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

DTT Magnet system

DTT info-day on TF magnets

Aula B. Brunelli, C.R. ENEA Frascati (Rome), Italy – 08/10/2019

G.M. Polli on behalf of the DTT team

Outline

- DTT magnet system overview
- Main procurements:
  - Superconducting and Copper strands
  - Cable in conduit conductors
  - Toroidal Field Coils casings
  - Toroidal Field Coils WP and integration
  - Central solenoid
  - Poloidal Field coils
  - Current leads
  - Cryogenic tests

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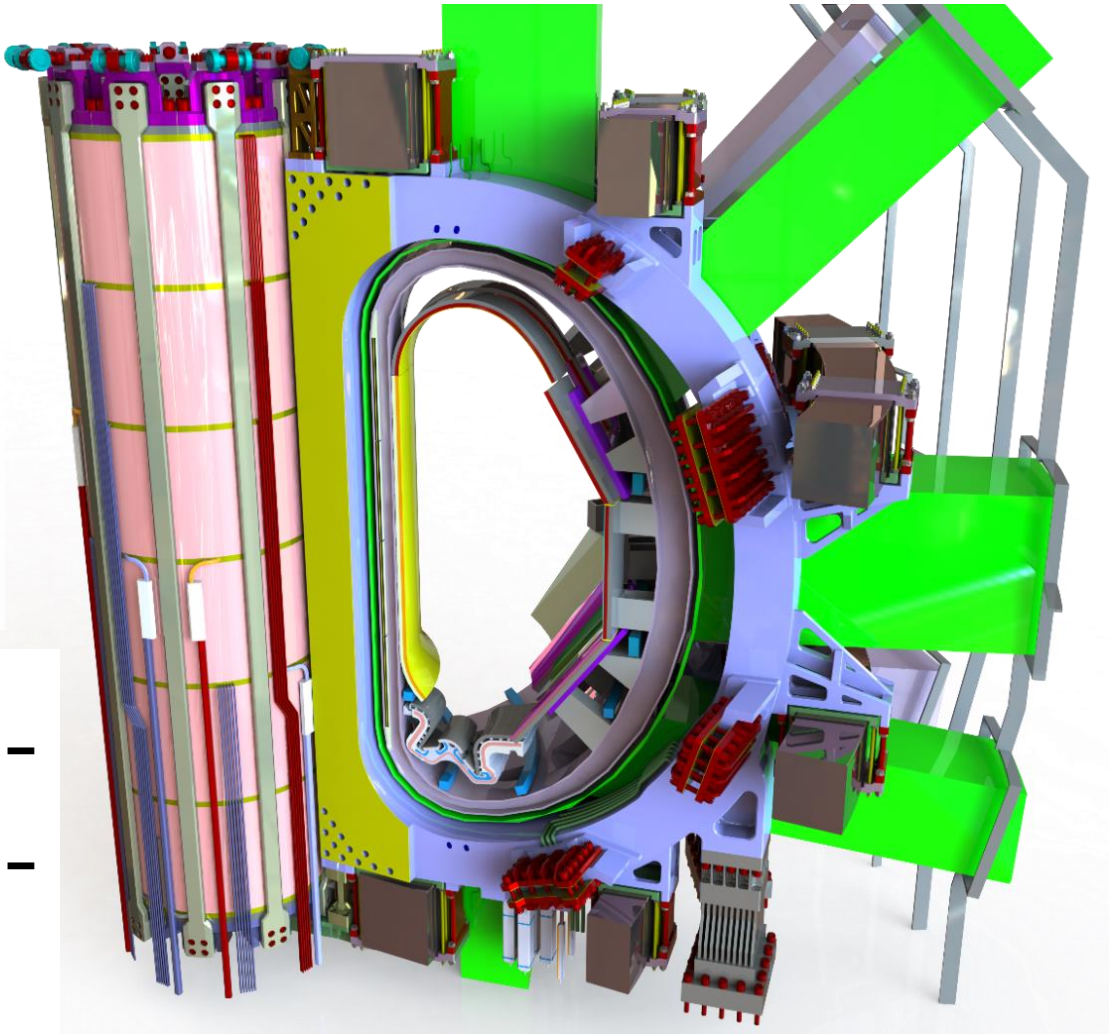
DTT Magnet System Overview

18 TF coils:
Nb_3Sn CICC: **44.8 kA – 11.9 T**
providing **6.0 T** over plasma major radius (**2.14 m**)

6 CS modules (indipendently fed)
Nb_3Sn CICC: **29 kA – 13.4 T**
providing **16.4 Weber** magnetic flux for plasma initiation at breakdown

6 PF coils
Nb_3Sn (PF1 & PF6) CICC: **28.3 kA – 9.1 T**
NbTi (PF2 to PF5) CICC: **28.6 kA – 5.4 T**
Identical in pairs to guarantee full top/down symmetry



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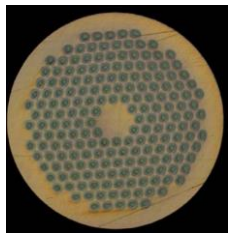
Superconducting & Copper Strands procurement

The procurement has been divided in 4 lots:

0.82 mm

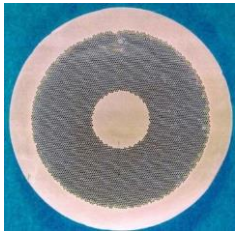


1. Nb_3Sn (chromium coated) for TF: L = 900 + n*900

55 tons for TFC

2. Nb_3Sn (chromium coated) for CS & PF1/6: L = 1050 + n*530

22 tons for CS & PF1/6

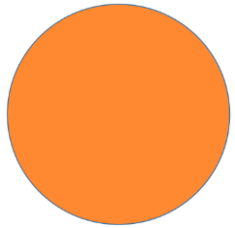


3. NbTi (nichel coated) for PF2/3/4/5: L = 5000 + n*10000

27.5 tons FOR PF2/3/4/5

4. Cu (chromium coated) for TF, CS & PF1/6 and Ni (nichel coated) for PF2/3/4/5: L = 5000 + n*10000

31 tons FOR TFC & CS & PF1/6 + 23 tons FOR PF



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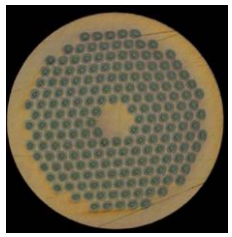

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55 tons for TF AWARDED

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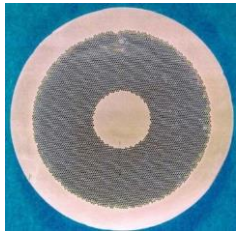
22 tons for CS & PF1/6 AWARDED



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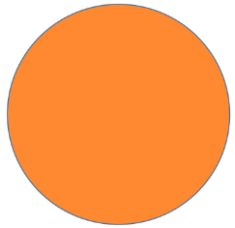

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Coils Conductors procurement

Conductors manufacturing will consist in:

- Cabling
- Jacketing & insertion
- Compaction & spooling
- Testing
- Shipping to coil manufacturers
- Tender launch within October 2019

Key issues:

- 316 LN jacket (samples and dummies to be provided in advance for winding test)
- 100% welds testing
- He leak testing (pressure, flow)
- Jacketing line ~ 880 m (for CS & PF)

- TF – Unit Lengths (ULs): 54 regular DP (rDP) + 36 side DP (sDP) + 8 spare
- PF1/6 - ULs: 18 DP + 1spare
- PF2/5 - ULs: 16 DP + 1 spare
- PF3/4 - ULs: 14 DP + 1 spare
- CS - ULs: 6 HF + 1 spare + 12 LF + 2 spare

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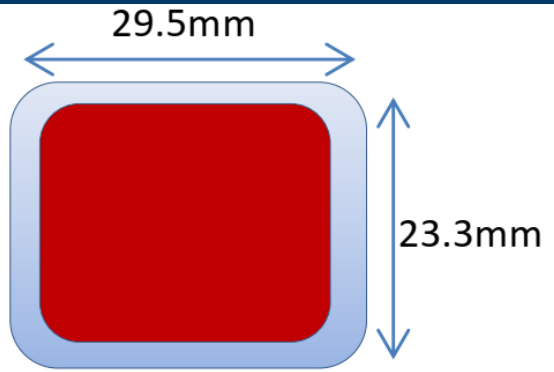
TF coils Conductors

TF Conductors procurement schedule:

- First delivery (dummy & superdummy UL) Summer 2020
- Production rate: 1 WP set/40 work. days (1° set to be delivered within the end of 2020)



Main features:

- Unit length (UL): 240 m (regular), 170 m (side)
- Total # of ULs: 54 (regular) + 36 (side) + 8 spare ~ 19 km
- Inner corner radius: 3.5mm
- VF: 26.4%
- Cabling pattern:
  [(1Cu+2Nb3Sn)+(1Cu+2Nb3Sn)+3Nb3Sn]*3*4*6
  Wrapping: 0.05mm thick, overlap 30%

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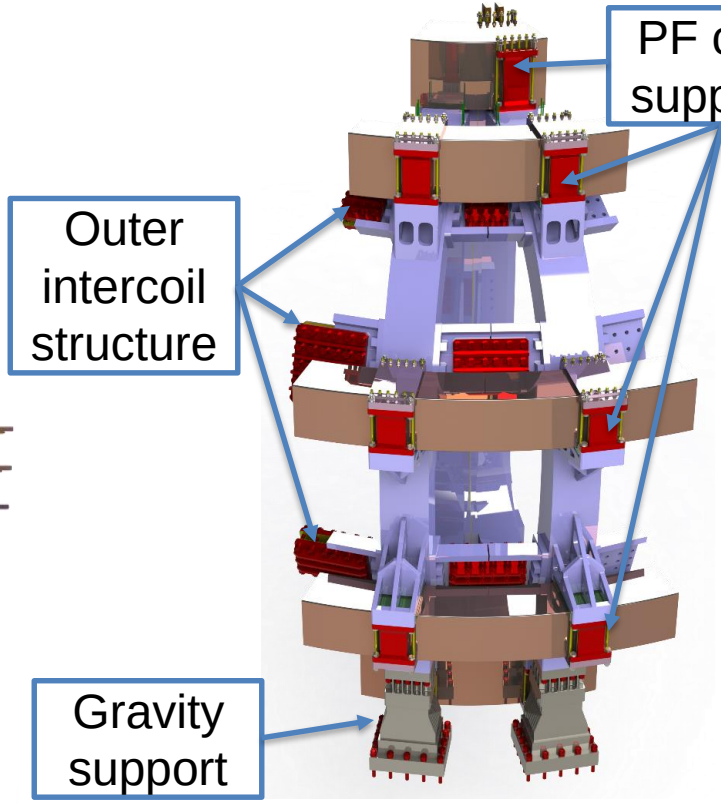
Toroidal Field Coils – case & supports



Structures are mainly based on 316L(N) material (low N limit range).

~ 10 tons

Max welding thickness: ~ 90 mm

Support structures for PF included

Outer and Inner Intercoil structures included

Gravity supports included

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Toroidal Field Coils – case & supports

Further information in Anemona's presentation

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~ 10 tons

Max welding thickness: ~ 90 mm

Support structures for PF included

Outer and Inner Intercoil structures included

Gravity supports included

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TF coils: casing

TF casing procurement schedule:

- Tender launch beginning December 2019
- Delivery of qualification mock-ups for coil integration around the end 2020
- First delivery of set components: October 2021
- Delivery rate: ~1 casing set/month

TF casing scope of supply:

- 18 TF casings (including Outer & inner intercoil structures + Gravity supports)
- Jigs for composition and transport
- 6 x 18 PF containment structures

Technical requirements:

- 316LN (limited N range) weld technology and inspection
- Vertical milling machine minimum 5 m large
- Laser tracking experience
- Leak testing experience

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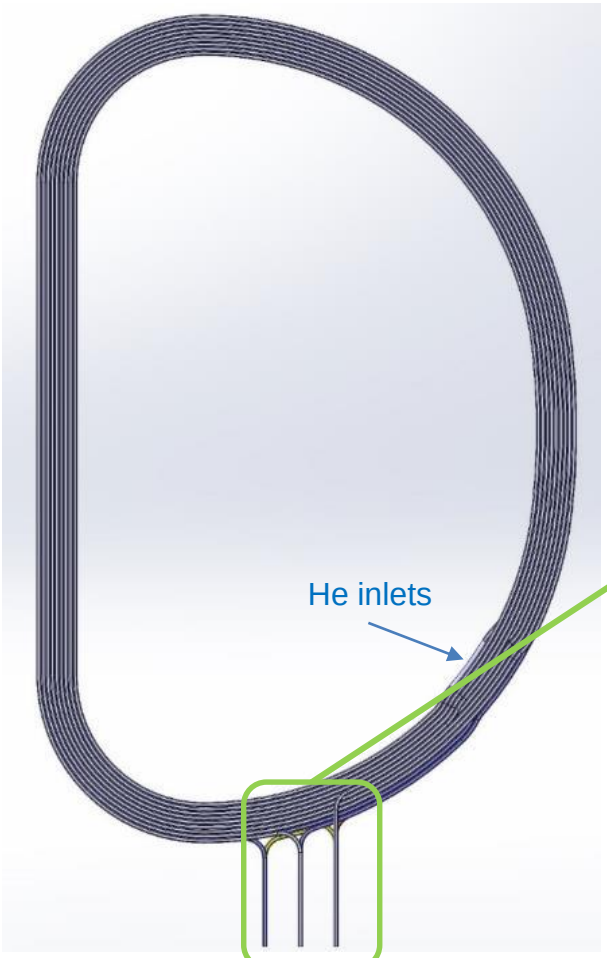
Toroidal Field Coils – Winding Pack



Double pancake-winding: **3 rDP**; **2 sDP**; 80 turns

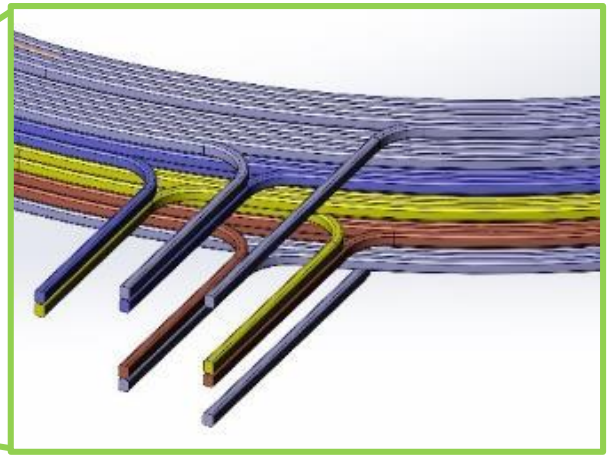
Total weight WP: ~**5 tons**

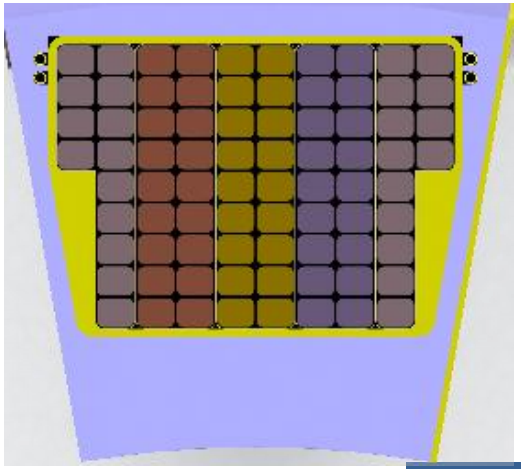
Turn insulation: **Fiber-glass (E-glass) + resin**

5 He inlets

4 internal joints + 2 terminal joints

Wind → React → Insulation → Impregnation





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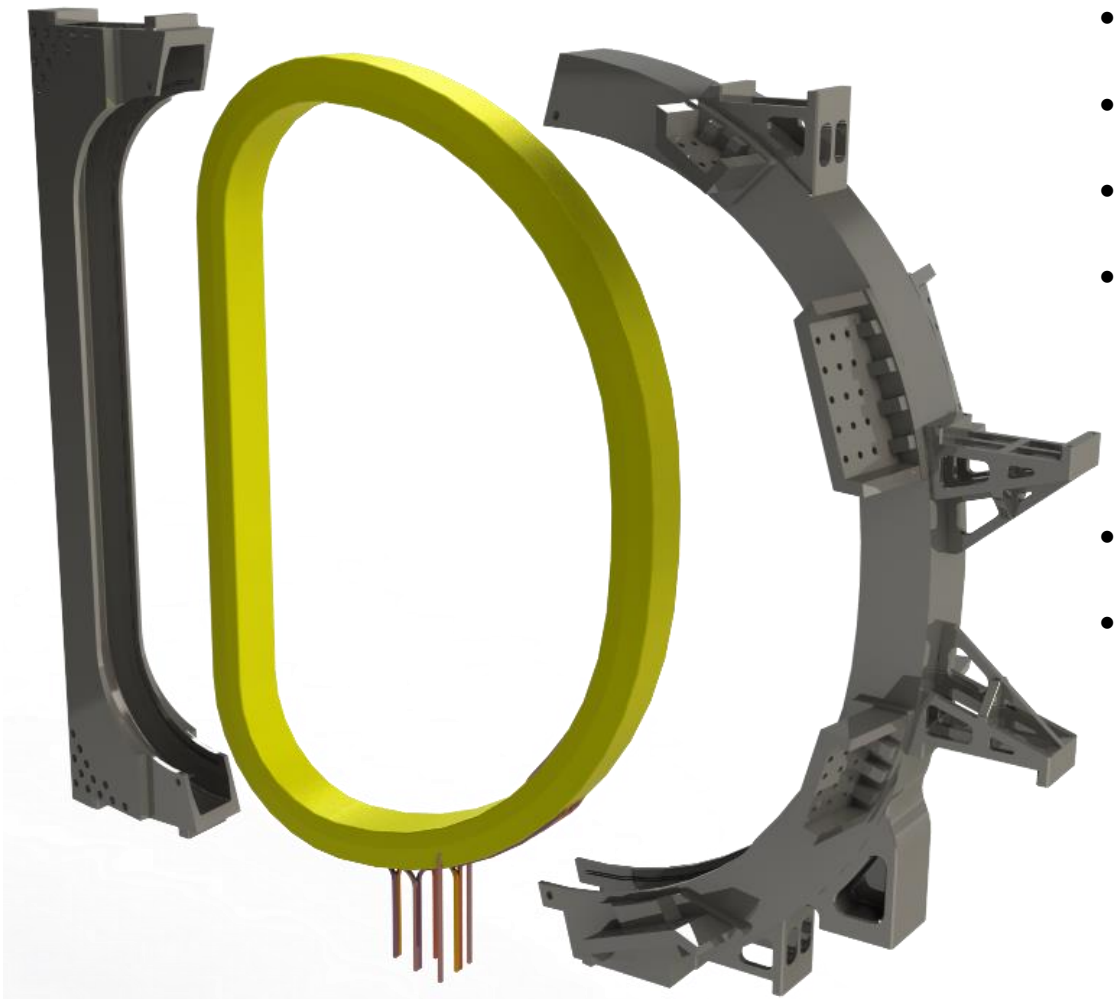
Toroidal Field Coils – module integration



- WP insertion
- Welding
- Embedding
- Machining (general medium tolerance class specified unless otherwise stated)
- Piping welding
- High voltage DC tests in vacuum (Paschen proof)

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Toroidal Field Coils – module integration

- WP insertion
- Welding
- Embedd[illegible]

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- High voltage DC tests in vacuum (Paschen proof)

Further information in Romanelli's presentation

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Toroidal Field Coils procurement

TF coil modules procurement schedule:

- Tender launch within November 2019
- First delivery: June 2022
- Delivery rate: ~1 module/month

TF coil modules scope of supply:

- 18 TF WPs
- 18 TF encasing integrations (with instrumentation)

Technical requirements :

- Heat treatment of Nb_3Sn DP
- Insulation after heat treatment
- Internal joint (<2nOhm)
- Vacuum pressure impregnation (VPI)
- Laser tracking experience
- 316LN Weld technology
- High voltage DC tests in vacuum (Paschen proof)
- Electrical breakers
- Leak testing experience
- Embedding impregnation

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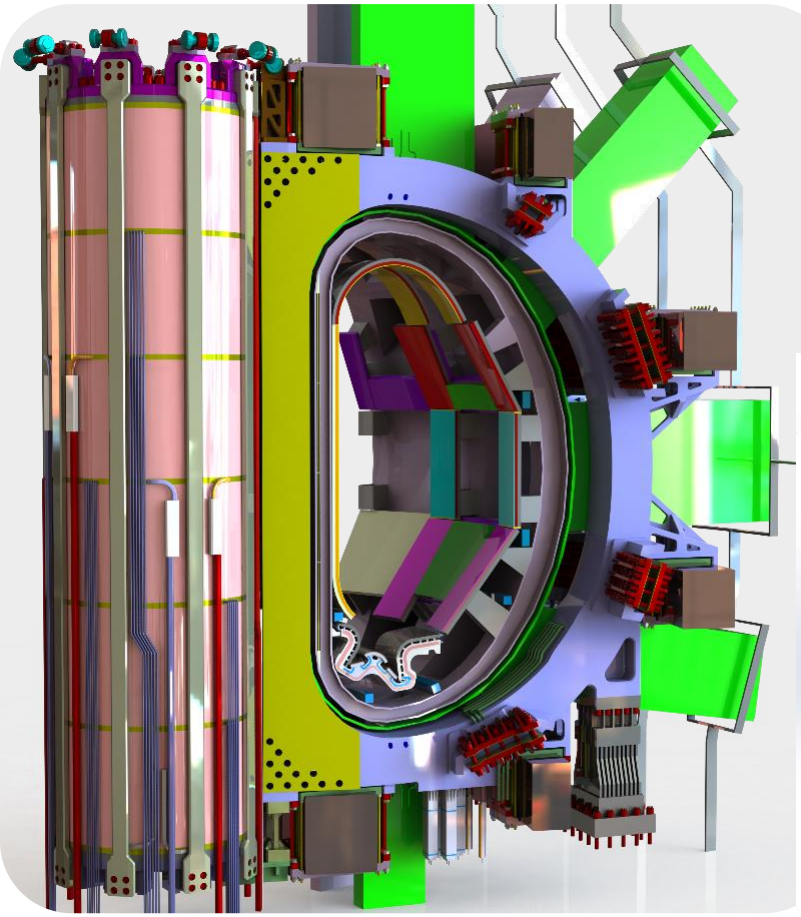
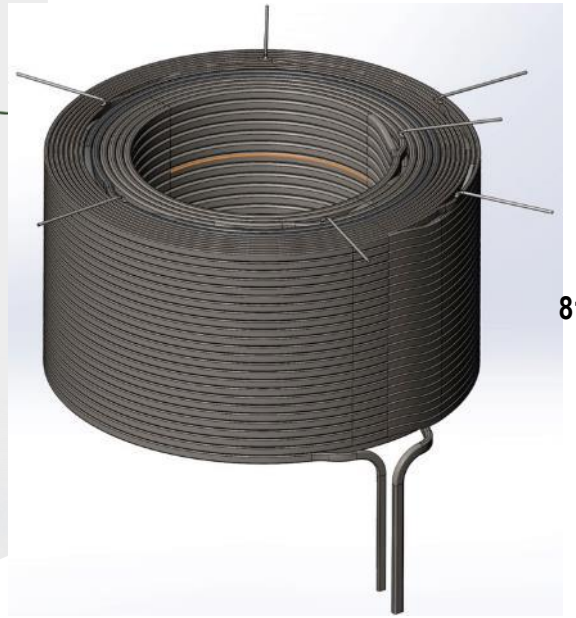
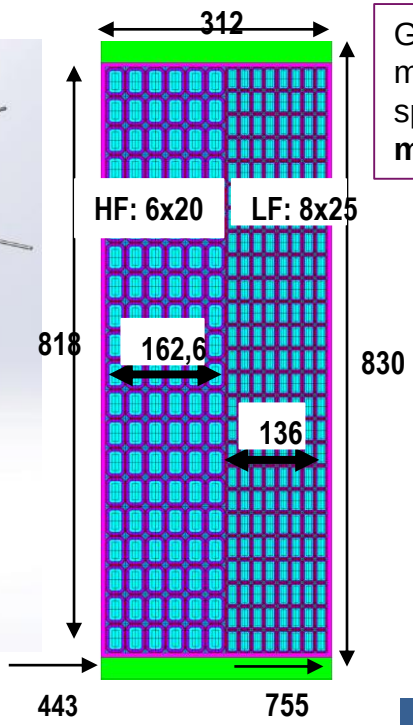
Central Solenoid modules



Design choices:

- 6 identical modules
- Layer wound (2 conductor grades)
- 1 inter-grade joint and 2 terminations per module
- 7 He inlets & 8 He outlets per module





G10 inter-module spacer (**60 mm**)

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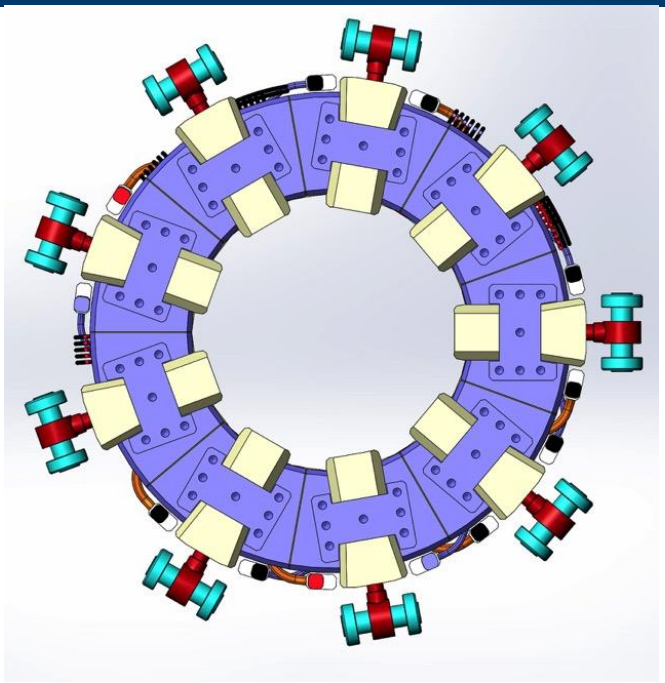
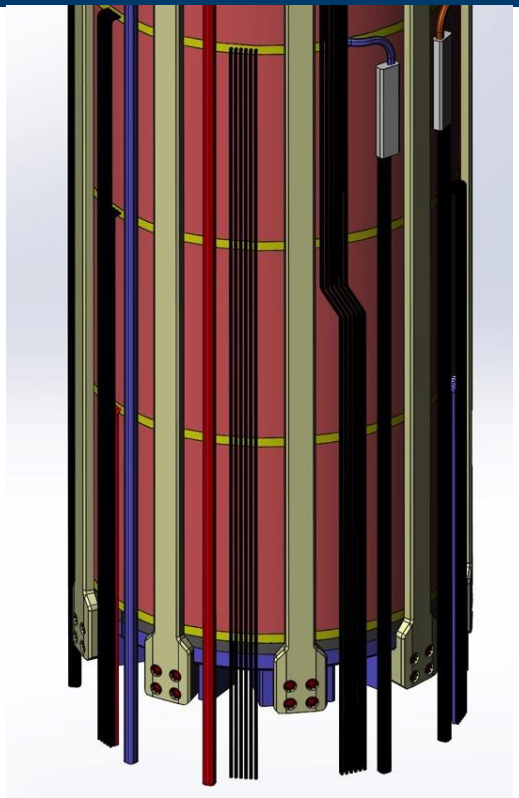
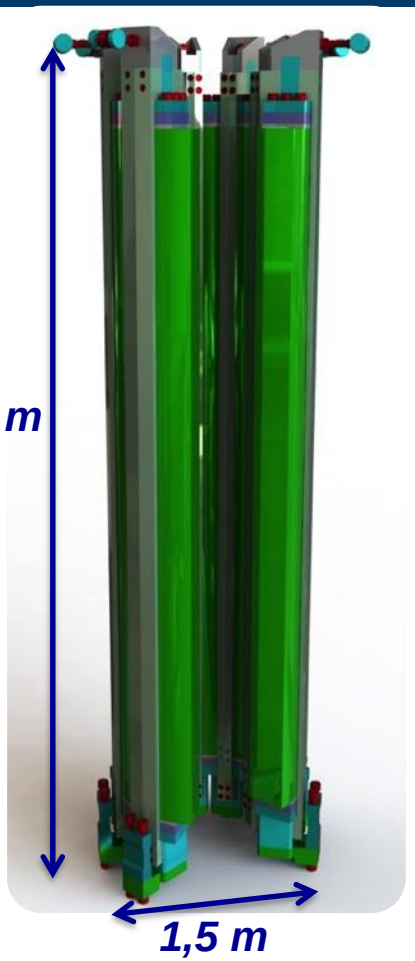
Central Solenoid assembly







CS pre-assembly to be performed after cold testing at full current

DTT heaviest component (~70 tons)

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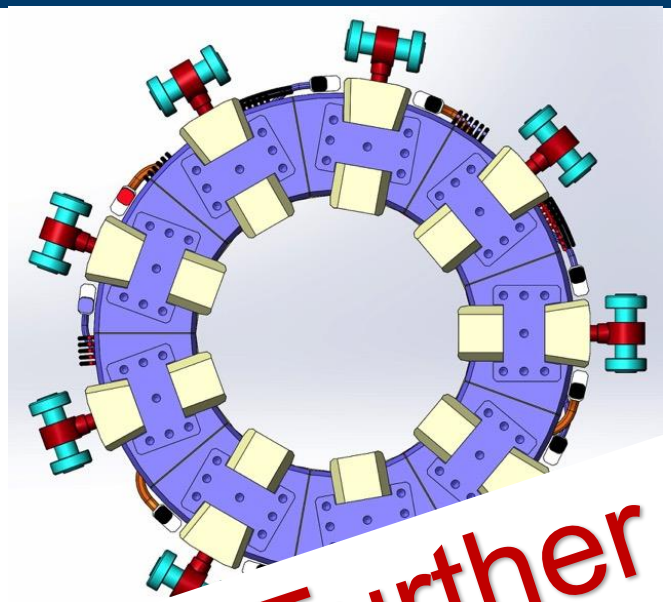
Central Solenoid assembly



Further information in Anemona's presentation

CS pre- ...be performed after cold testing at full current

DTT heaviest component (~70 tons)

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Central solenoid procurement

CS procurement schedule:

- Tender launch within February 2020
- First delivery: December 2021
- CS stack assembly: within May 2024

CS scope of supply:

- 1 + 6 modules
- Pre-compression structures
- CS stack assembly

Technical requirements :

- Heat treatment of Nb3Sn
- Insulation before heat treatment (S-glass)
- Layer-wound approach
- Electrical joints (<2nOhm)
- Vacuum pressure impregnation (VPI)
- High voltage DC tests in vacuum (Paschen proof) -> Vacuum
- Electrical breakers
- Laser tracking experience
- Leak testing experience

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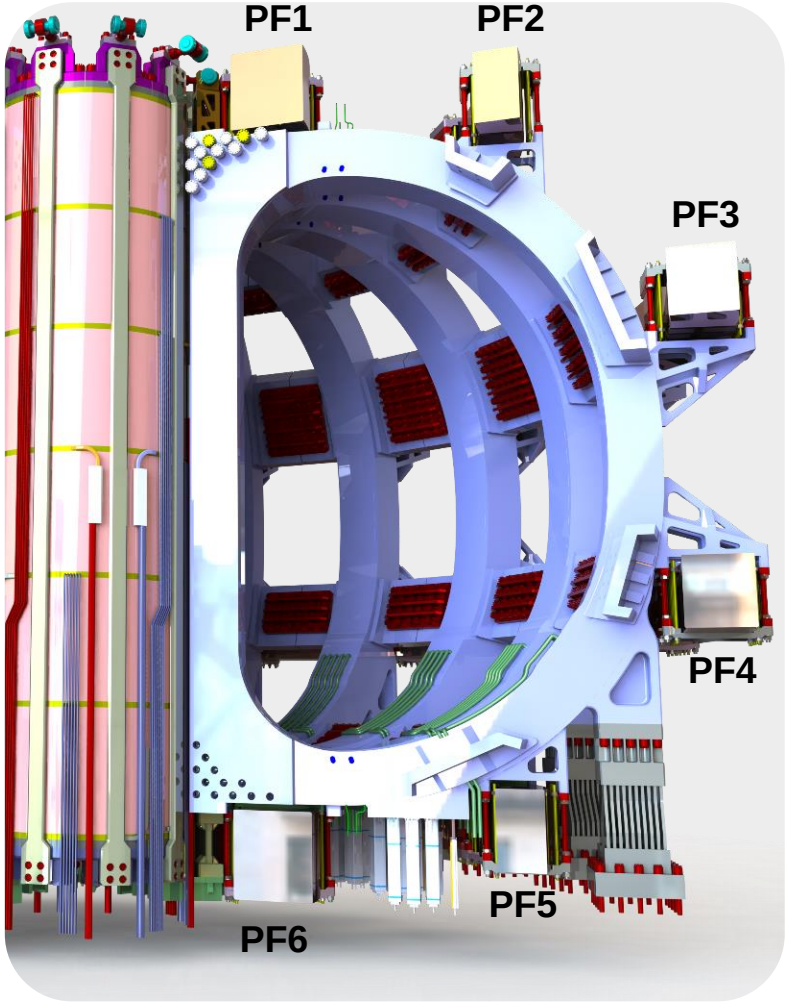
Poloidal Field Coils



6 independent coils
On PF1&6 max B around 9T → Nb_3Sn strands
Designed identical in pairs for symmetry

	PF1/6	PF2/5	PF3/4
Bmax (T) (input data)	9.1	4.2	5.3
Phi average (mm)	2832	6136	8670
ΔR (mm)	542	302	422
ΔZ (mm)	590.4	516.8	452.2
Ground Insulation	5mm		
# turns (radial)	20	10	14
# turns (vertical)	18	16	14
Total N turns	360	160	196
L (H)	0.454	0.298	0.690
V_{max} (V)	2150	1350	3290
Weight (tons)	15	16	28
delay / discharge constant	1.5 s / 6 s		

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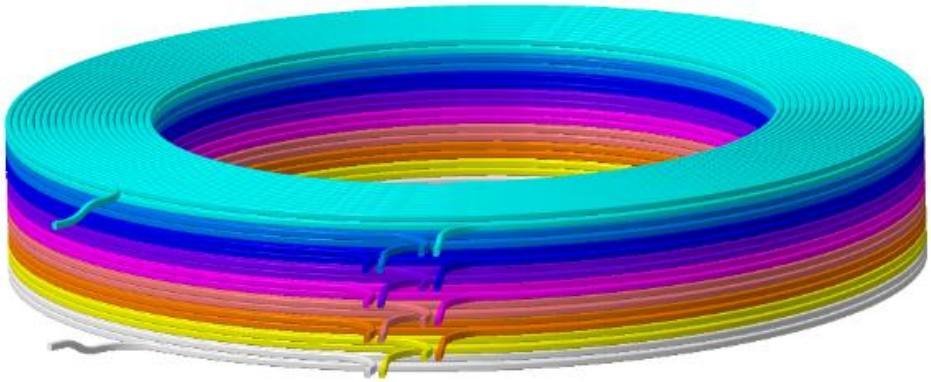
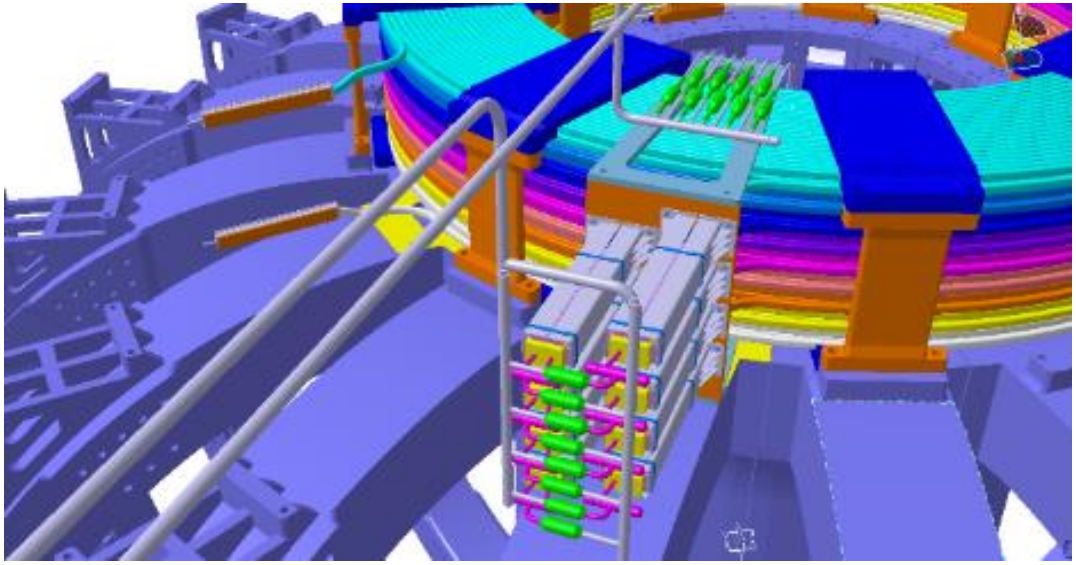
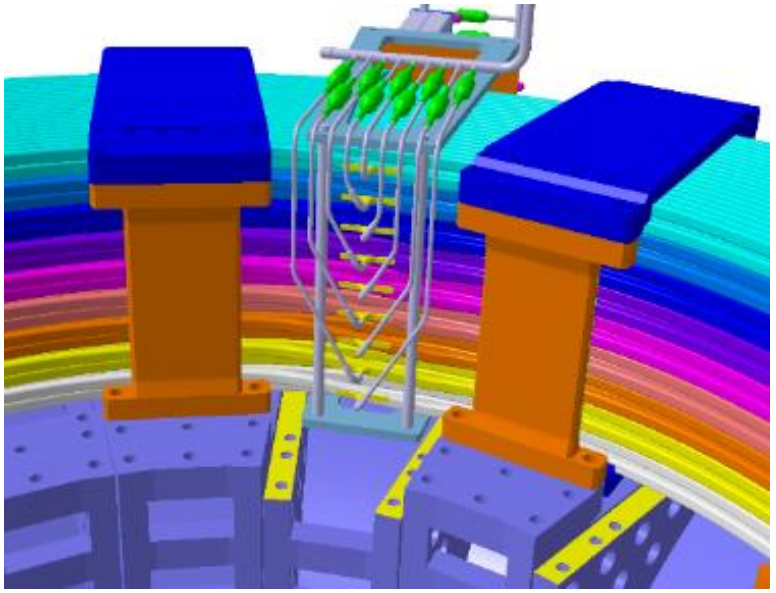
Poloidal Field Coils



PF1/6 -> 9 DP
PF2/5 -> 8 DP
PF3/4 -> 7 DP





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PF coils procurement

PF procurement schedule:

- Tender launch within February 2020
- First delivery: December 2021 (PF6 will be the first coil to be assembled in DTT)

PF scope of supply:

- 2 coils (PF1/6) in Nb3Sn
- 4 coils (PF2/3/4/5) in NbTi

Technical requirements:

- Heat treatment for PF1/6
- Insulation after heat treatment
- pancake-wound approach
- Internal joint (<2nOhm)
- Vacuum pressure impregnation (VPI)
- High voltage DC tests in vacuum (Paschen proof) -> Vacuum
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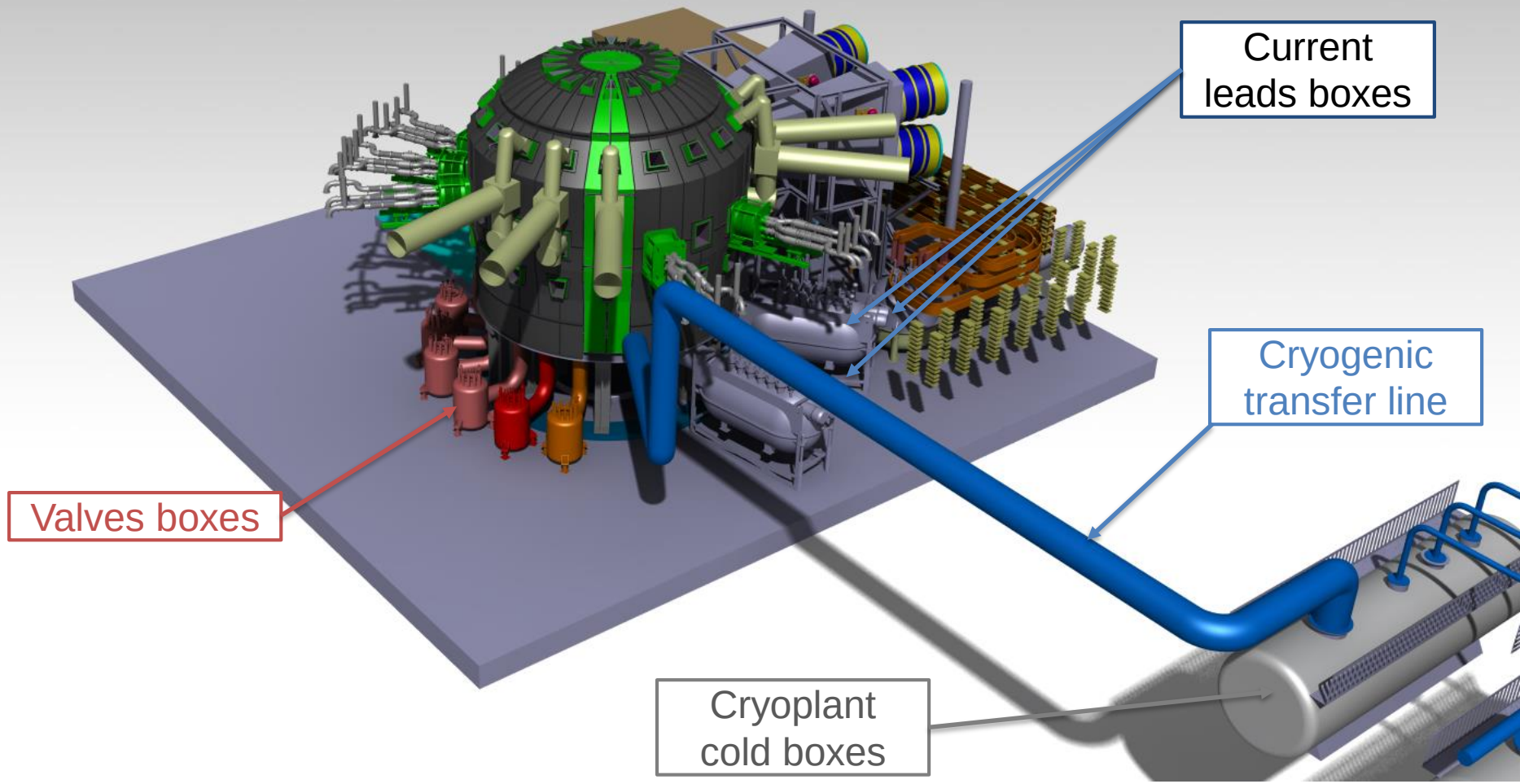
Current leads



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Current leads procurement

Current leads procurement schedule:

- Tender launch within July 2020
- Final delivery within half 2024

Current leads scope of supply:

- 6 CL + cold box for TFC in HTS -> ~45 kA
- 12 CL + cold box with He dewar for PFC resistive -> ~30 kA
- 12 CL + cold box with He dewar for CSC resistive -> ~30 kA

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Cold test facility

→ ENEA decided to create a new infrastructure in Frascati

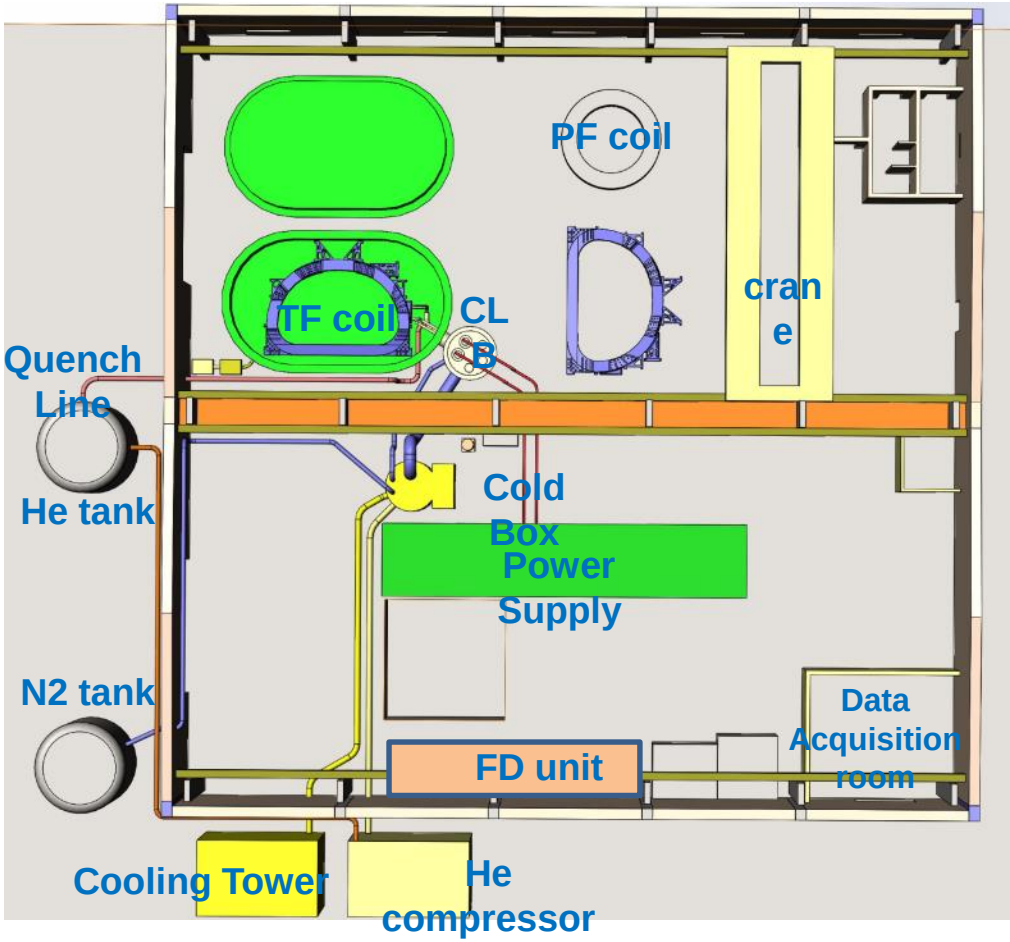
18 TF coils + 7 CS modules + PF1 & 6 will be tested at 4.5K

Current leads, Power Supply & Quench protection prototypes will be used for cold tests and thus qualified against real conditions

This activity is in addition to the DTT budget (ENEA's investement only)

Adaptation of the Superconductivity lab to host the new facility is already started

First test January 2022 on CS-00



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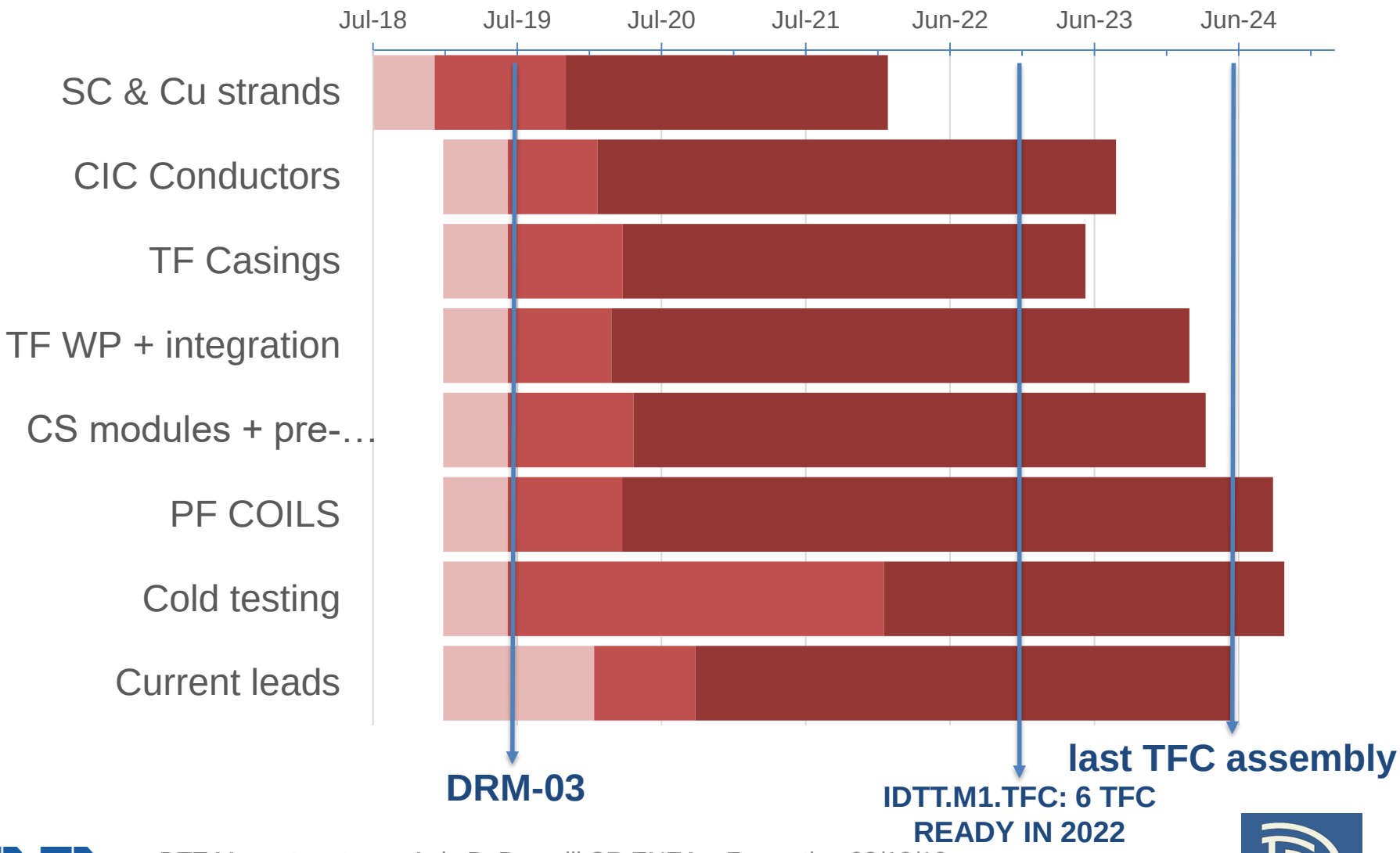
DTT magnet system: overall planning



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QUESTIONS?

gianmario.polli@enea.it

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