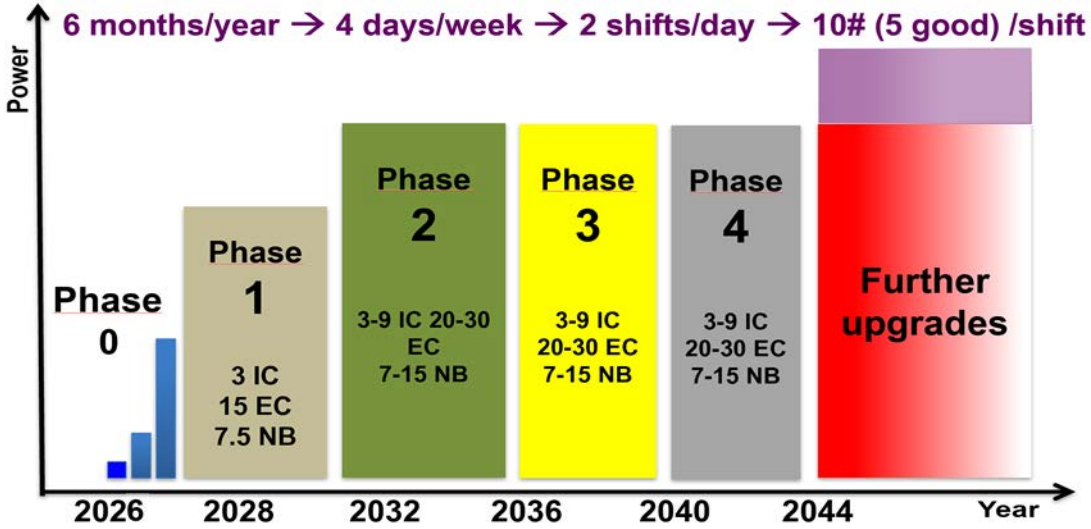


	DTT	ITER	DEMO
R (m)	**2.14 (2.19)**	6.2	9.1
a (m)	**0.64**	2	2.93
A	**3.3**	3.1	3.1
I_p (MA)	**5.5**	15	19.6
B (T)	**6**	5.3	5.7
Heating P (MW)	**45**	50	50
P_{sep} /R (MW/m)	**15**	14	17
λ_q(mm)	**0.7**	0.9	1.0
Pulse length (s)	**95**	400	7600

+

Flexibility and DEMO relevant technologies

How? DTT experimental program



The DTT facility is planned to operate on a very long time scale (of the order of 25÷30 years), accompanying the ITER experiment and contributing to DEMO design.

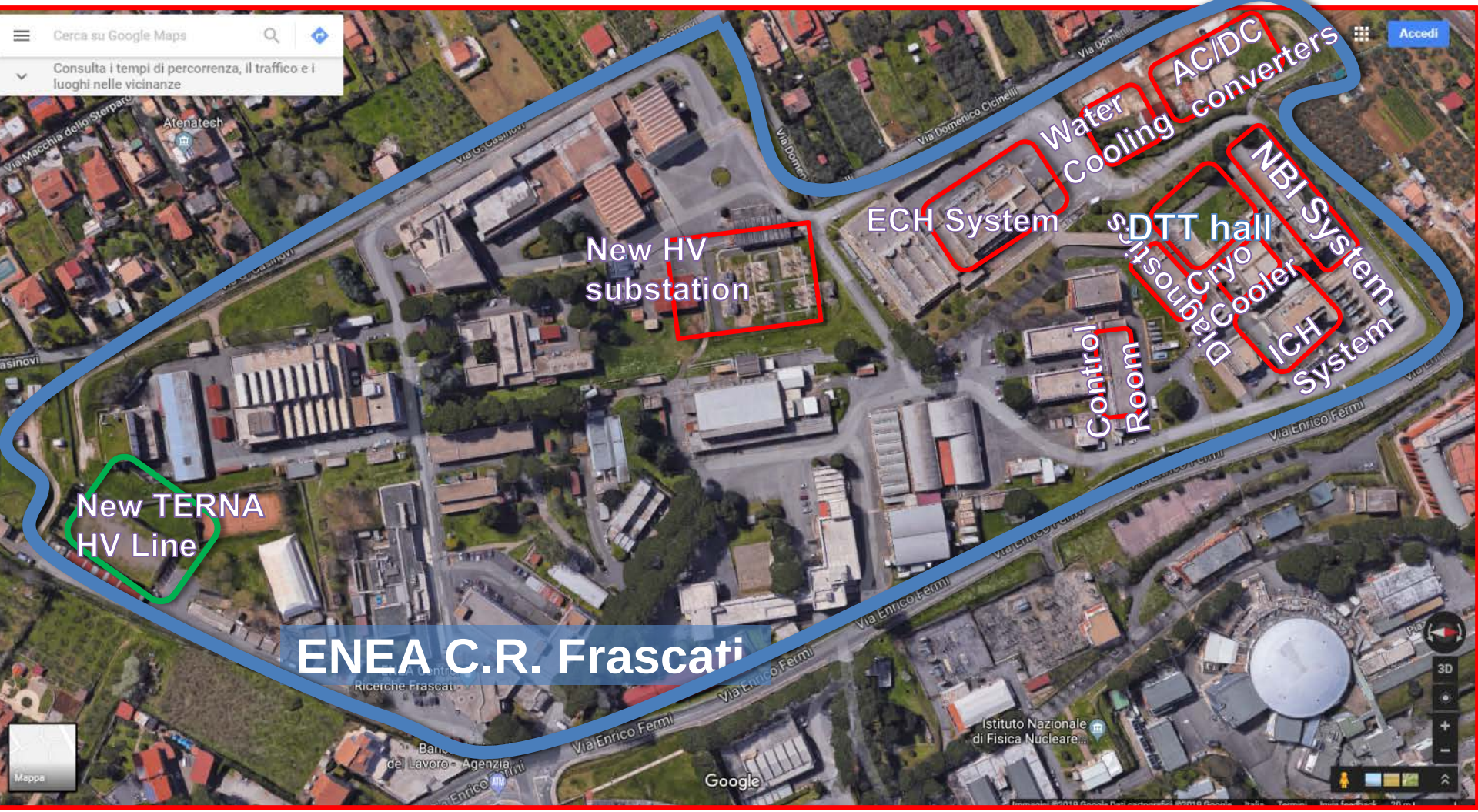
Schedule foresees that the DTT construction will last 7 years and that, consequently, the commissioning phase could start in 2026.

In the first 2÷3 years DTT will operate in standard configurations for the full commissioning of all systems with the final target to achieve good plasma performance at high power and with physics parameters close to DEMO.

During this phase machine upgrades have been planned: heating power will be increased from the initial value (25÷28MW) up to the final one (45÷50MW).

A new divertor, "dedicated and optimized" for an alternative divertor magnetic configuration and/or liquid metal technologies, will be designed together with Eurofusion.

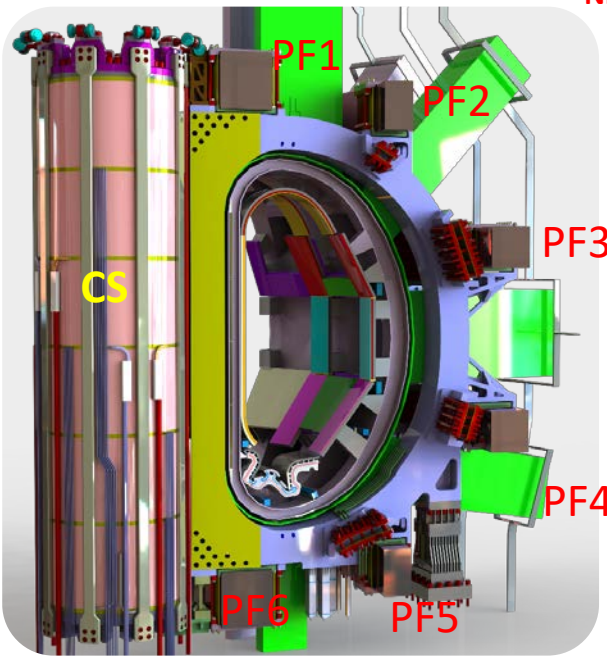
Where DTT: site – ENEA Research Center



DTT main components and systems

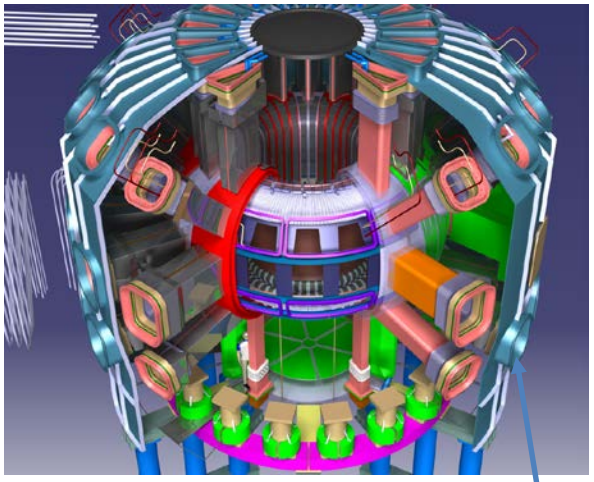
DTT Magnetic System

Nb3Ti PF1/6 ~ 17 tons each
NbTi PF 2/5 ~ 17 tons each
NbTi PF3/4 ~ 30 tons each

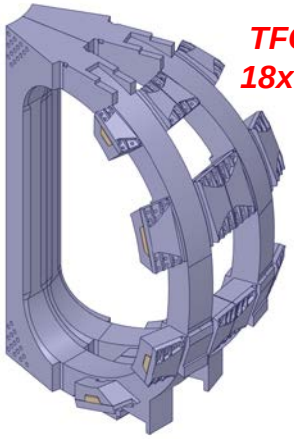


Nb_3Sn Central Solenoid
45 tons
1,5 m

DTT Vessel-in Vessel ancd Cryostat

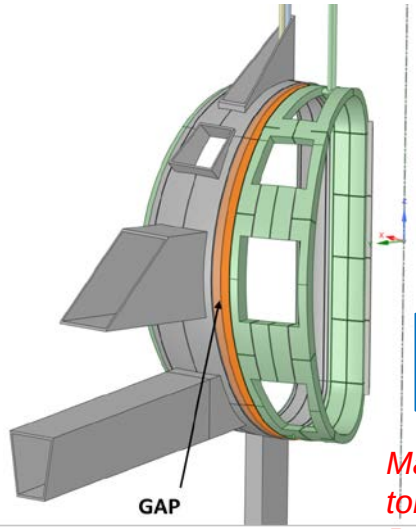


Cryostat ~ 100 tons



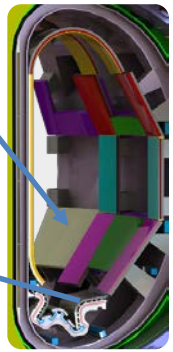
***TFC** Casings*
18x10 tons

Nb_3SnToroidal Field coil
18*5 tons



First Wall

54 cassettes divertor



Main double-walled vessel -37 tons
Ports – 80 tons

Additional heating

ECRH: **16** gyrotrons

Scheme:

4 Solid State HVPS

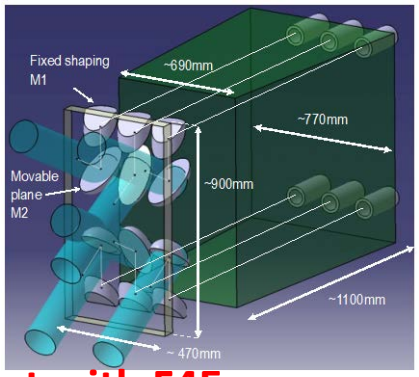
8 Gyrotrons (**1MW/170GHz**/100s) *(ITER like)*

1 Multi-Beam **Quasi Optical** TL *90% efficiency*

Front Steering Antennas:

6 Lines in 1 Equatorial Port

2 Lines in 1 Upper Port



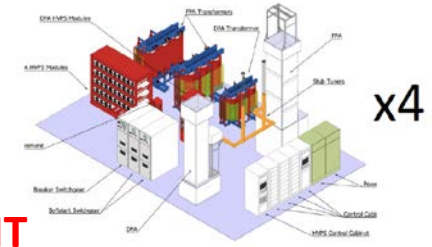
Joint procurement with F4E

ICRH: Main features

60-90 MHz frequency range,

3 MW at plasma,

4 MW at generators.

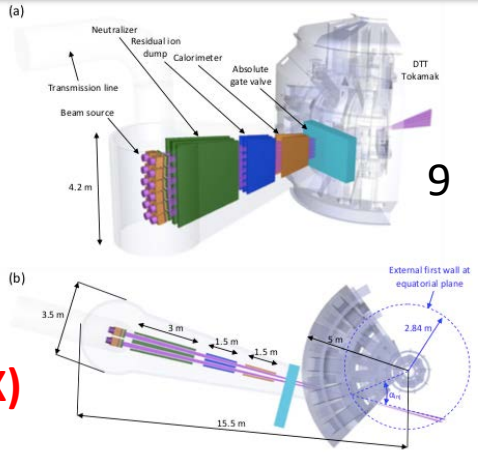


Collaboration with MIT

NBI: Main features

Coupled power to plasma 10 MW

Beam energy: **510 keV**



ITER technology (MITICA facility by CRFX)

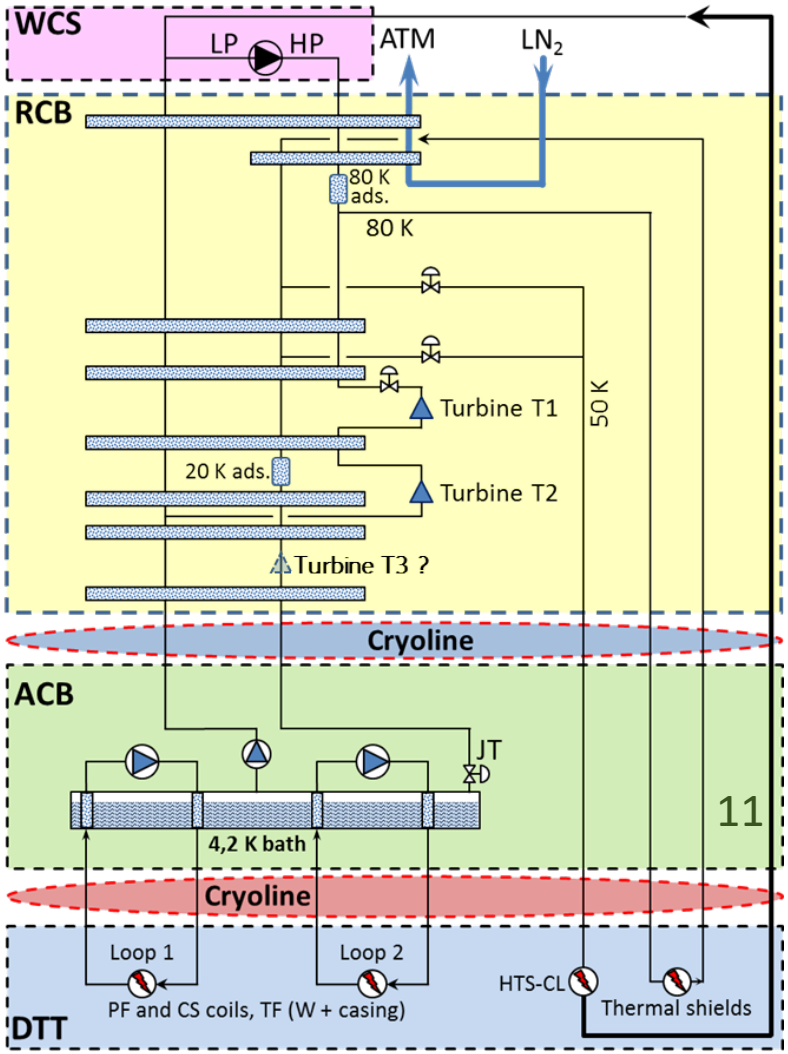
Power Supplies

Power Supply System	Main characteristics
Central Solenoid /Poloidal Field Coils	• Current 30 kA • Voltage >1 kV • Duration 220 s
Toroidal Field Coil	• Nominal current 45 kA
Central Solenoid /Poloidal Fieldc Switch Network Unit	• Current 30 kA • Technology adopted: IGCT
Central Solenoid /Poloidal Field Coils Fast Disharge Unit	• Current 30 kA • Not identical FDUs • New technology identified
Toroidal Field Coils Fast Disharge Unit	• "Nominal" current reduced 45 kA • Voltage 6.5 kV
HV/MV substation	• Number of transformer 3-4 (but identical) • Secondary voltage 36 kV → 20 kV
Internal HV cable	• 150 kV for about 1 km
Reactive compensation and filters	• Nominal voltage 20 kV • STATCOM instead of SVC • (Hypothesis of revamping MFG3)
In Vessel coil	• Voltage 500 V • Protection against disruption critical
Dertor Coils	• DIV current 25 kA • DIV voltage increased 500 V • Protection against disruption necessary

Cryoplant

The 5 kW DTT cryogenic system will include the following systems:

- **A Warm Storage System (WSS)** – a set of large storage vessels having sufficient capacity to store the whole helium inventory required for the cryogenic plant; one of the vessels will be used for quench recovery.
- **Liquid nitrogen storage tanks.**
- **A Warm Compression Station (WCS)**, including an **Oil Removal System (ORS)** and a **full flow dryer**.
- **A Refrigeration Cold Box (RCB).**
- **An Auxiliary Cold Box** with thermal dampers, cold circulators and cryogenic loops.
- **The cryo-lines** connecting the ACB to the RCB and the tokamak.



Water Cooling System Requirements

FACILITY	THERMAL POWER TO BE DISSIPATED kW	POWER DURATION (SECONDS)	INLET COOLING TEMPERATURE (°C) INTO PRIMARY SYSTEM	OUTLET TEMPERATURE (°C) FROM PRIMARY SYSTEM TO HEAT EXCHANGER
ECRH	40.000	50	15	40
Power Supply ECRH	3.200	50	15	35
ICRH	11.000	50	20	40
TF Power Supply	245	1	25	35
CS	3.360	300	25	35
IV_S	1.680	100	25	35
SNU	1.200	10	25	35
FDU	120	10	25	35
PF	500	150	25	35
CRYOPLANT	3.000	1	15	25
COLDBOX for CRYOPLANT	30	1	12	14
NBI	23.000	50	15	35
DIVERTOR	30.000	50	60	74
FIRST WALL	15.000	50	60	74
VACUM VESSEL	-40	1	60	74
TOTAL	132.295			50

	FLOW-RATE AT FULL POWER (m^3/h)	MAXIMUM TEMPERATURE ARISED IN THE WARM TANK(°C)	POWER REQUIRED SUPPLIED BY CHILLER (kW)	ELETTRIC POWER ABSORBED BY CHILLER (kW)
ECRH	1.376	28,7	556	192
Power Supply ECRH	138	34,1	44	15
ICRH	473	30,9	153	53
TF Power Supply	21	25,1	245	85
CS	289	145,4	280	97
IV_S	144	65,1	47	16
SNU	103	26,4	3	1
FDU	10	25,3	0	0
PFC	43	42,9	21	7
CRYOPLANT	258	15,1	3.000	1.038
COLDBOX for CRYOPLANT	13	12,0	30	10
NBI	989	26,0	319	111
DIVERTOR	1.843	70,2	417	144
FIRST WALL	921	77,9	208	72
VACUM VESSEL	2	60,1	40	14
	6.622	44,5	5.323	1.842

15 independent circuits for a total peak power in excess of 130 MW

DTT RH SYSTEM

DIV Handling

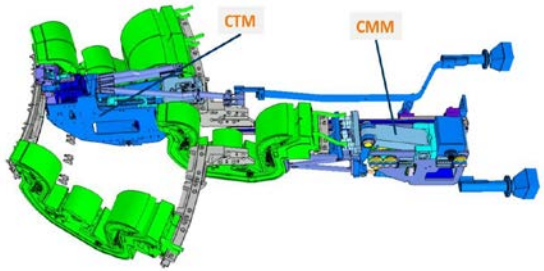
Other activities

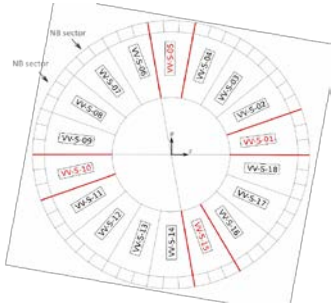
CUTTING & JOINING TEC

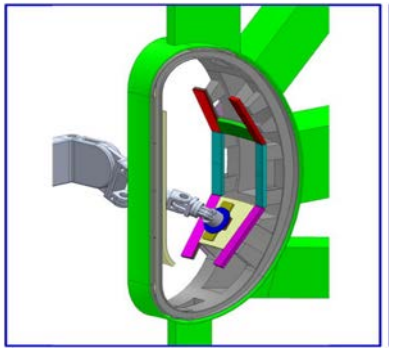
TRAINING FACILITY

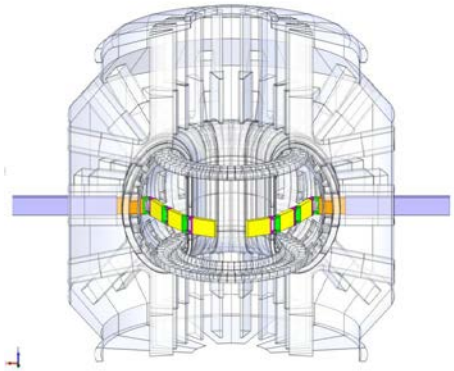
CONTROL ROOM

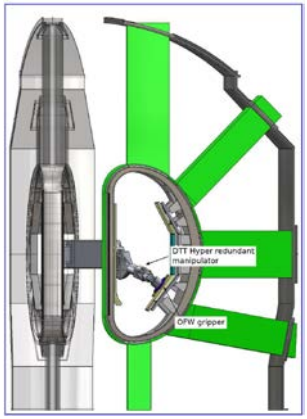
FW Handling

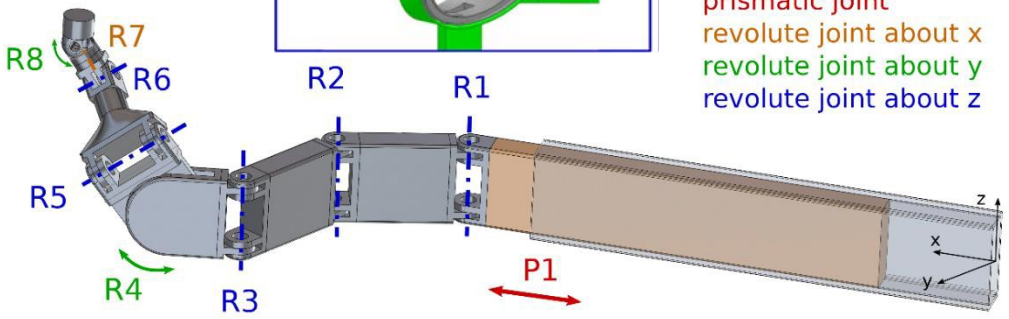






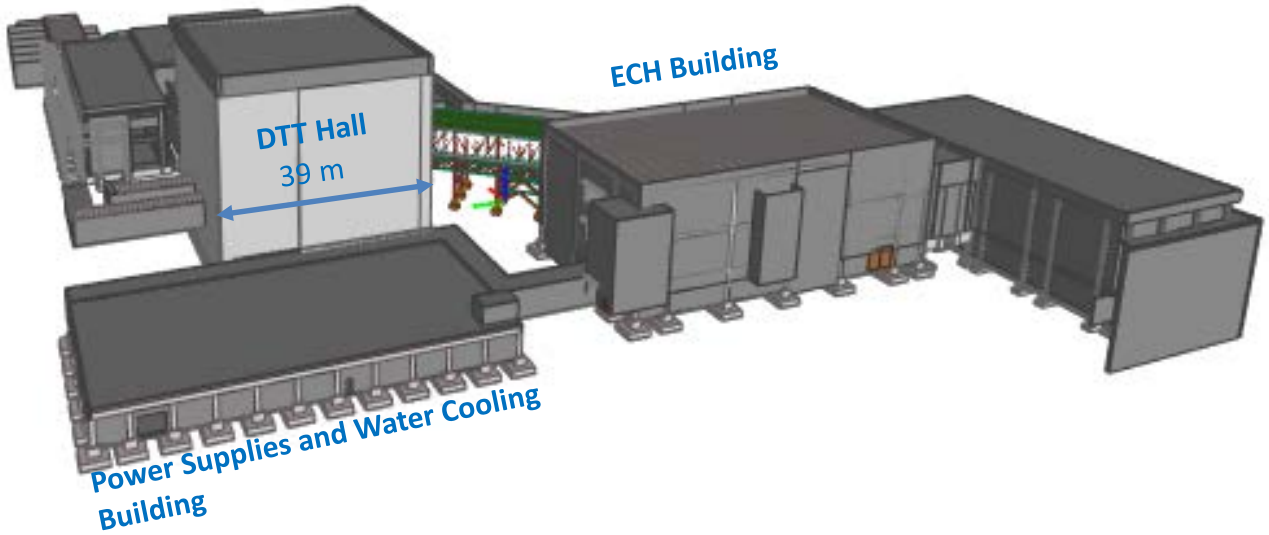




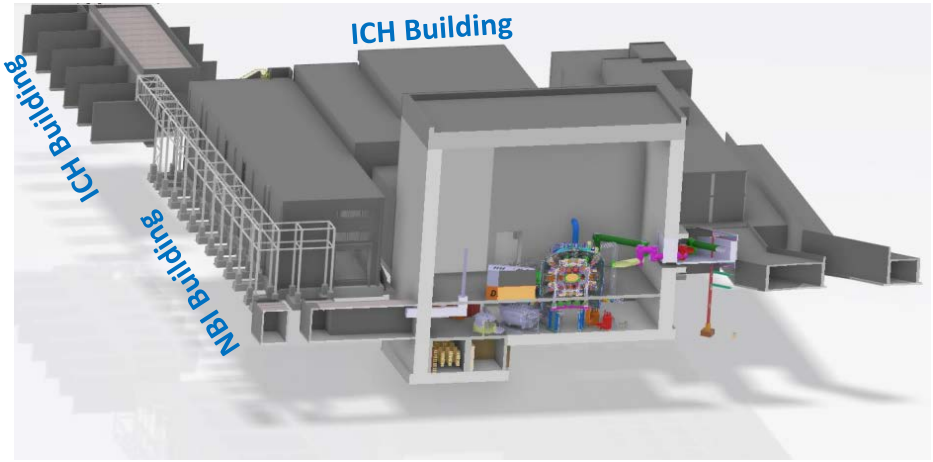


prismatic joint
revolute joint about x
revolute joint about y
revolute joint about z

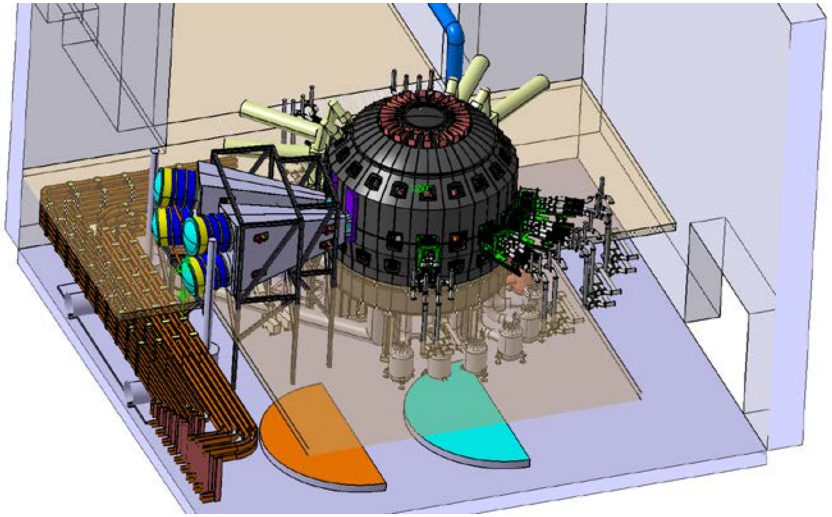
The DTT plant



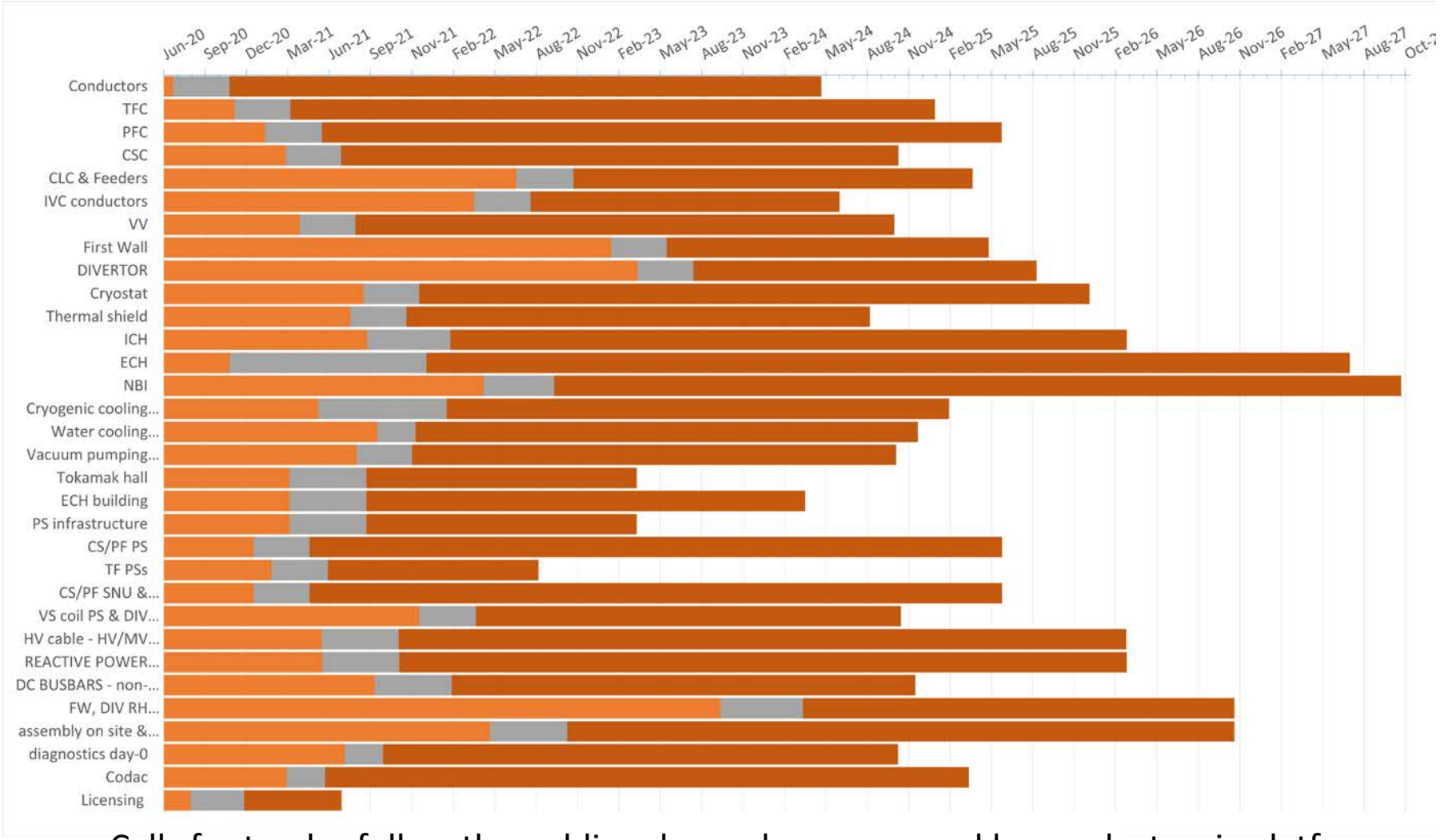
DTT Hall section



DTT Hall Lay out



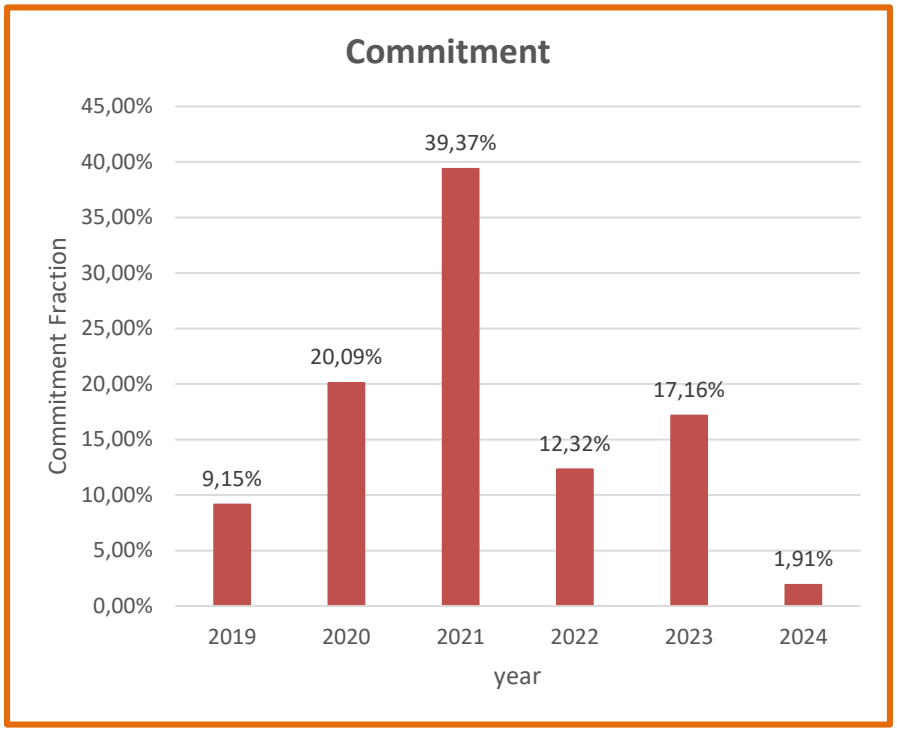
DTT Procurement planning

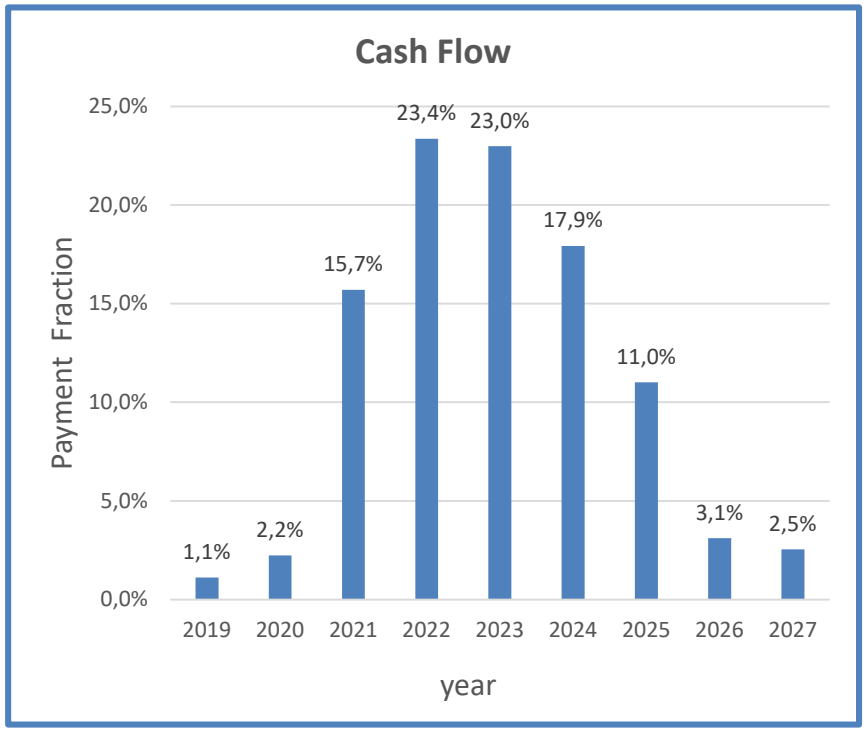


Calls for tender follow the public rules and are managed by an electronic platform

Contracts for the superconductive strand already assigned

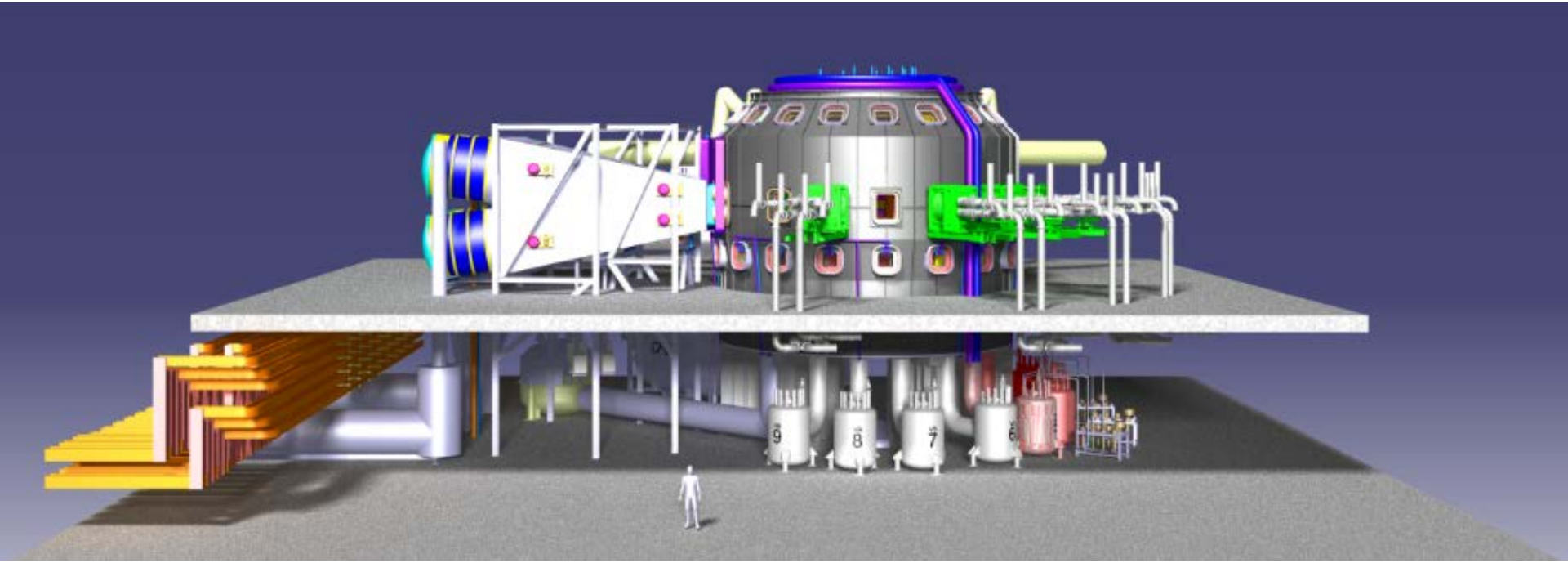
Spending Profile





The DTT added value

- DTT is a new device, where the modern technologies (control, diagnostics, HHF materials and components…) can be tested and further developed; this would be extremely difficult on the presently operating Tokamaks, designed about 40 years ago;
- The DTT heat exhaust handling achievements will contribute to bridge ITER and DEMO;
- DTT construction helps keeping industry linked to fusion field thanks to the 600 million investment as well as DTT will be an extraordinary incubator for new high-tech enterprises
- DTT would be the ideal training device to grow the new generations needed for feeding ITER and, subsequently, DEMO with skilled people. Academia will play a major role for DTT exploitation. It is worth mentioning the role of Universities in crucial areas where are providing valuable contributions.



DTT Scarl members

create

ENEA
Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

eni

Institutions interested in being part of DTT Scarl

CONSORZIO RFX
Ricerca Formazione Innovazione

Consiglio Nazionale delle Ricerche

INFN
Istituto Nazionale di Fisica Nucleare

Politecnico di Torino

Università degli Studi di Milano Bicocca

Alma Mater Studiorum