THEMATIC WORKSHOP
Heating & current drive program

Caroline DARBOS
ITER Electron Cyclotron Engineer

iter
china eu india japan korea russia usa

With an electronic engineer diploma and a specialization in high frequency system, Caroline Darbos has worked a few years for the industry, before joining the Tore Supra department, in the EC system section.

In 2008, she joined the ITER Organization, in the EC project where she is now responsible of the RF sources.

Chairperson:

Ana Belèn del Cerro Gordo
Ministry of Science, Innovation & Universities , ILO Spain

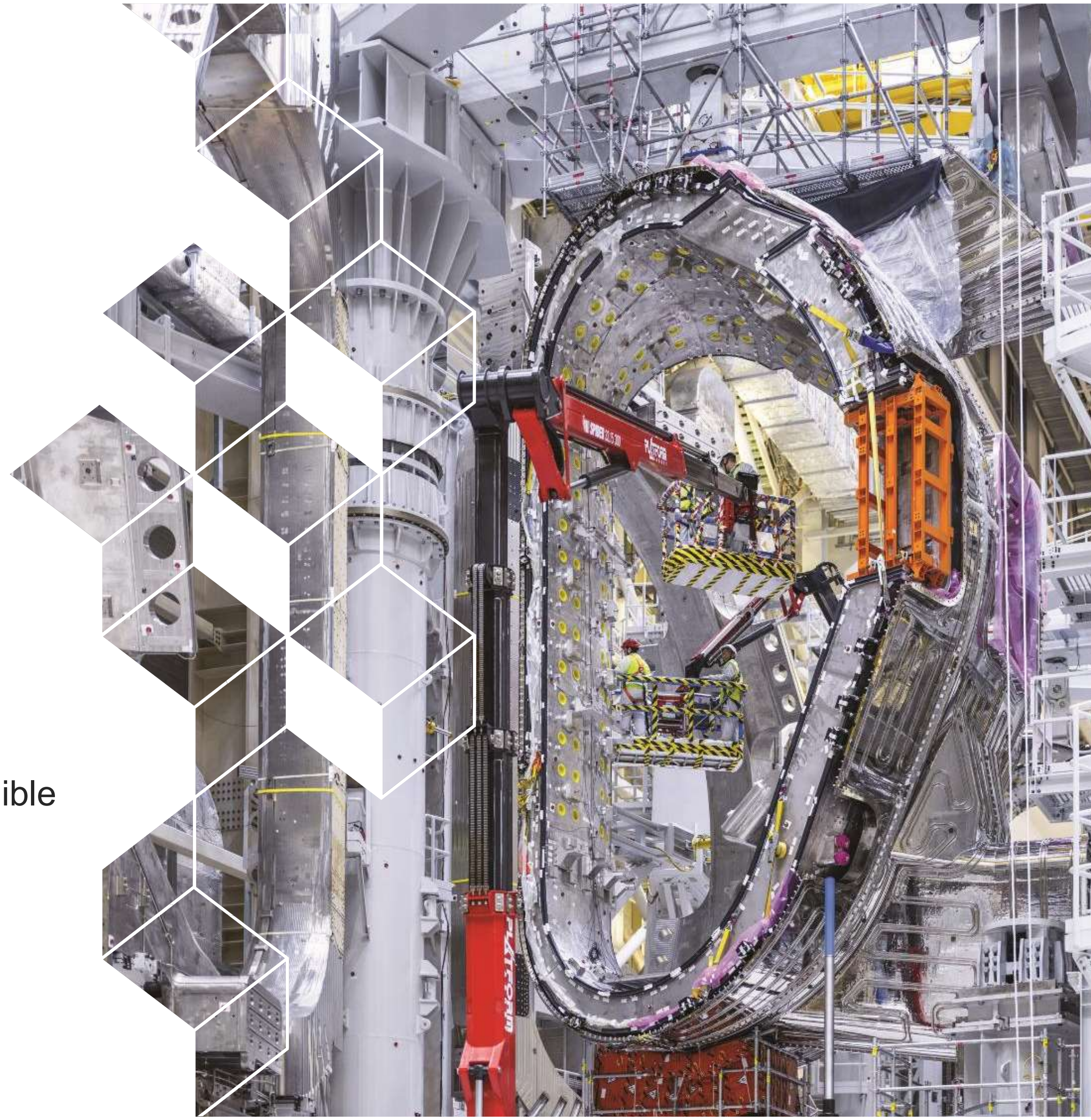
Gonzalo MICÓ MONTAVA
F4E Heating & Current Drive Project Manager

FUSION FOR ENERGY

Experienced Project Manager currently overseeing the Neutral Beam Confinement project at F4E in Barcelona.

With over 20 years of engineering experience, he has advanced from technical roles to managing complex, high-value projects in nuclear fusion technology. Since 2019, he has served as a Project Manager in the Heating Systems Program.

IBF/25
INTERNATIONAL
ITER BUSINESS FORUM



HEATING & CURRENT DRIVE PROGRAM

Caroline DARBOS

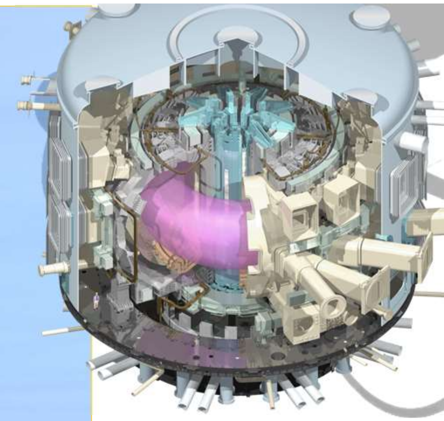
ITER Organization – Technical Responsible Officer for the EC RF sources

THURSDAY APRIL 24th

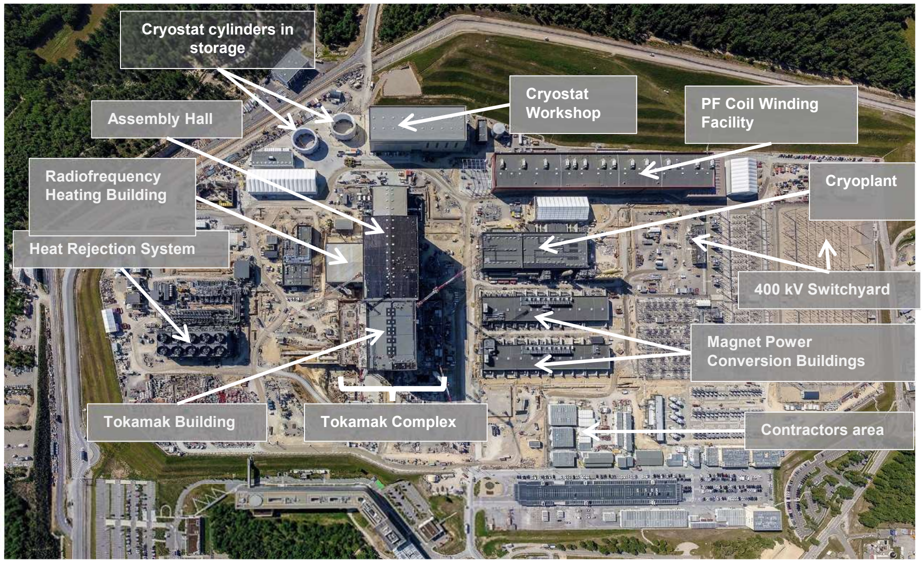
Overview

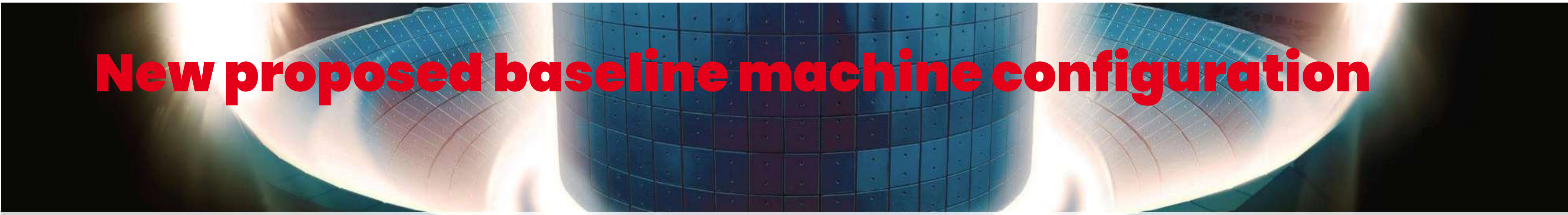
1. **The ITER project**
2. **NB system**
3. **ICRH system**
4. **ECRH system**

1. The ITER Project



The ITER project

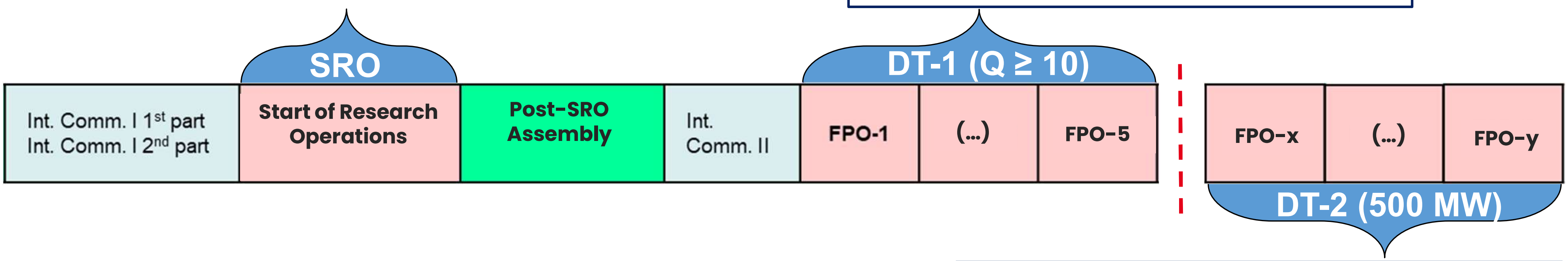




New proposed baseline machine configuration

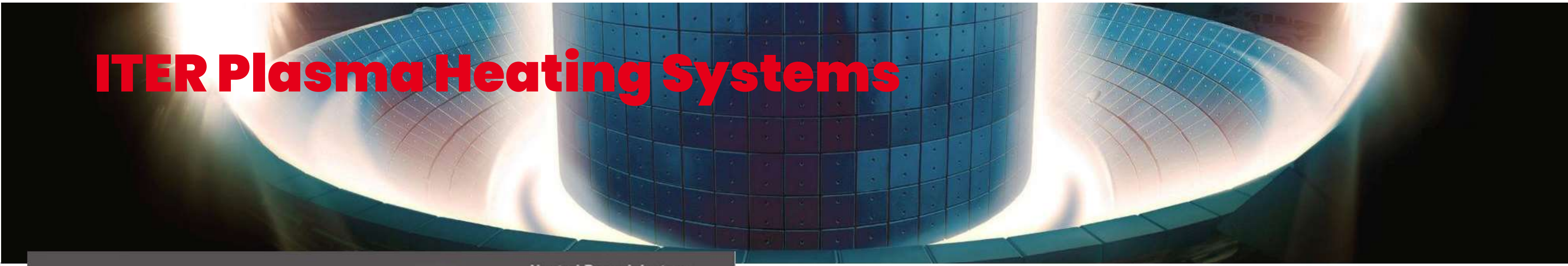
- 40 MW EC heating power (4 Upper + 1 Equatorial Launchers)
- 10 MW of ICWC & ICH
- Boronization system (Glow Discharge Cleaning + *dropper*)
- Full in-vessel coil system (ELM control and VS)
- 4 Pellet injectors (fueling + ELM control)
- W divertor (water cool.) + inertially cooled W wall in key areas

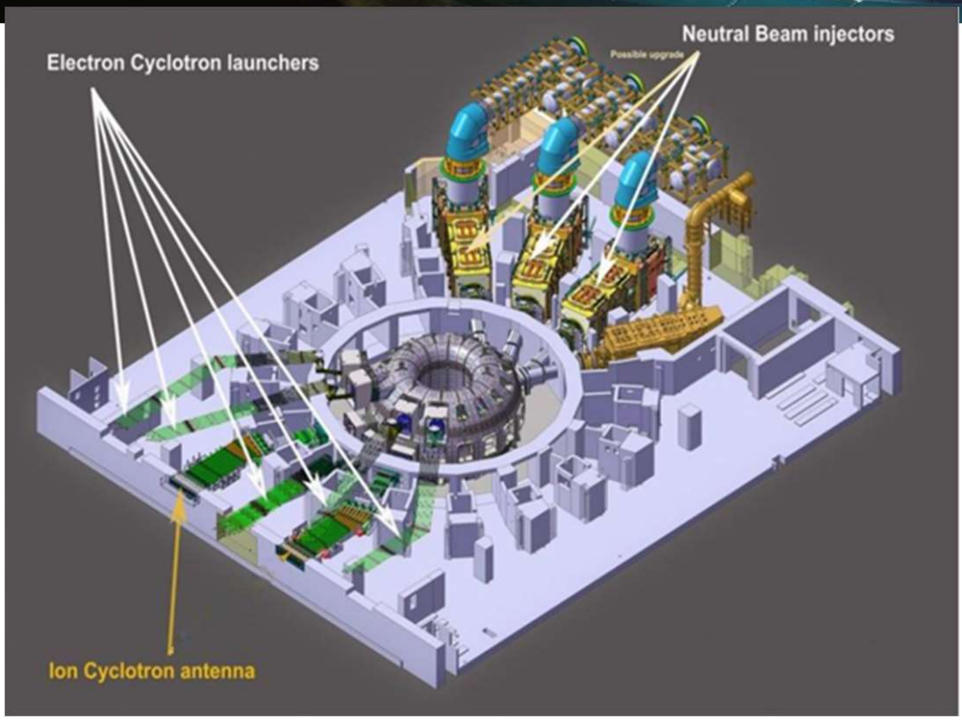
- **All SRO systems, plus …**
- 67 MW EC heating power (4 Upper + 2 Equatorial Launchers)
- 33 MW Neutral Beam (NB) heating power
- 10 → 20 MW IC heating (depending on SRO test results)



- **All DT-1 systems, plus …**
- Possible upgrade to 50 MW NB heating
- Other upgrades required to meet DT-2 goals (e.g. increased shielding, etc.)

ITER Plasma Heating Systems



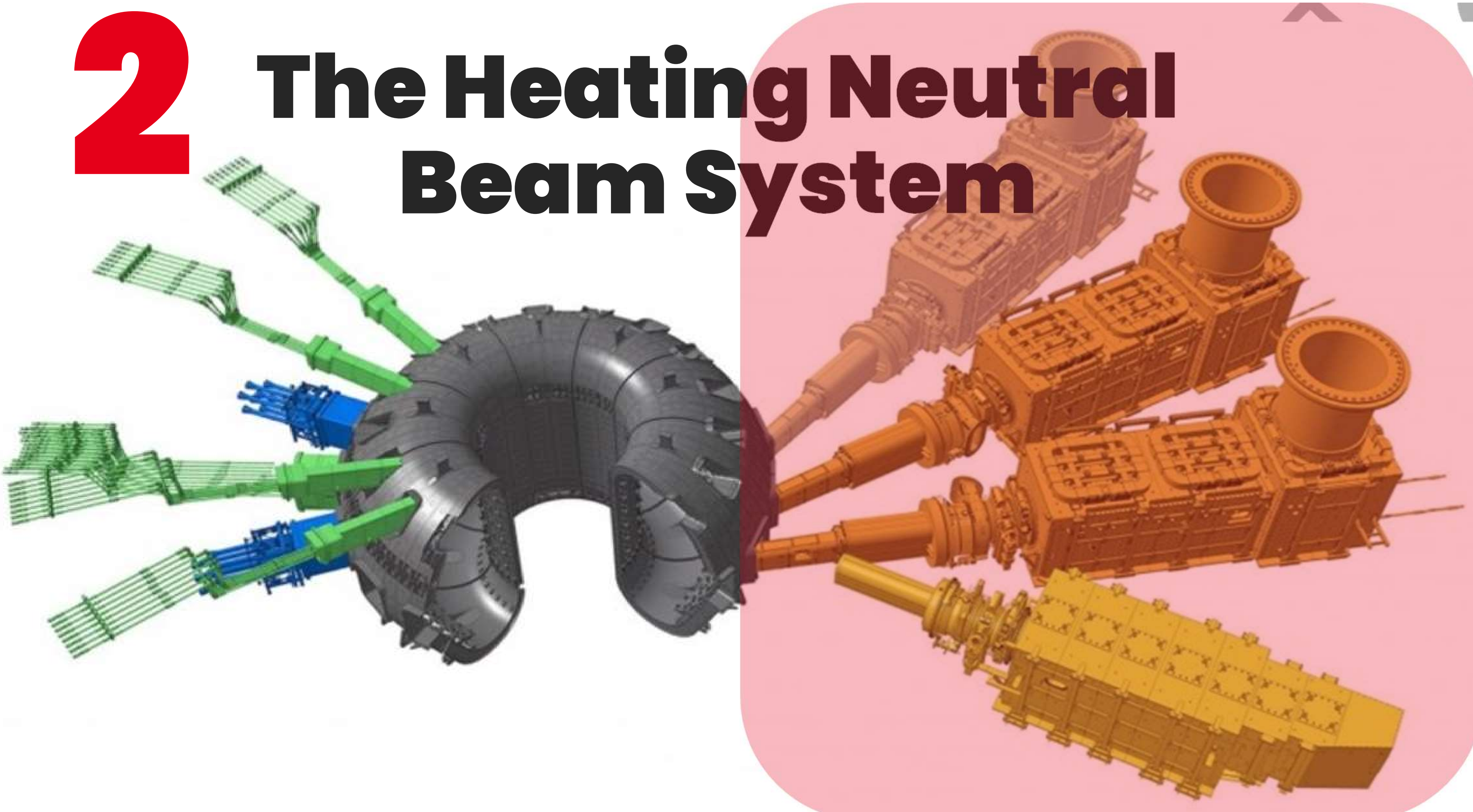


The ITER Tokamak will rely on **3 sources of external heating** to bring the plasma to the temperature necessary for fusion: high-frequency electromagnetic waves— Ion and **Electron Cyclotron (EC) heating** (left) and **Neutral Beam (NB) injection** (right)

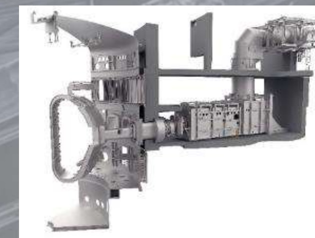
The Heating Systems in ITER have the main functions:

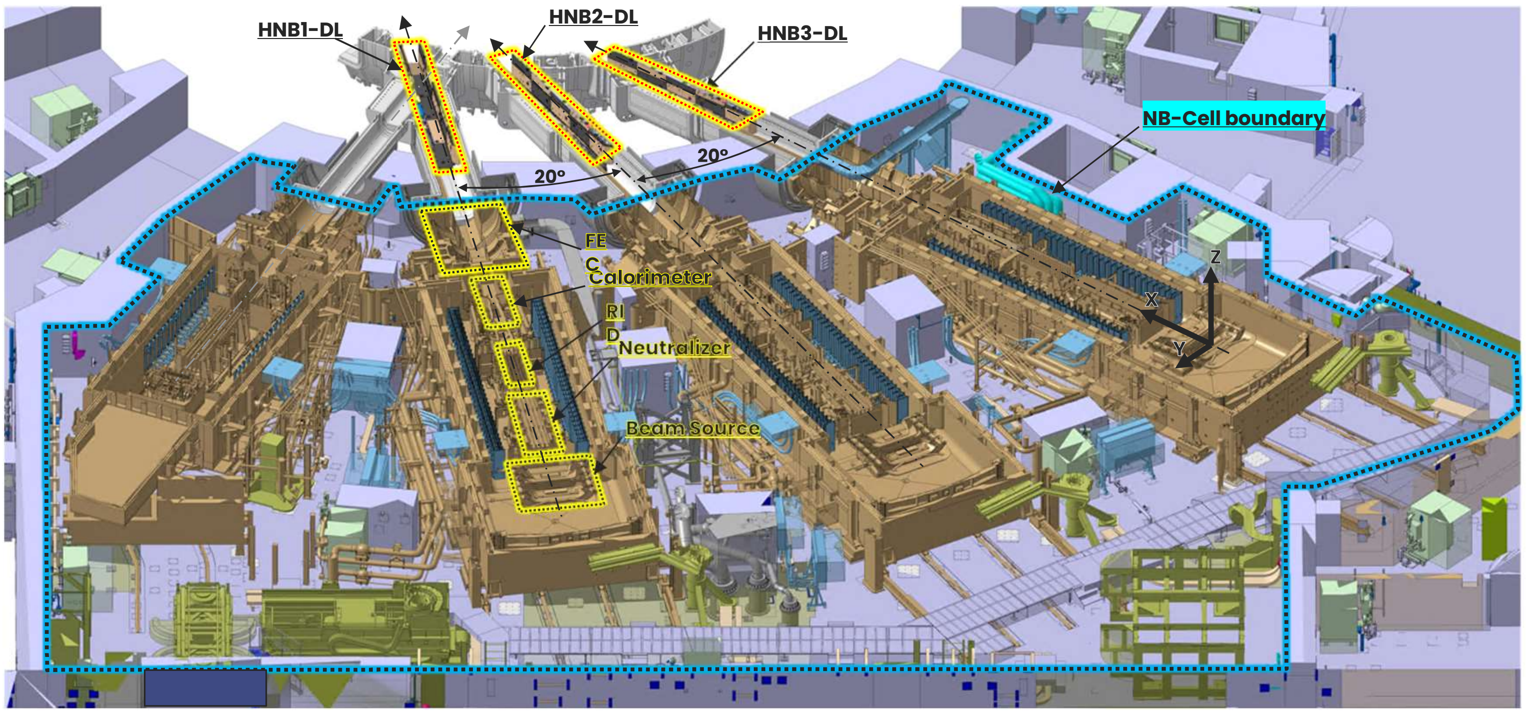
- to **heat up** the plasma to temperatures (~ 150 million degrees C) where fusion reactions can occur at a rate viable for the production of substantial fusion power.
- To "**drive**" the plasma current and allow to sustain longer pulses
- To **control** some plasma instabilities

2 The Heating Neutral Beam System



ITER Heating Neutral Beam System (HNB)



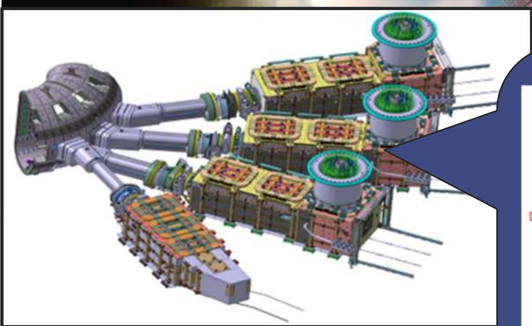


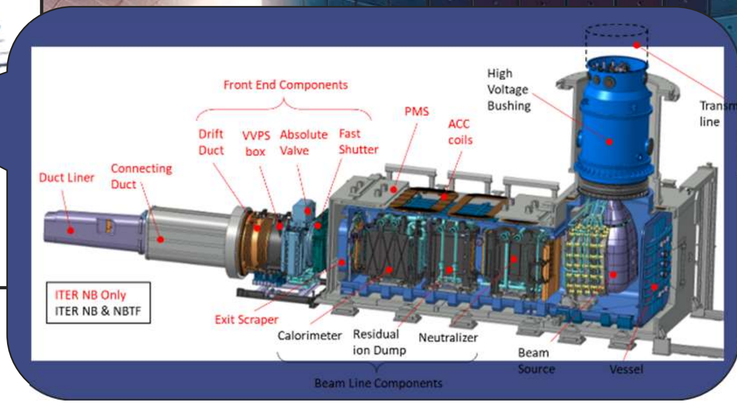
2 HNB
Injectors as Baseline
(+ captive components of optional 3rd injector)

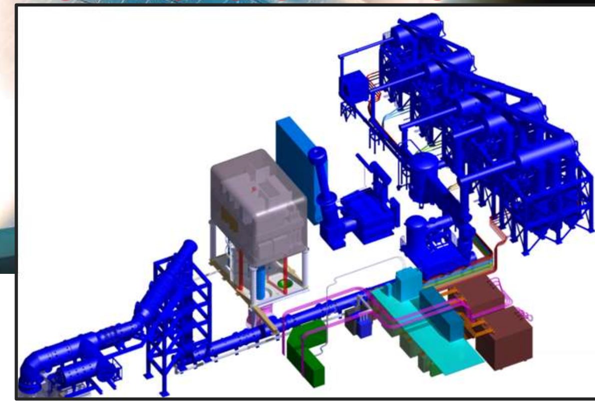
Each Injector:

P_{beam} = 16.5 MW
I = 40 A
V = 1 MV
T_{pulse} = 3600 s

Neutral Beam Project: Status of 2016 Baseline







3 x Duct Liners - IO (TBD)
- **On-going CFT**
- Contract Signature later 2025
- Delivery expected for 2030
- Assembly in 2031

2 x Connecting Duct Liners - IO
- CFT later 2025
- Delivery expected for 2030

3 x Drift Duct – (2 EUDA + 1 INDA)
- To be procured
- Manufacturing starts in 2027
- Delivery in 2030

2 x VVPSS Box – (IO)
- CFT later in 2025
- Delivery in 2029

3 x Absolute Vale - (2 EUDA + 1 INDA)
- FDR planned for 2027
- Delivery expected for 2035

3 x Fast Shutter - (2 EUDA + 1 INDA)
- FDR planned for 2027
- Delivery expected for 2036

3 x NB Vessels – (2 EUDA + 1 INDA):
- EUDA: WALTER TOSTO
- INDA: Vacuum Techniques
- Manufacturing on going
- Delivery in 2030

3 x PMS & ACCC – (2 EUDA + 1 INDA)
- To be procured
- Delivery in 2030

3 x BLC Set (2 EUDA + 1 INDA)
- INDA contribution: PVA TEPLA
- EU contribution: To be procure
- FDR planned for 2027
- Delivery expected for 2034

3 x HVB - (2 JADA + 1 INDA)
- JADA Contribution: HITACHI
- INDA Contribution: TBD
- FDR planned 2026
- Delivery expected for 2032

3 x HV TLs – (2 EUDA + 1 INDA):
- JADA Contribution: HITACHI
- INDA Contribution: TBD
- FDR planned 2026
- Delivery expected for 2032

2 x 1MV AGPS (EUDA/JADA)
- EUDA/JADA contribution: NIDEC ASI /HITACHI Ltd
- Delivery on going / Manufacturing on going

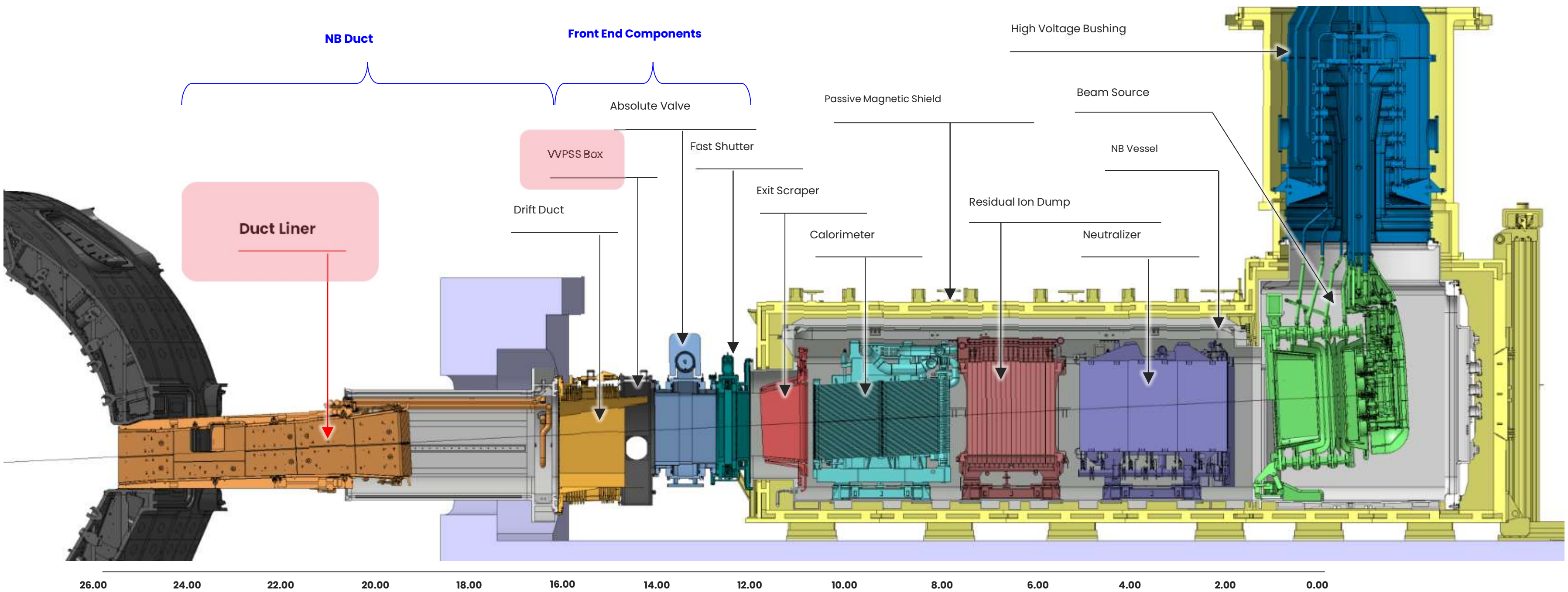
2 x 1MV HVD1 - (2 EUDA)
- EUDA Contribution: Innomotics GmbH
- Delivery on going

2 x RID PS – (2 EUDA):
- EU Contribution: OCEM
- Delivery on going

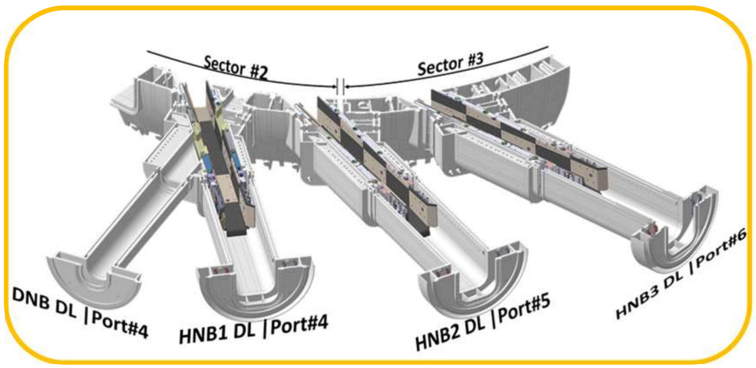
2 x ISEP PS – (2 EUDA):
- EU Contribution: OCEM
- Delivery expected for 2028

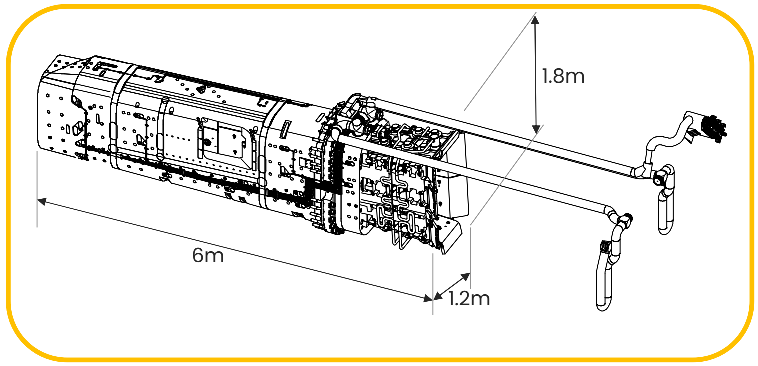
1 x DNB PS Set – (INDA):
- Partial set commissioning
- Delivery expected for 2031 and 2034

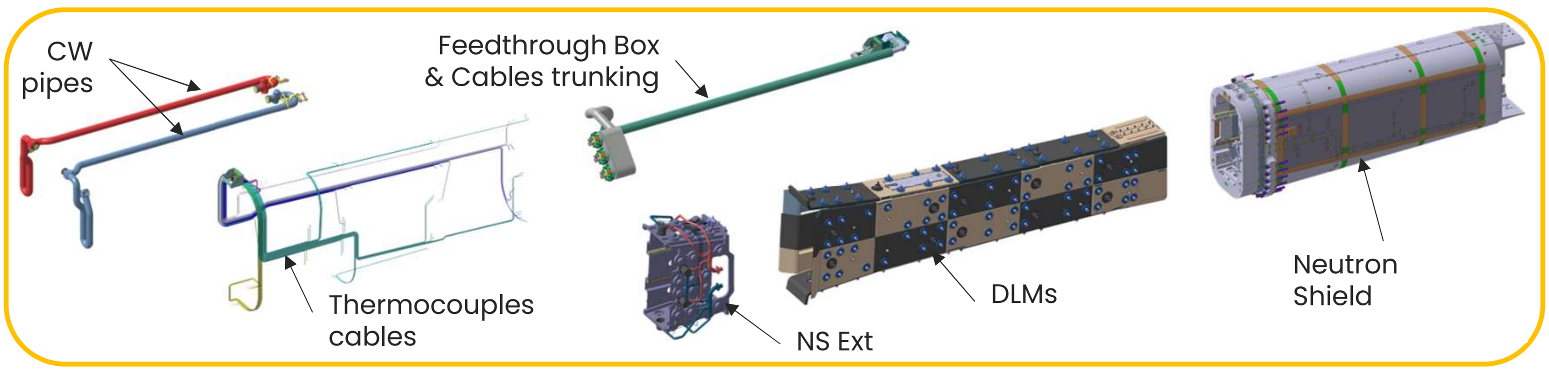
HNB main components



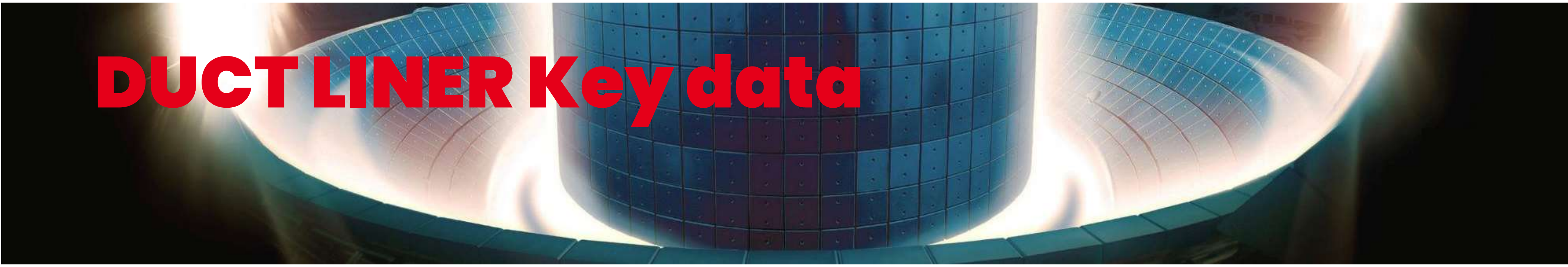
DUCT LINER components

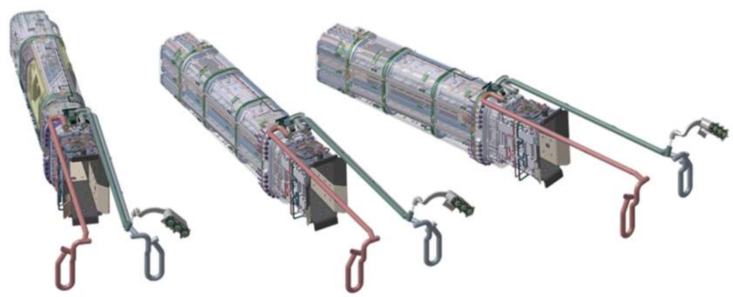






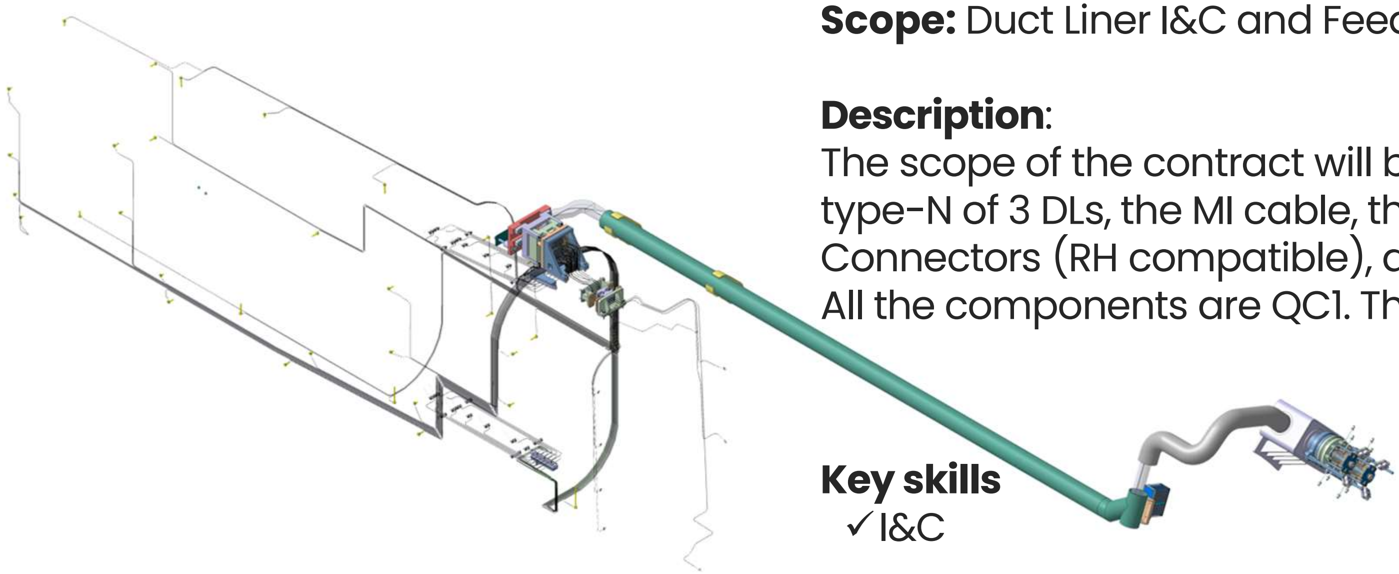
DUCT LINER Key data





- The DLs are in-vessel components (QC1).
- The DL is to be delivered in July 2031.
- Estimated manufacturing duration: 5 years
- Each of the 3 DLs masse is ~26 tons. (mainly made of 316L(N)-IG (85%) and CuCrZr)
- The DL fabrication includes 18-ton NS and 7-ton DLMs made of 316L(N)-IG or CuCrZr.
- There are 40 DLMs for the DL HNB1 and 35 DLMs for the 2 others.
- Key steps are forging, precision machining, TIG/EB welding with 99% NDT, and possible copper layering (via explosive bonding, HIP, plasma spraying, or electrodeposition).
- The assembled DLs are subjected to rigorous leak testing and dimensional checks.

DUCT LINER I&C procurement

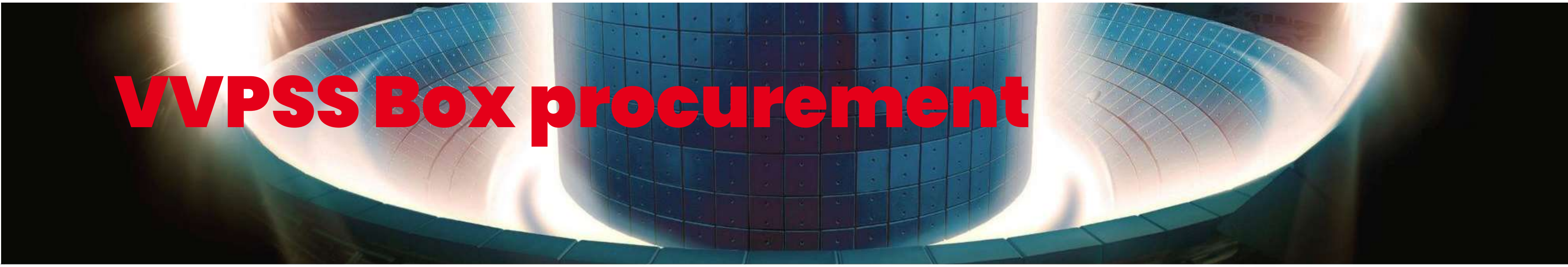


Scope: Duct Liner I&C and Feedthrough Box

Description:
The scope of the contract will be to procure Thermocouples type-N of 3 DLs, the MI cable, the Junction Box, the Connectors (RH compatible), and the Junction Box.
All the components are QC1. The Feedthrough-Box is SIC.

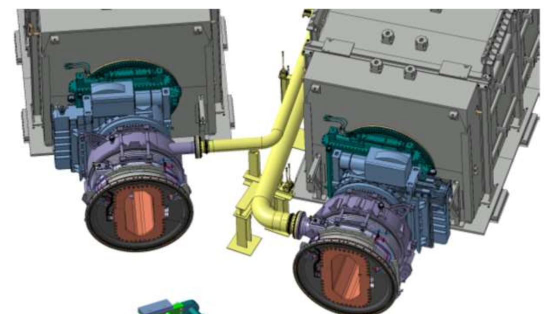
Key skills
- ✓I&C

Status and pre-procurement activities:
- ✓Call for tender to be launched in 2026



VVPSS Box procurement

Description:
The main function of the VVPSS Box is to provide a **low loss flow pathway between the VV and the VVPSS Line**.

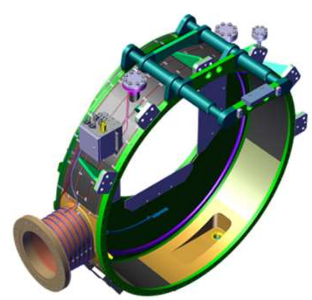


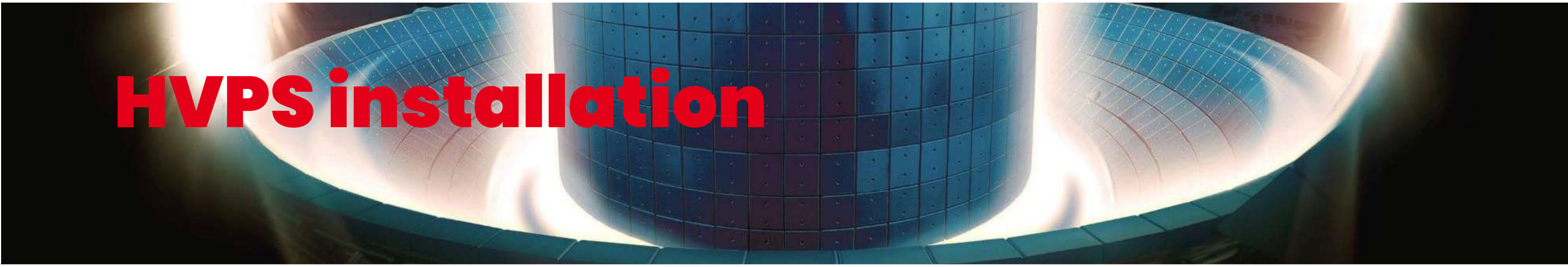
Key skills

- ✓ Nuclear: The VVPSS Box is part of the Primary Vacuum Boundary for the Neutral Heating Beam Line Injectors. **It is a PIC-SIC 1 component.**

Status and pre-procurement activities:

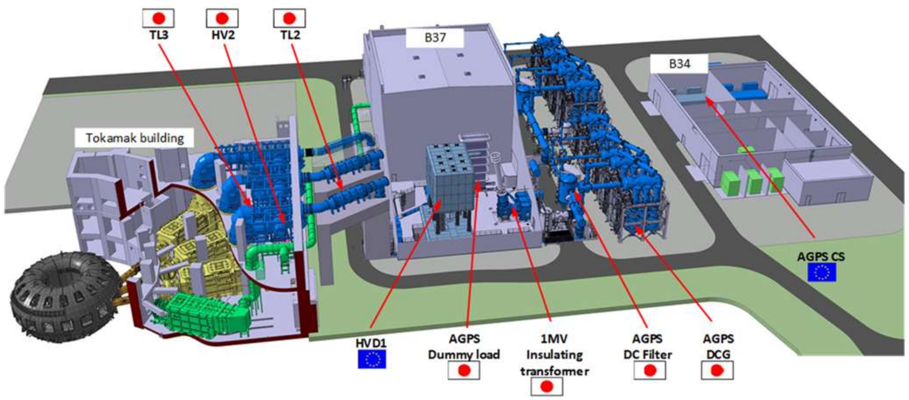
- ✓ FDR has been carried out the 28th November .
- ✓ BtP drawings are on-going to be finalized .
- ✓ The tender process shall be launched by end of 2025.





HVPS installation

Description:
The Heating Neutral Beam injectors are supplied at ultra high DC voltage (-1MV dc) to fix the potential of the RF ion source and for the acceleration grid.
The qualification and tests will be performed at the Neutral Beam Test Facility, Prima site in Padua (Italy)
The Installation at ITER site is planned to begin in mid 2026.

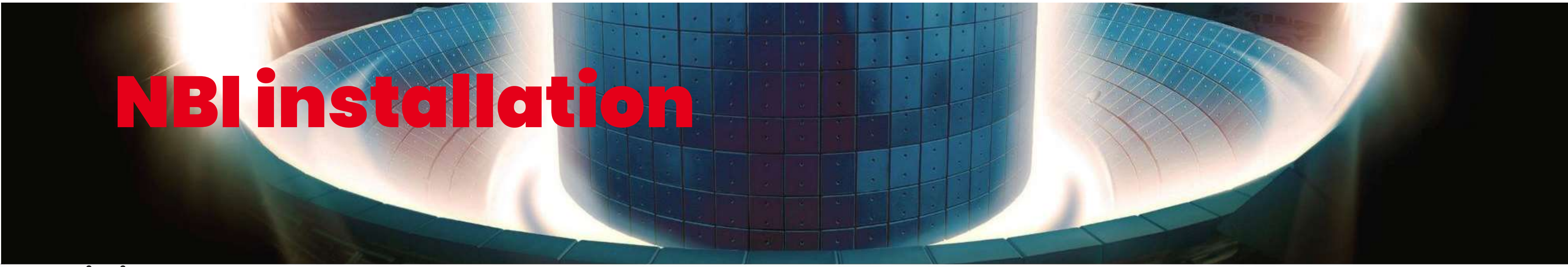


Key skills
- ✓ Installation of High voltage components (1 000kV)
- ✓ Installation of pressurized vessels (SF6 @ 6bar)
- ✓ Installation of mechanical structure

Status and pre-procurement activities:
- ✓ Preparation of the call for tender in 2025
- ✓ Contract signature 03/2026
- ✓ Start of installation mid 2026



Pictures from the Neutral Beam Test Facility in Italy



NBI installation

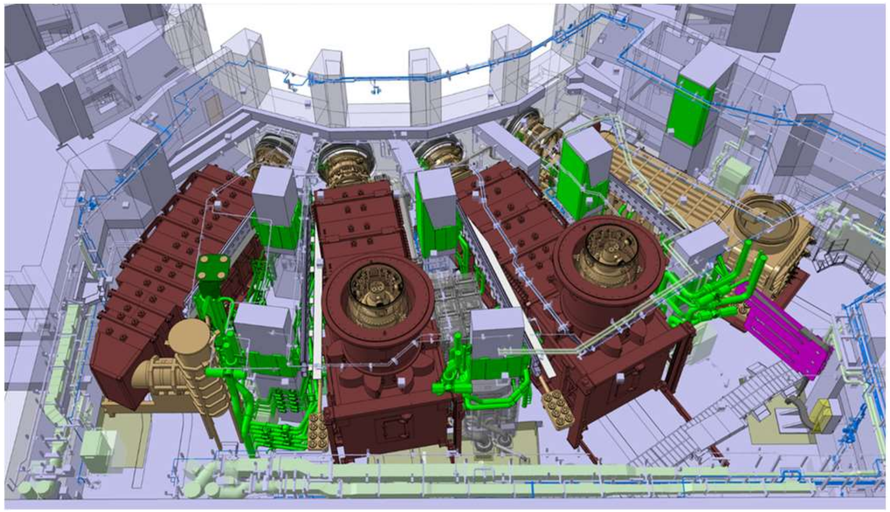
Description:
The Neutral Beam system includes two Heating Neutral Beams (HNBs), one Diagnostic Neutral Beam (DNB), and a partially installed third HNB, all housed within the Neutral Beam cell in the tokamak building. Each HNB measures approximately 20 meters in length, 4 meters in width, and 10 meters in height, with a mass of about 850 tons. The DNB is approximately 15 meters long, 4 meters wide, and 4 meters high, with a mass of around 524 tons. These components are part of the primary confinement barrier. Internal components for neutral beams creation and control operate in an ultra-high vacuum environment. The installation also includes associated services such as piping, valves, and cabling.

Key skills

- ✓ Installation of mechanical components
- ✓ Installation of plant systems
- ✓ Working in clean environment
- ✓ Non Destructive tests
- ✓ Testing activities (vacuum leak test, electrical tests)

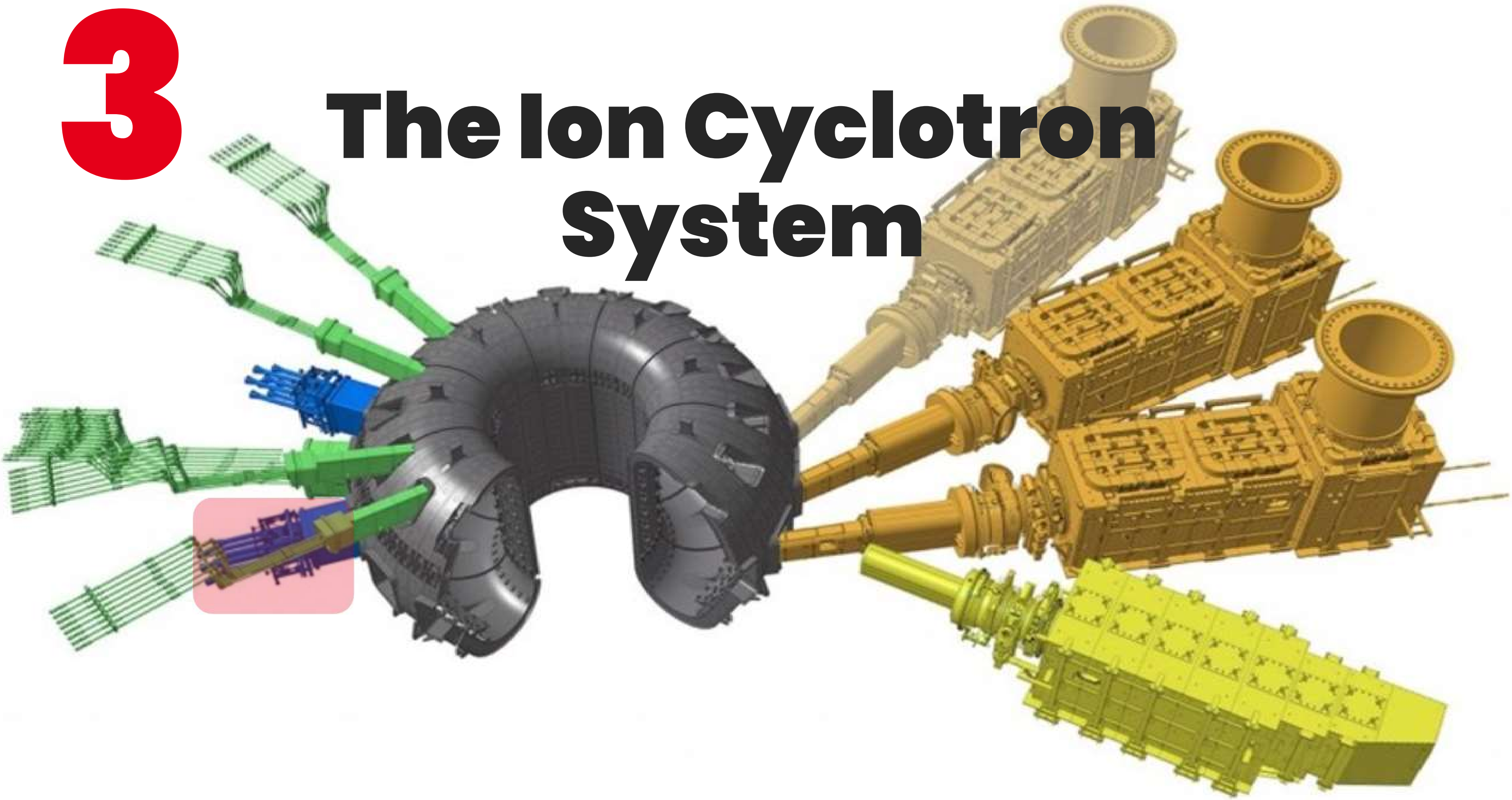
Status and pre-procurement activities:

- ✓ Installation is planned to start in 2031.
- ✓ Discussion on going with other systems to have unique contract for assembly activities in the NB cell



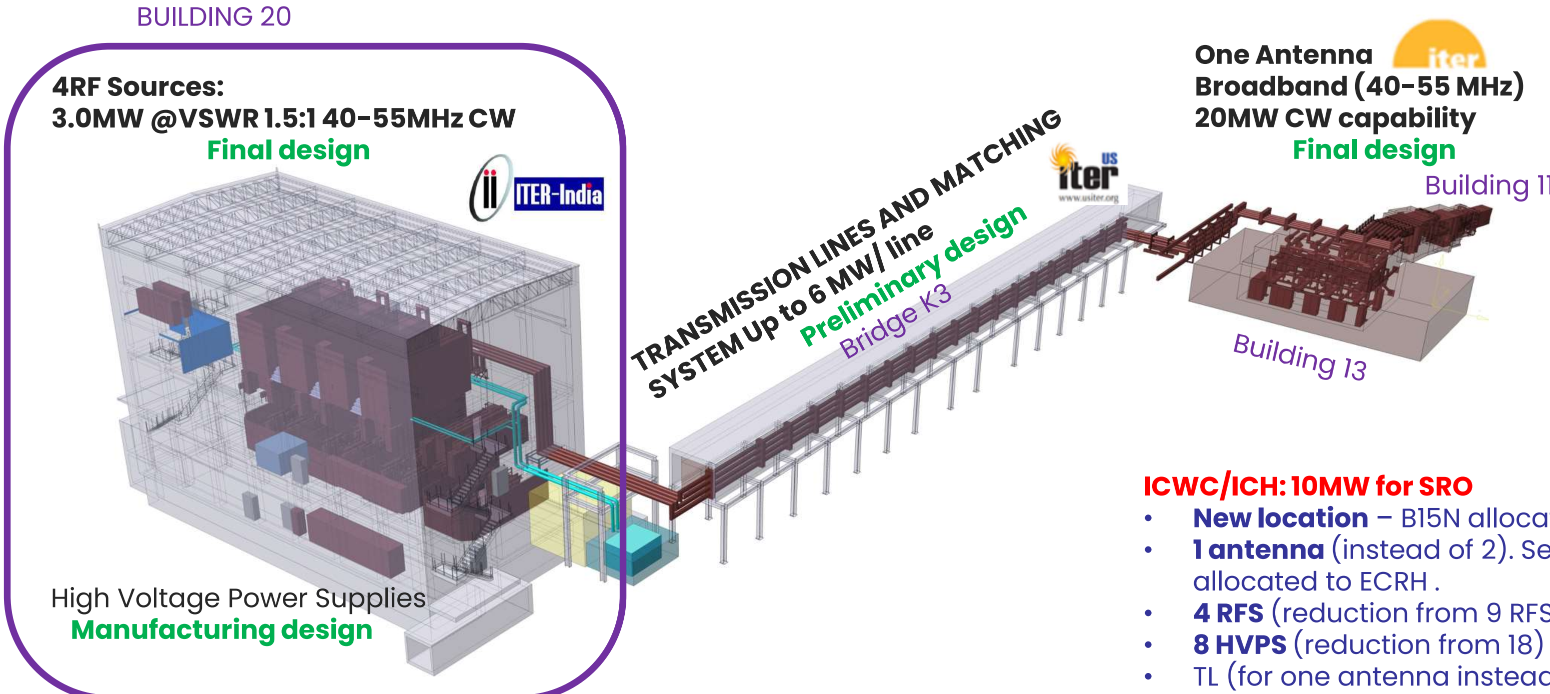
3

The Ion Cyclotron System



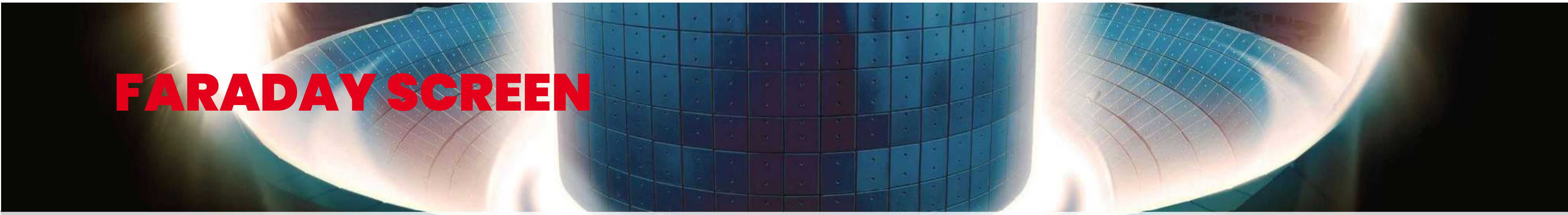
ITER Ion Cyclotron Heating & Current Drive system

No technical requirements are modified for the individual components of the ICRH system.



ICWC/ICH: 10MW for SRO

- **New location** – B15N allocated to ECRH.
- **1 antenna** (instead of 2). Second port allocated to ECRH .
- **4 RFS** (reduction from 9 RFS)
- **8 HVPS** (reduction from 18)
- TL (for one antenna instead of 2), captive lines in B11 required, re-routing of TL from new location to B11 for 4 TL
- No changes to EQ13 or TL to EQ13 in B11



FARADAY SCREEN

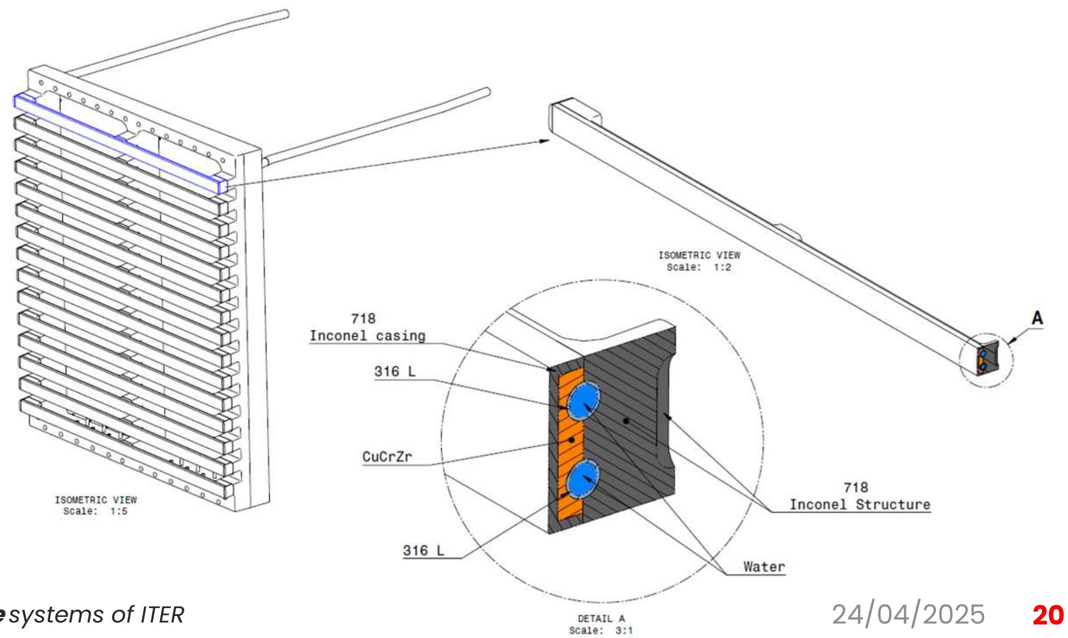
Description:
Plasma facing component, shielding and radiofrequency function
Main dimension width 1m, height 1m, about 150kg of 316L(N)-IG
Actively cooled (50bars / 70°C - 126°C), compatible with 240°C baking process
Copper coating on Radio Frequency surfaces / low Z material coating on plasma facing surfaces (such as Boron coating)

Key skills

- ✓ TIG welding
- ✓ Hot Isostatic Pressing (HIP)
- ✓ NDT of dissimilar joints
- ✓ High precision machining
- ✓ Testing capability (high flux test…)

Status and pre-procurement activities:

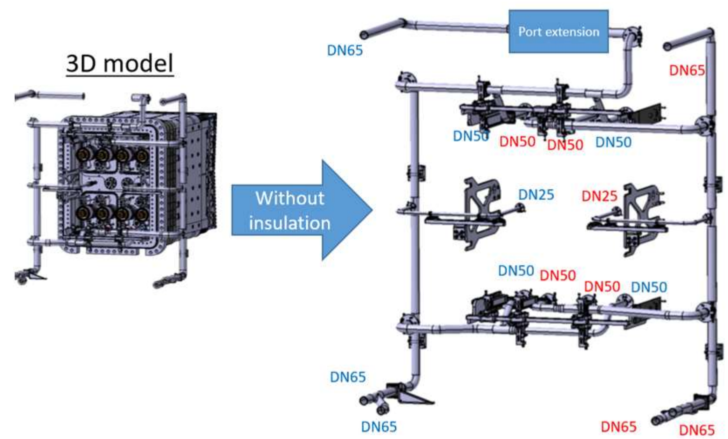
- ✓ Tendering phases expected to be launch mid 25
- ✓ Prototype manufacturing in 2026/2027
- ✓ Series production (4 units) by mid 2028



ICH Antenna Primary heat transport system piping

Description:
Ex vessel piping system feeding the Antenna (primary heat transport system)
Compatible for component cooling (44Kg/s, 50bars, 126°C) and component baking (0.44kg/s, 50bars, 240°C)
Nuclear pressure equipment classified
Permanent piping and supports, several section are removable for maintenance

Key skills
- ✓ Nuclear pressure equipment design and manufacturing
- ✓ Implementation EU directive for design, manufacturing and testing
- ✓ Design justification by FEA and testing
- ✓ High Energy Line Break assessment and mitigation
- ✓ Mastery of EU harmonized standards and their implementation
- ✓ Manufacturing of the pipework, welding and Non-Destructive Examination
- ✓ Qualification of items (such as quick connectors)



Status and pre-procurement activities:
- ✓ Tendering phases expected to be launched early 2026
- ✓ Design finalization and compliance with ESPN regulation demonstrated by mid 2027
- ✓ Series production by mid/end 2028

ICH Antenna High Power RF test facility

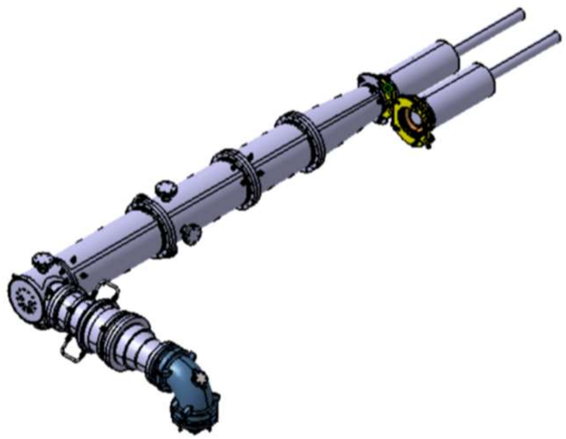
Description:
Custom transmission lines for Antenna prototype and final antenna high Power RF testing
Support structure for ~20m of 9"/12" transmission lines
Heat exchanger for Radio Frequency generator cooling water
Installation tooling and Antenna prototype handling tool and supporting structure

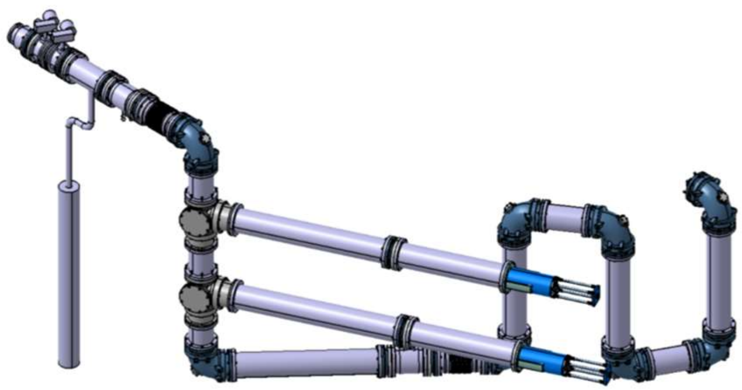
Key skills

- ✓ TIG welding
- ✓ Nondestructive examination of welds
- ✓ Copper coating
- ✓ Production of manufacturing drawings and tolerances analysis
- ✓ Design development of heating / cooling water system (heat exchanger / tank design)
- ✓ Mastery of EU harmonized standards and their implementation
- ✓ Installation of equipment on ITER site

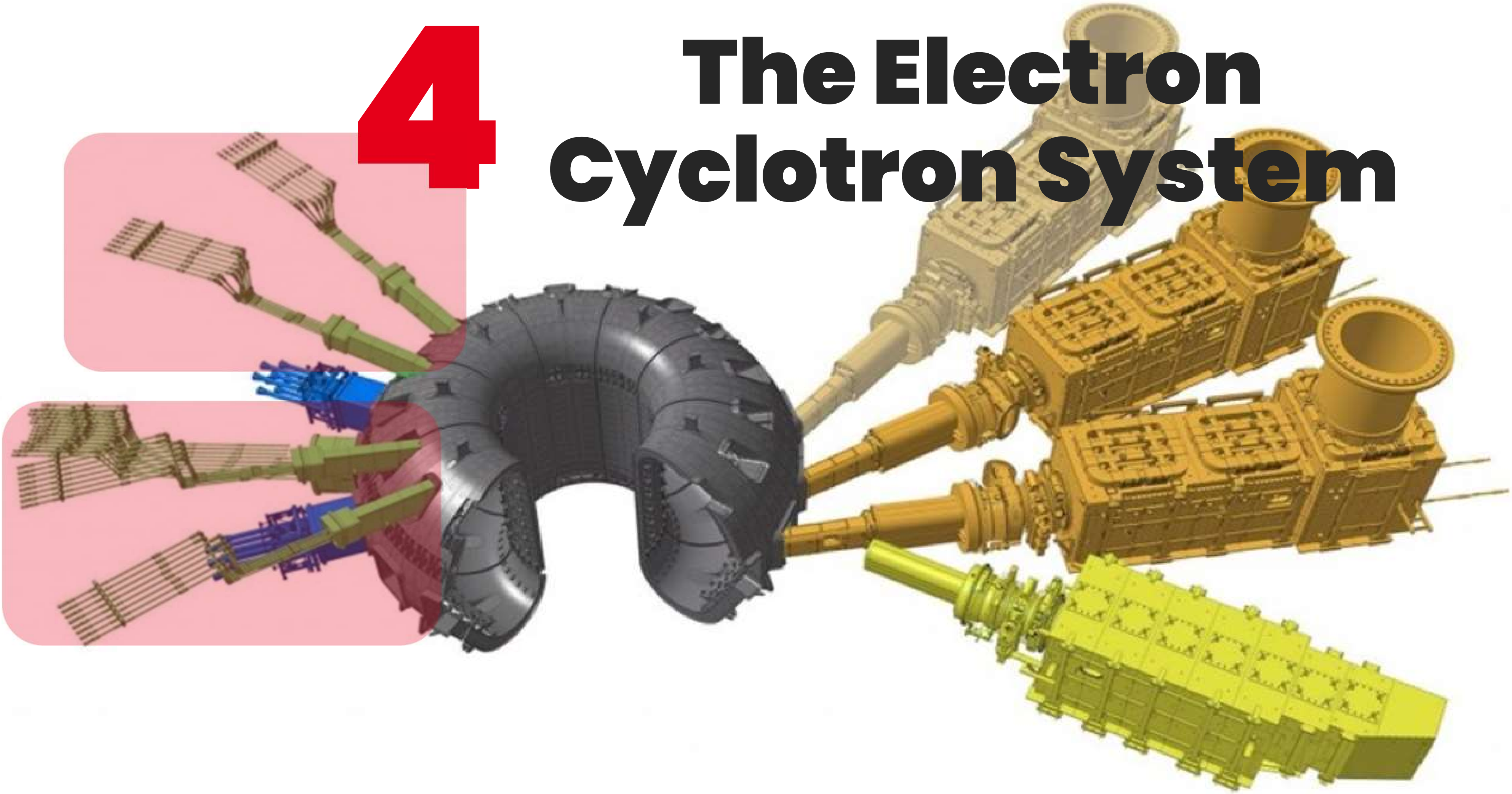
Status and pre-procurement activities:

- ✓ Several tenders foreseen
- ✓ Tendering phases expected to be launched early 2026 (even before while possible)
- ✓ Manufacturing phases in 2026/2027
- ✓ On site installation in 2027

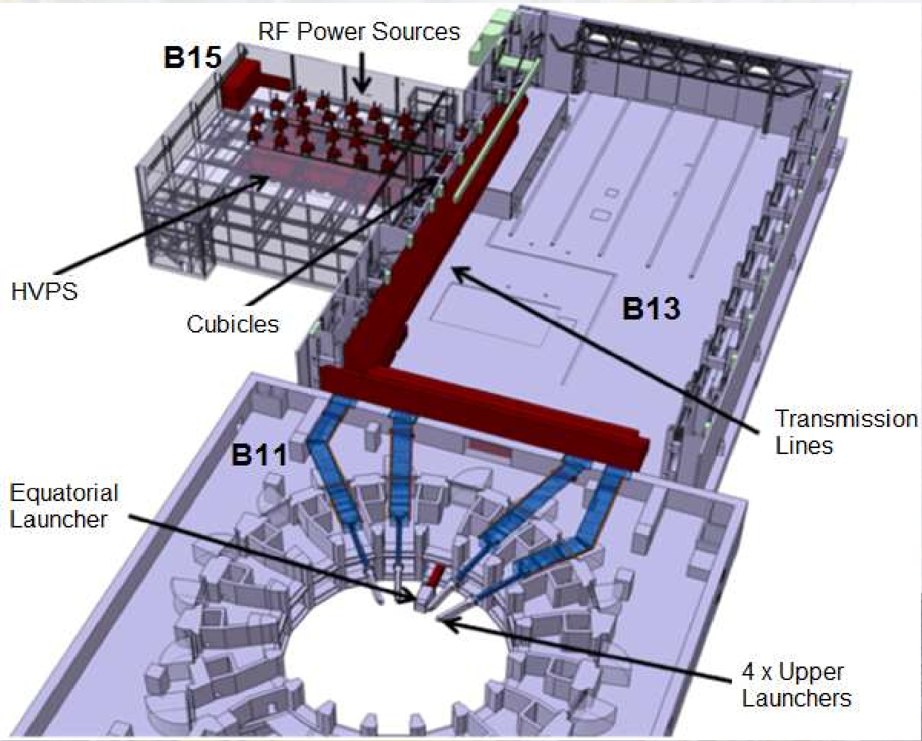




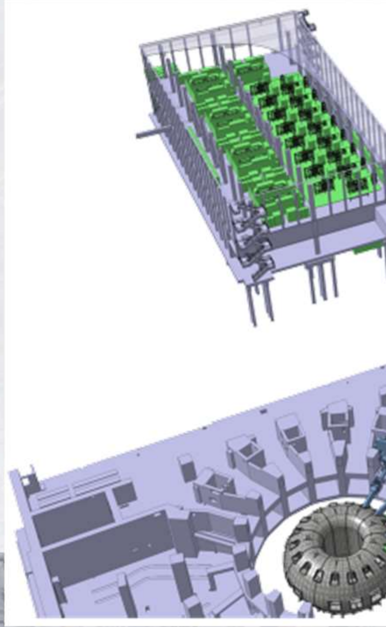
4 The Electron Cyclotron System



ITER Electron Cyclotron Heating & Current Drive system

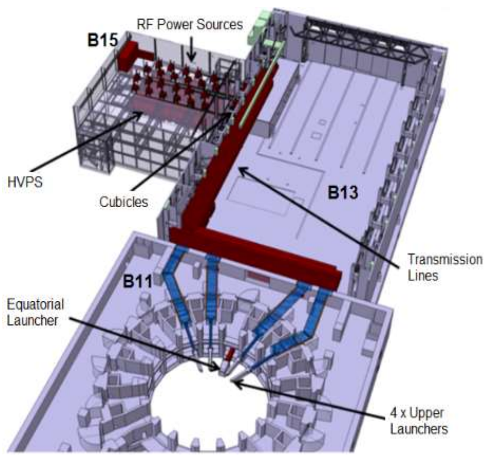


The new 2024 baseline require 48 new gyrotrons (24 for SRO and 24 for DT-1)



New proposed Baseline

Electron Cyclotron Project: Status of 2016 Baseline



8 HVPS from EUDA (Ampegon)

- All manufactured, FAT completed successfully
- All installed
- Commissioning started in B15 (levels 1/2)

4 HVPS from INDA
- Manufacturing to start
- Delivery in 2028

8 Gyrotrons from JADA (Canon)

- 8 gyrotrons manufactured, FAT completed successfully
- 8 gyrotrons delivered on site
- Installation started in B15 (level 3)
- Commissioning planned

8 Gyrotrons from RFDA (Gycom)

- 8 gyrotrons manufactured, FAT completed successfully
- 4 gyrotrons delivered on site
- Installation started in B15 (level 3)
- Commissioning to follow after the first JADA gyrotron

6 Gyrotrons from EUDA (Thales)

- Prototype completed with first tests (full power long pulse, lower efficiency)
- FDR planned for 2025
- Delivery from Sept 27 to Sept 29

2 Gyrotrons from INDA (to be procured)

- One ITER like gyrotron procured for tests at INDA facility
- FDR planned for 2025
- Delivery in 29

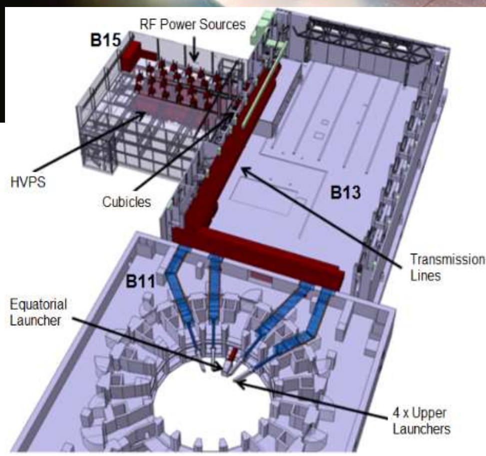
TL from USDA

- Still in final design phase
- Supports for B11/B15 delivered
- Installation started in B15 for the supports.
- Several deliveries scheduled from now to 2030.
- Main installation will start in 2027

UL from EUDA & EL from JADA

- Still in final design phase
- Installation starts in 2031 for the 1st UL & EL.

Electron Cyclotron Project: Status of 2016 Baseline



View of the installation of JADA & RFDA gyrotrons in B15 L3

View of the installation of MHVPS manufactured by Ampegon in B15 L2

Overview of next calls for tender

		2025	2026	2026+
NB	VVPSS Box	CFT	Target contract signature	
	Duct Liner mechanical components	CFT on-going, Target contract signature mid 2025	60 months for manufacturing	
	Duct Liner I&C		CFT & target signature before end Q4	2 years manufacturing
	HVPS Installation	CFT	Target signature end Q1 Start installation Q3	
	NB Cell installation			Start installation 2031
IC	Faraday screen	CFT mid year	Prototype manufacturing	series production 4 units by 2028
	Antenna piping		CFT Q1	series production by end 2028
	Antenna test bed		multiple CFT Q1	manufacturing then on-site installation in 2027
EC	Cooling manifold systems	Preparation CFT	CFT Q1, target signature end Q2	1st delivery beginning 2027
	I&C	Preparation CFT	CFT Q1, target signature end Q2	1st delivery beginning 2027

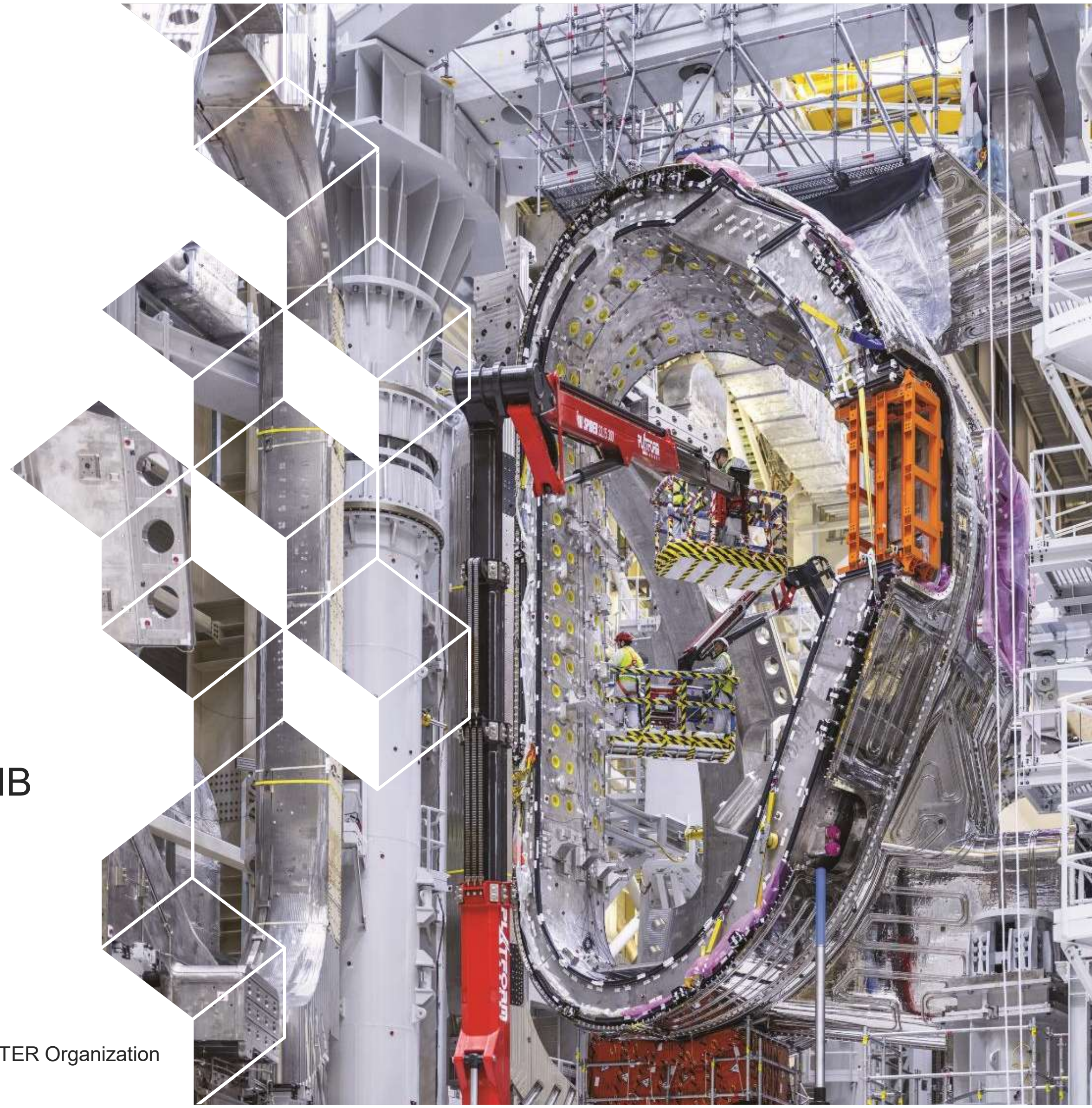
THANKS

TO BE PART OF THE WORLDWIDE **FUSION** NETWORK

PROCUREMENT OPPORTUNITIES AT F4E ON NEUTRAL BEAM (Heating & Current Drive)

Gonzalo Micó

Project Manager on behalf of F4E NB Program Team



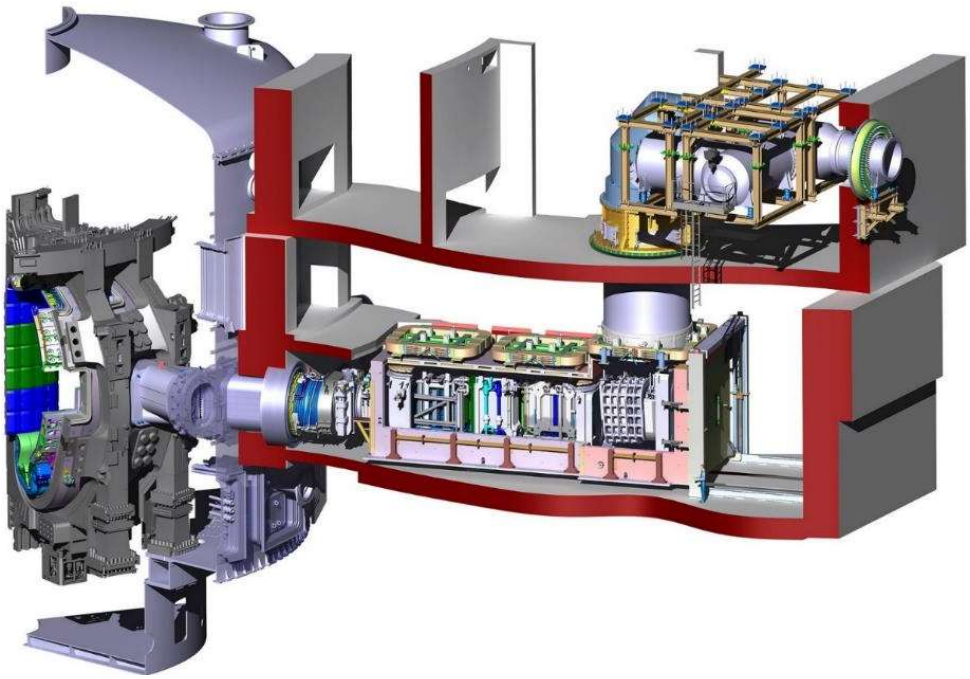
THURSDAY, APRIL 24th

Outline

1. **Heating Neutral Beam (HNB)**
2. **Status of F4E Procurements**
3. **Procurement Opportunities in HNB Mechanical components**

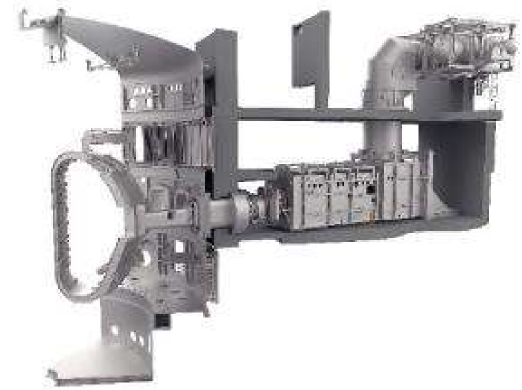
1. Heating Neutral Beam

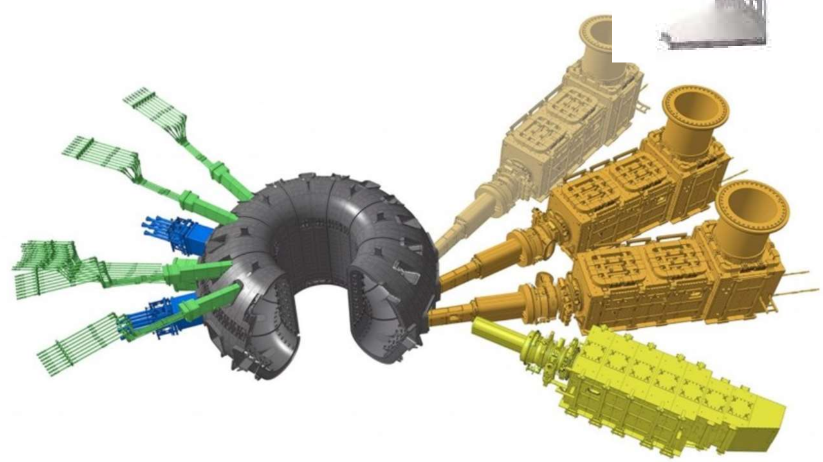
Heating Neutral Beam



2 <u>Heating Neutral Beam (HNB)</u> Injectors as Baseline

(+ captive components of optional 3rd injector)

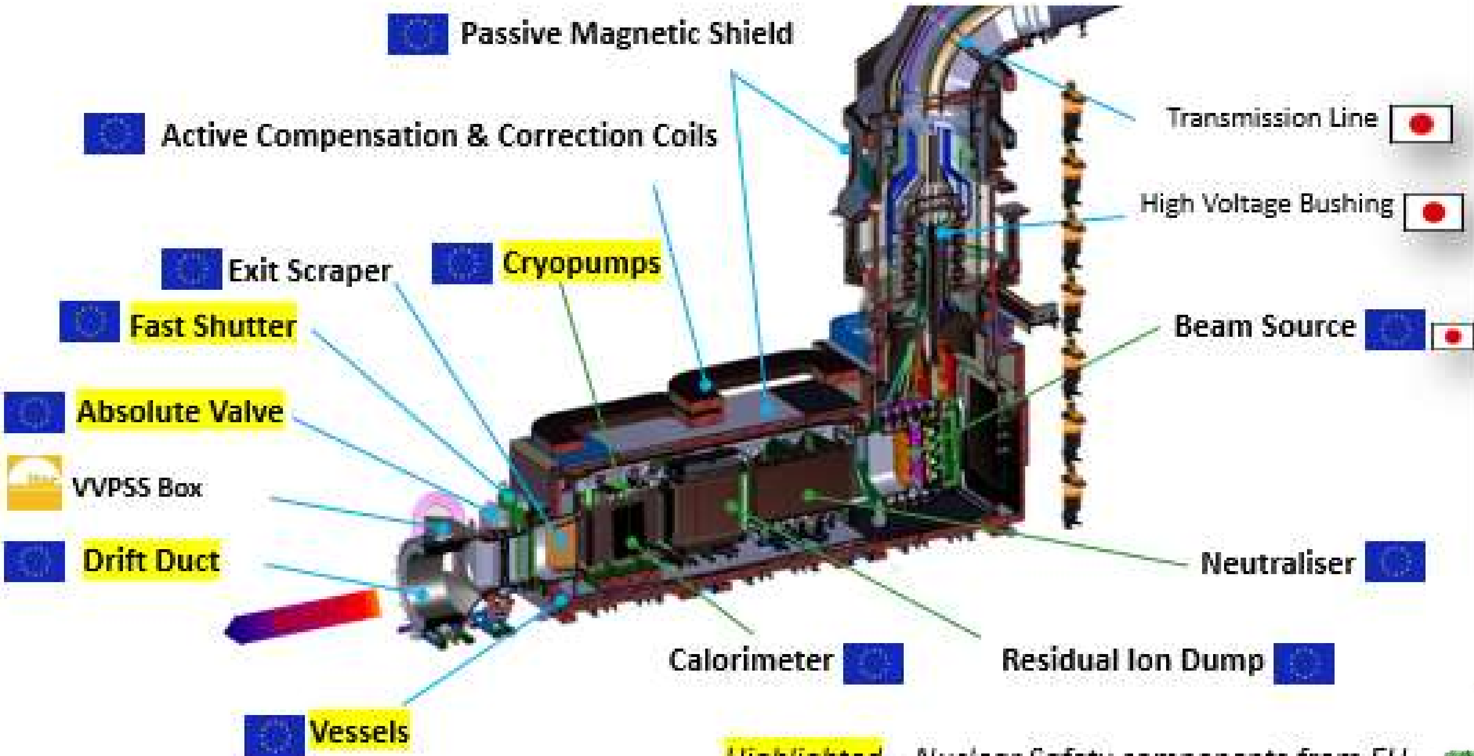




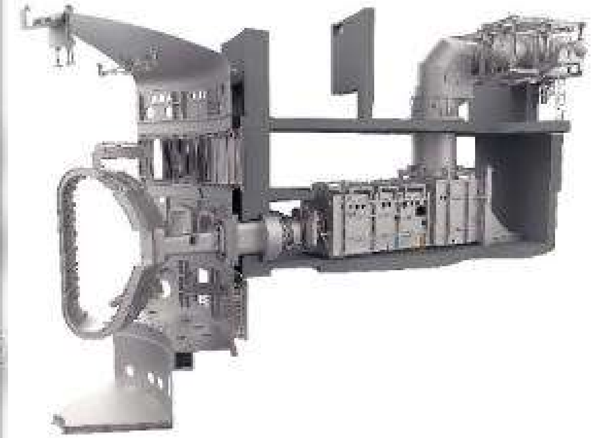
The **European contribution** includes:

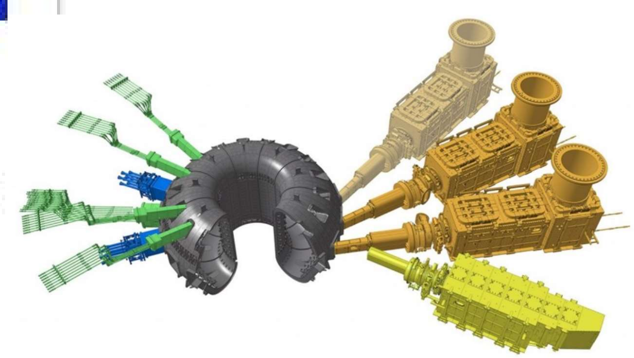
- The Neutral Beam Injectors (1MV 2x16.5MW)
- The Electron Cyclotron system (170GhZ, 20MW)

Heating Neutral Beam (HNB)



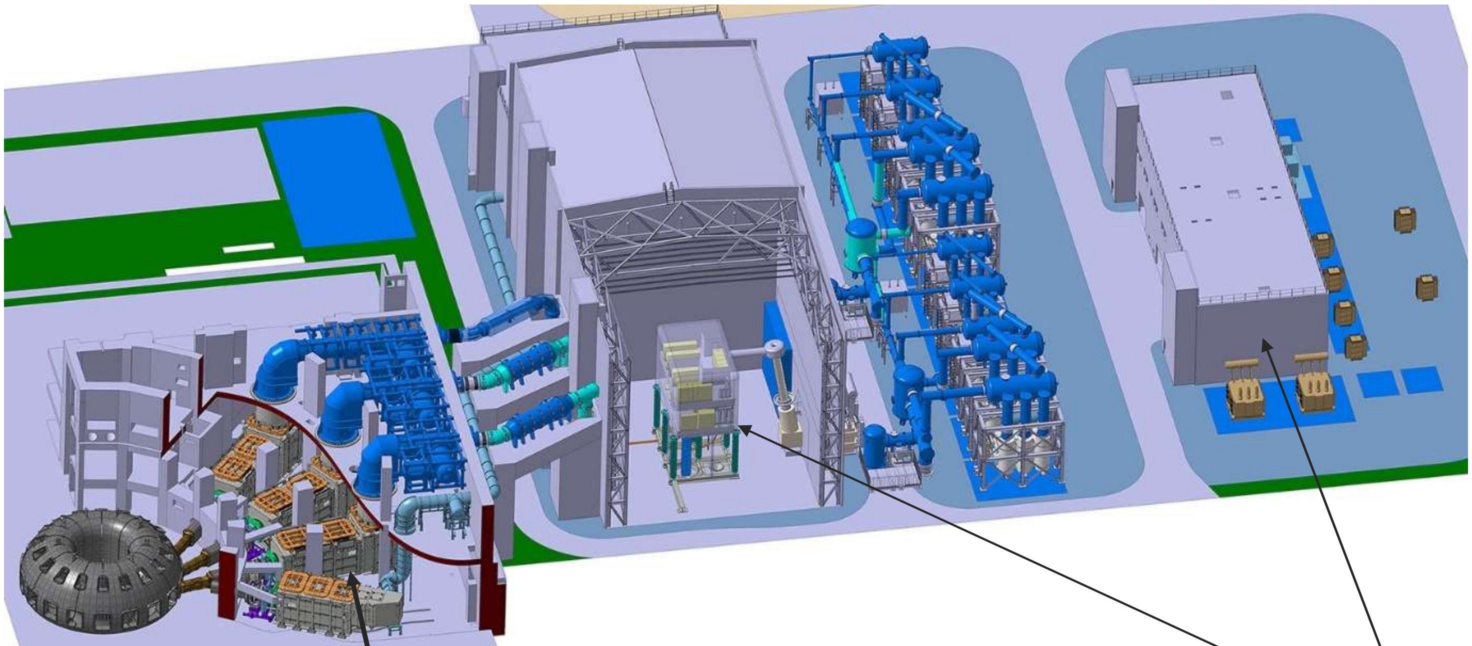
Highlighted = *Nuclear Safety components from EU*





2. Status of F4E Procurements

Neutral Beam procurement status



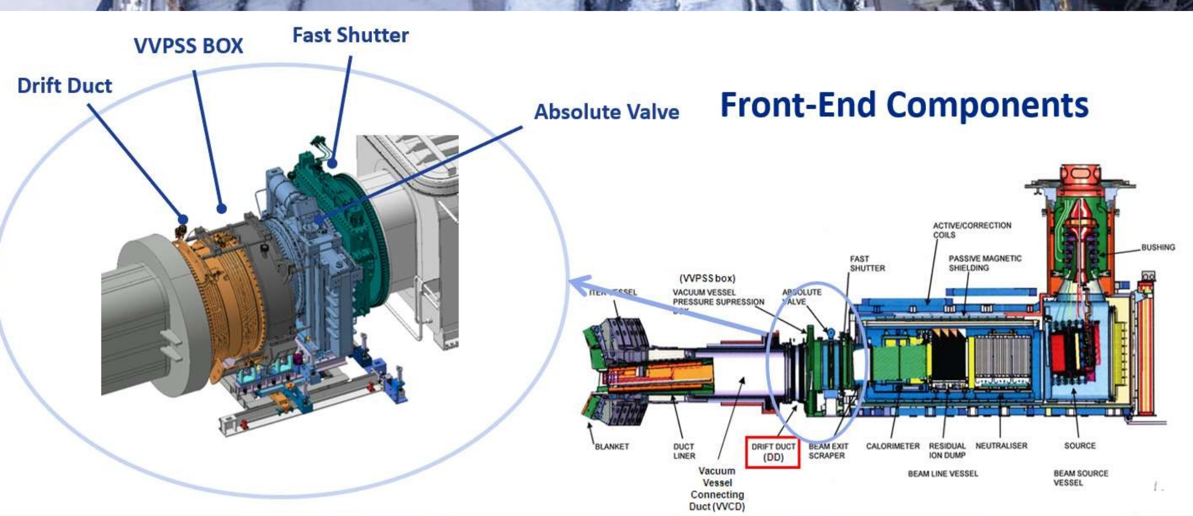
Contract ongoing for first set of some components (NBTF)
Procurement of first components for ITER ongoing (Vessel, Assembly tools)

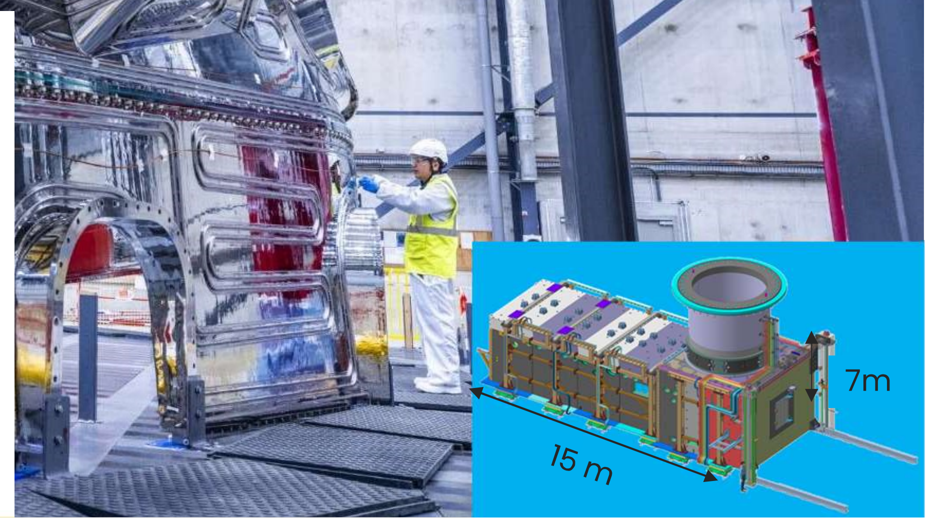
Power supplies Ongoing
First set for Neutral Beam Test Facility delivered
+ 2 sets for ITER in design/manufacturing

First of a kind components vs MITICA components

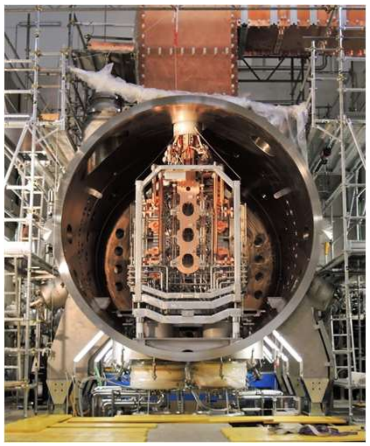
First of a kind
Passive Magnetic Shielding (PMS)
Active Compensation Correction Coils (ACCC)
FEC (Front-End-Components) (Fast shutter, Absolute Valve, Drift Duct, VVPSS box)
Exit Scraper

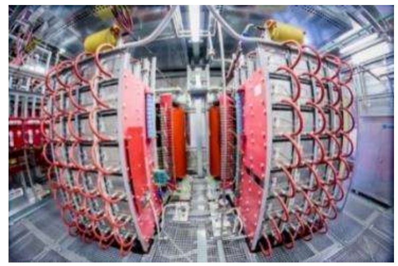
Already Prototyped in MITICA
Beam Line Components (Neutralizer, Residual Ion Dump & Calorimeter)
Beam Source
Cryopump
Vessel
Power supplies, control system

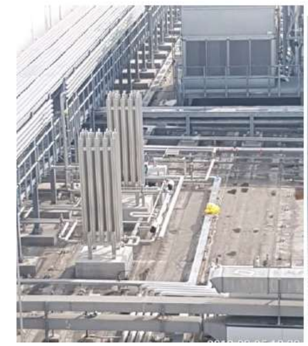


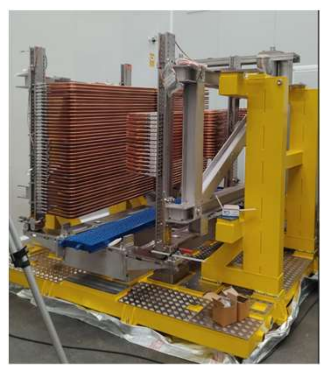


F4E delivering to the NB Test Facility









3. Procurement opportunities at F4E in HNB Mechanical components

- **A** Item range **300 000 – 2 000 000 EUR**
- **B** Item range **1 500 000 – 5 000 000 EUR**
- **C** Item range **4 000 000 – 12 000 000 EUR**
- **D** Item range above **10 000 000 EUR**

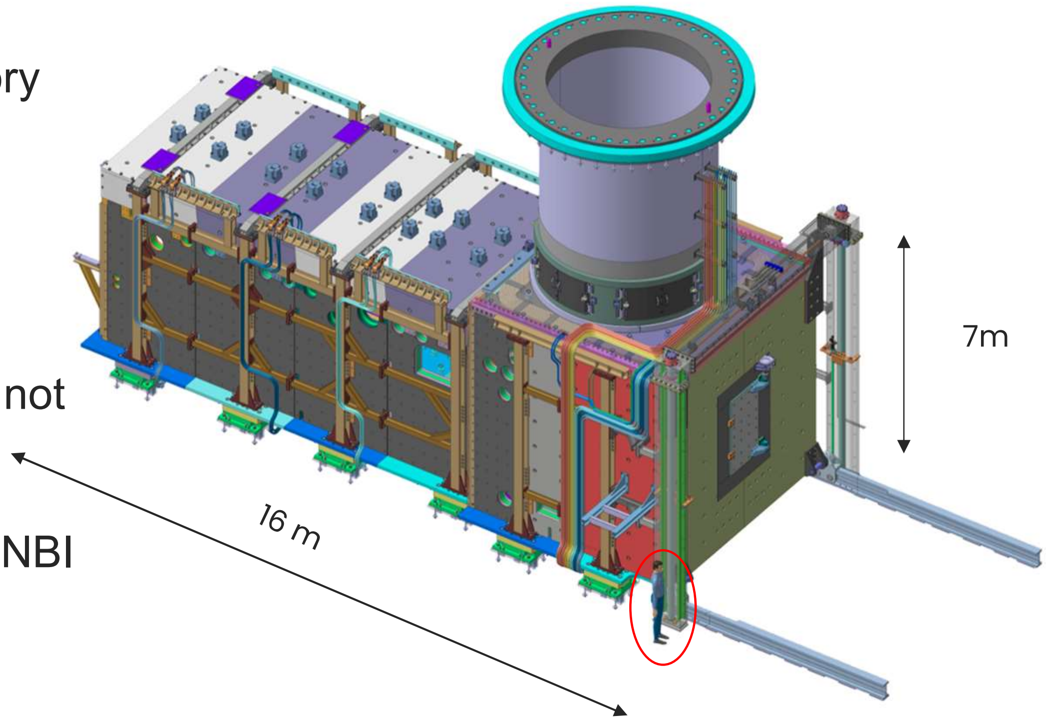
HNB Magnetic Shielding (1/2)

❖ **Scope**: 2 Magnetic Shields, including coils

- Manufacturing engineering, manufacturing, factory assembly and testing, delivery to IO site
- 600 tons (mainly S235, 75mm thick plates) / >10,000 parts
- 8 copper coils (each > 3 tons, 4m) impregnated, not cooled

❖ **Key function**: Ensure magnetic shielding of the NBI from the magnetic fields of the Tokamak.

❖ **Nuclear Safety**: Safety Important (Support)



HNB Magnetic Shielding (2/2)

❖ **Key technologies**:

- Construction and precise machining of Carbon Steel plates
- Factory assembly of the entire PMS with adjustment of maximum 1 mm gap between plates
- Manufacturing following RCC-MR (support section) e.g. welding and painting
- RCC-MR and low impurities (Co) materials
- Large resistive coils manufacturing
- Gamma and Neutron shielding (Lead and Polyethylene)
- Heavy hydraulic machinery (Rear door)

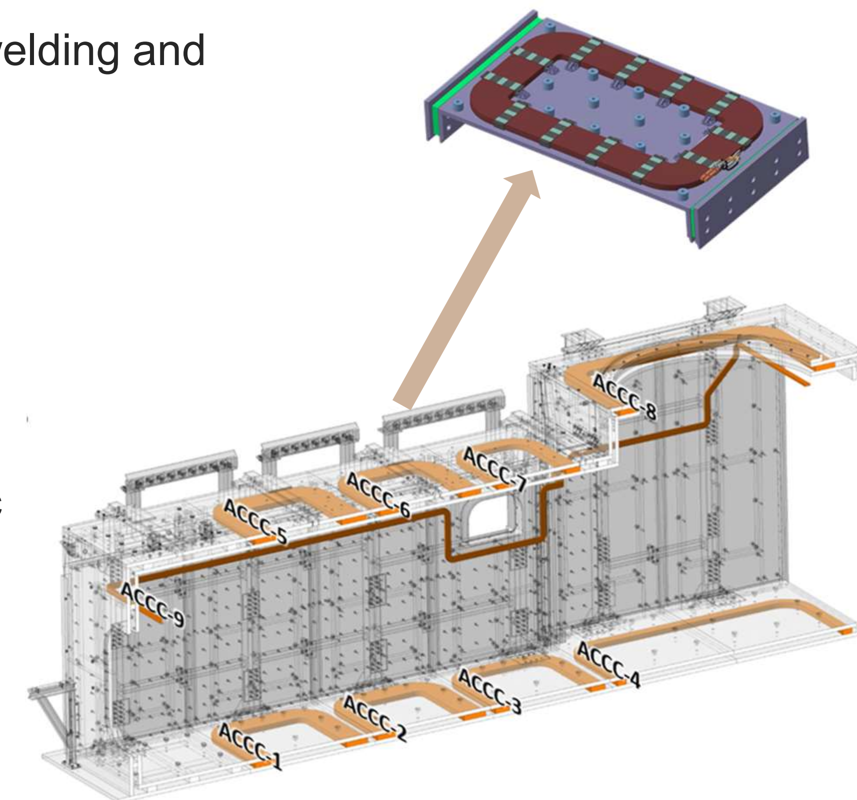
❖ **Status and Procurement activities:**

✓Market Survey for steel material (closed) – historic data here

✓Market survey (closed) technical description here

✓Target call for tender: Q2 2025

✓Value range > 10M EUR



HNB Absolute Valve

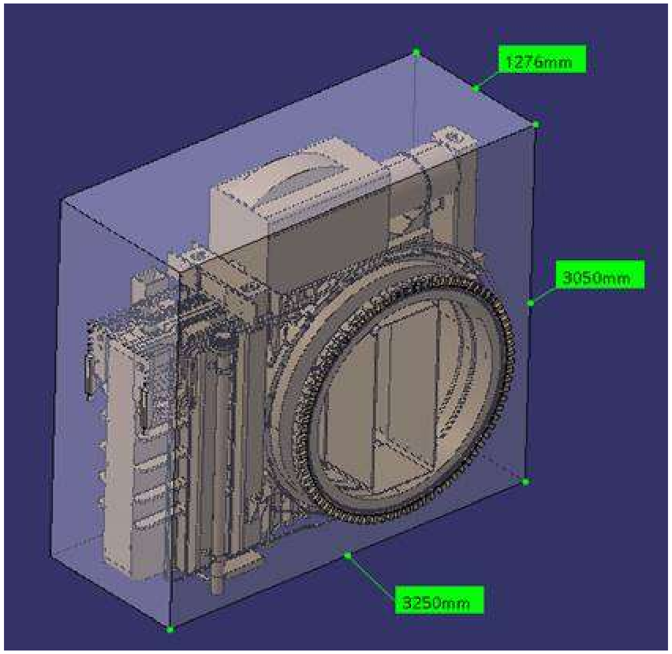
- **Scope**: 2 Absolute Valves, manufacturing, assembly, testing and delivery to IO site

- **Key function**: Maintain two different levels of pressure between the NBI and the Tokamak (in case of maintenance or accident).

- **Nuclear Safety**: Extension of the primary vacuum barrier. First confinement Barrier. Nuclear safety relevant. Nuclear code for manufacturing.

- **Key technologies**: metallic sealing, valves manufacturing, nuclear code compliance, high vacuum tightness requirements, PIC qualification, pneumatic actuators

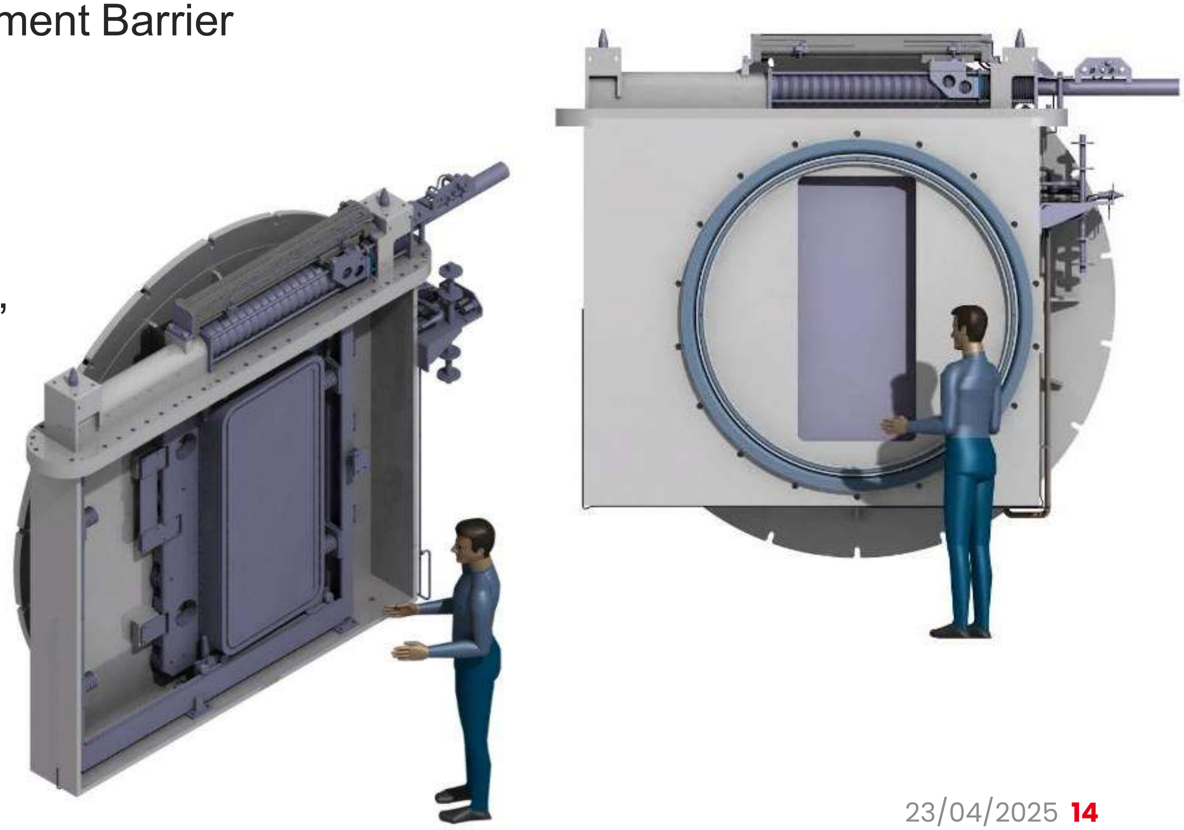
- **Status and Procurement activities:**
  - ✓Market survey closed
  - ✓Feasibility study (by IO) on-going: Q3-2024 to end-2025
  - ✓Call for tender for final design and manufacturing: 2027
  - ✓Value range > 10M EUR



HNB Fast Shutter

- **Scope**: 2 Fast Shutters, manufacturing, assembly, testing and delivery to IO site
- **Key function**: Shut quickly (< 5 s) to protect the NBI from an accident inside the Tokamak (pressure increase). First confinement Barrier
- **Nuclear Safety**: Extension of the primary vacuum barrier. Nuclear safety relevant.
- **Key technologies**: double metallic O-rings, vacuum brazing, deep drilling, qualification program, fast customized actuator, ITER requirements materials, bellows, vacuum compatibility, leak tightness
- **Status and Procurement activities**:
  - ✓ Design finalization
  - ✓ Call for tender +2027
  - ✓ Value range > 10M EUR

D



HNB Exit Scraper

- **Scope**: 2 Exit Scrapers, manufacturing, assembly, testing and delivery to IO site

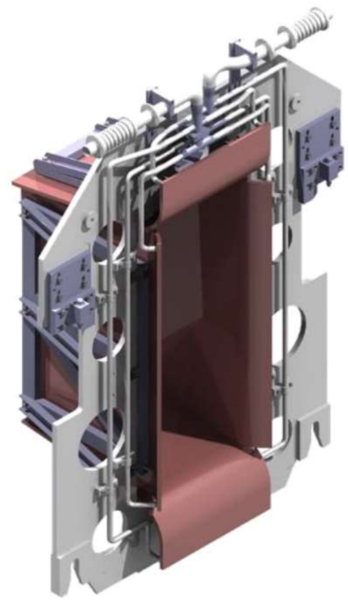
- **Key function**: Define the shape of the Beam and protect the Beam Line Vessel at the exit of the Calorimeter

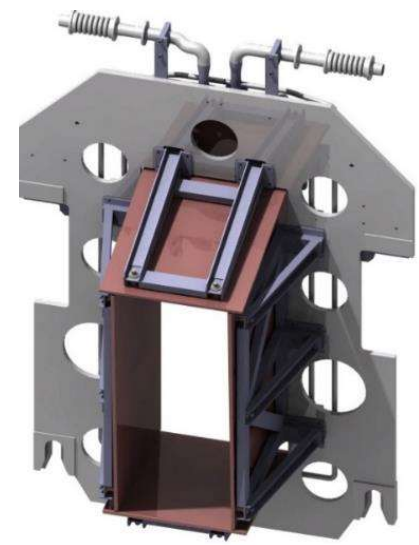
- **Nuclear Safety**: Non safety relevant

- **Key technologies**: High vacuum, deep drilling in CuCrZr, Electron Beam Welding of CucrZr, pipework, heterogeneous joints welding, MICs, instrumentation, fine machining, bending, precise assembly

- **Status and Procurement activities:**
  - ✓ Design finalized
  - ✓ Call for tender +2027
  - ✓ Value range > 10M EUR

D



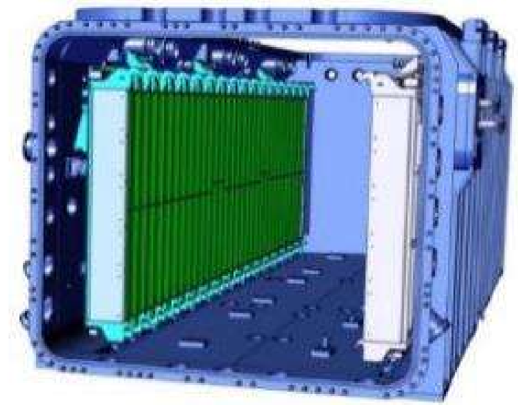


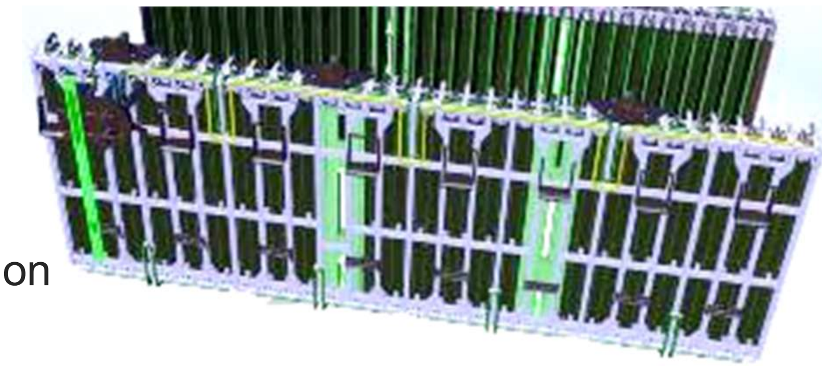
HNB Cryopumps

- ❖ **Scope**: 2 HNB Cryopumps + 1 DNB Cryopump, manufacturing, testing and delivery to IO site.
- ❖ **Key function**: Vacuum pumping inside the BLV-BSV by cryo-absorption
- ❖ **Nuclear Safety**: Primary confinement, Protection Important Component (PIC)
- ❖ **Key technologies**: tight tolerances, charcoal deposition, SS tubes expansion and extrusion process, cold shock, welding:
  - > 100m2 pumping surface
  - > 1000 panels
  - > 9000 welds including Rx
  - > 500 leak tests
- ❖ **Status and Procurement activities:**

✓ Prototype testing (MITICA) & Manufacturing doc. In preparation
✓ Est. contract 2026 (Tender)
✓Value range > 10M EUR

D





HNB Beam Line Components (BLCs)

- **Scope**: 2 BLC units: Neutraliser + Residual Ion Dump + Calorimeter, manufacturing, assembly, testing and delivery to IO site

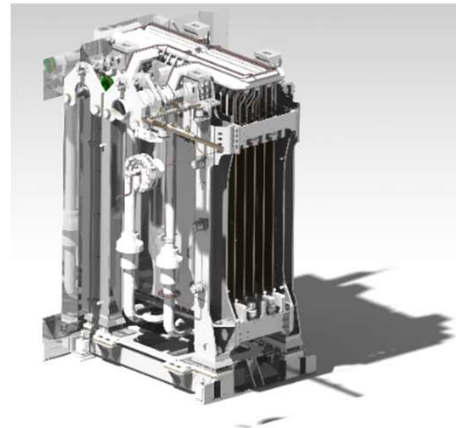
- **Key function**: Neutralize the beam, dump electron power, deflect residual ions, and provide a moveable beam dump for independent injector testing

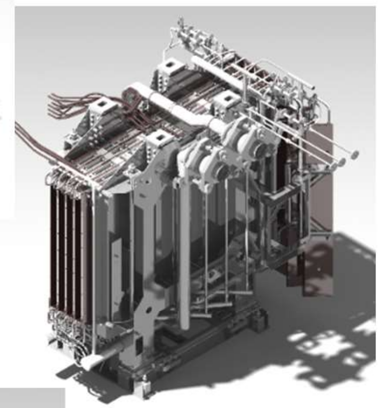
- **Nuclear Safety**: Non-Safety relevant

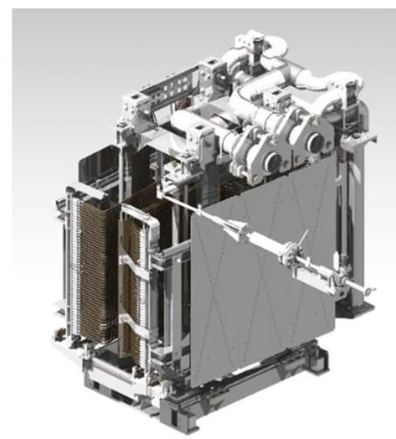
- **Key technologies**: tight tolerances, High vacuum, deep drilling in Cu alloys, Electron Beam Welding, precision assembly, heterogeneous welding, ITER requirements material

- **Status and Procurement activities:**
  - ✓ MITICA BLCs. NED and ERID delivered. CAL on-going.
  - ✓ Call for tender +2027
  - ✓ Value range > 10M EUR

D







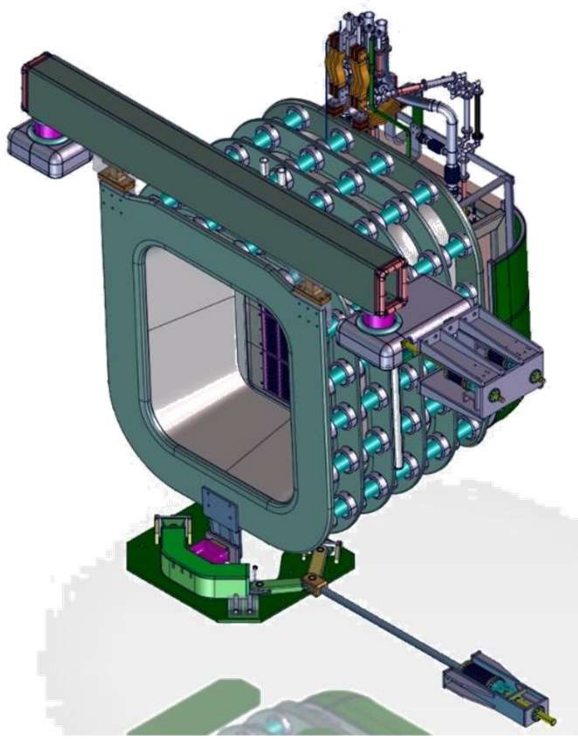
HNB Beam Source (BS)

❖ **Scope**: 1 Beam Source unit (Ion Source + Accelerator) + 1 Accelerator: manufacturing, assembly, testing and delivery to IO site

❖ **Key function**: Create negative ions of Deuterium and accelerate them to the required energy with electrical fields.

❖ **Nuclear Safety**: Non-Safety relevant

❖ **Key technologies**: High Precision fabrication of Mechanical Components, tight tolerances, High vacuum conditions, High Precision Milling and Galvanic Deposition of Copper, high leak tightness requirements, High Voltage Vacuum Insulation



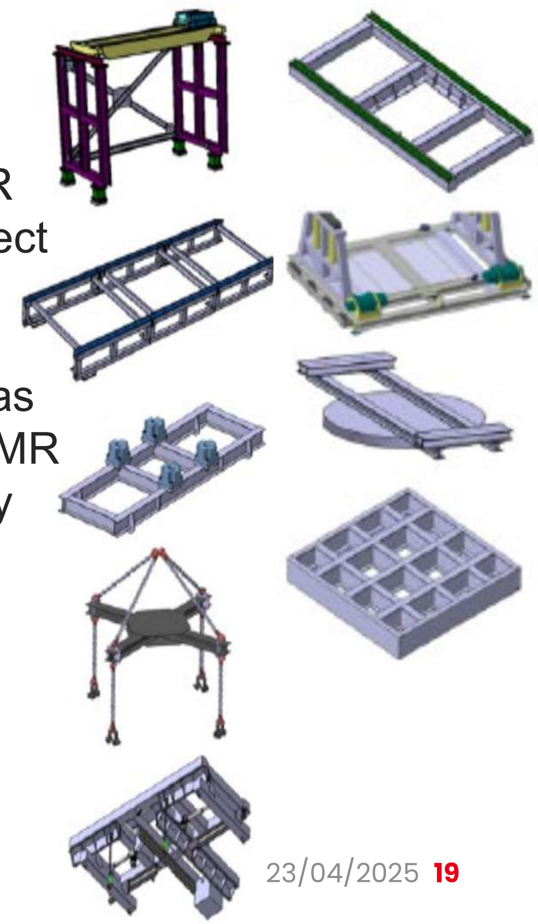
❖ **Status and Procurement activities:**
- ✓ MITICA BS on-going.
- ✓ Call for tender +2027
- ✓ Value range > 10M EUR

D

HNB Assembly

- **Scope**:
  - Stage 1 = Assembly Tooling design, procurement, delivery
  - Stage 2 = HNB1 & HNB2 Assembly & Testing
  - Stage 3 = Cooling & Gas injection systems design, procurement, installation and testing

- **Key function**: Assembly services and auxiliaries inside the NB cell at ITER site, including provision of specialized tooling, managed as integrated project with IO.
- **Nuclear Safety**: Primary confinement (cooling system, VV)
- **Key technologies**: CE marking and compliance with EU standards such as machinery directive, low voltage, EMC and lifting devices (stage 1); RCC-MR site welding and PIA activities, site testing like high vacuum, HV test, X-ray (stage 2); radiation and magnetic field resistance line instruments, design, manufacturing installation following ESPN (PED + RCC-MR) for plant systems (stage 3).
- **Status and Procurement activities:** Assembly tooling contract on going, call for tender for Assembly and Testing 2026 (by IO)
- Value range > 10M EUR



THANKS

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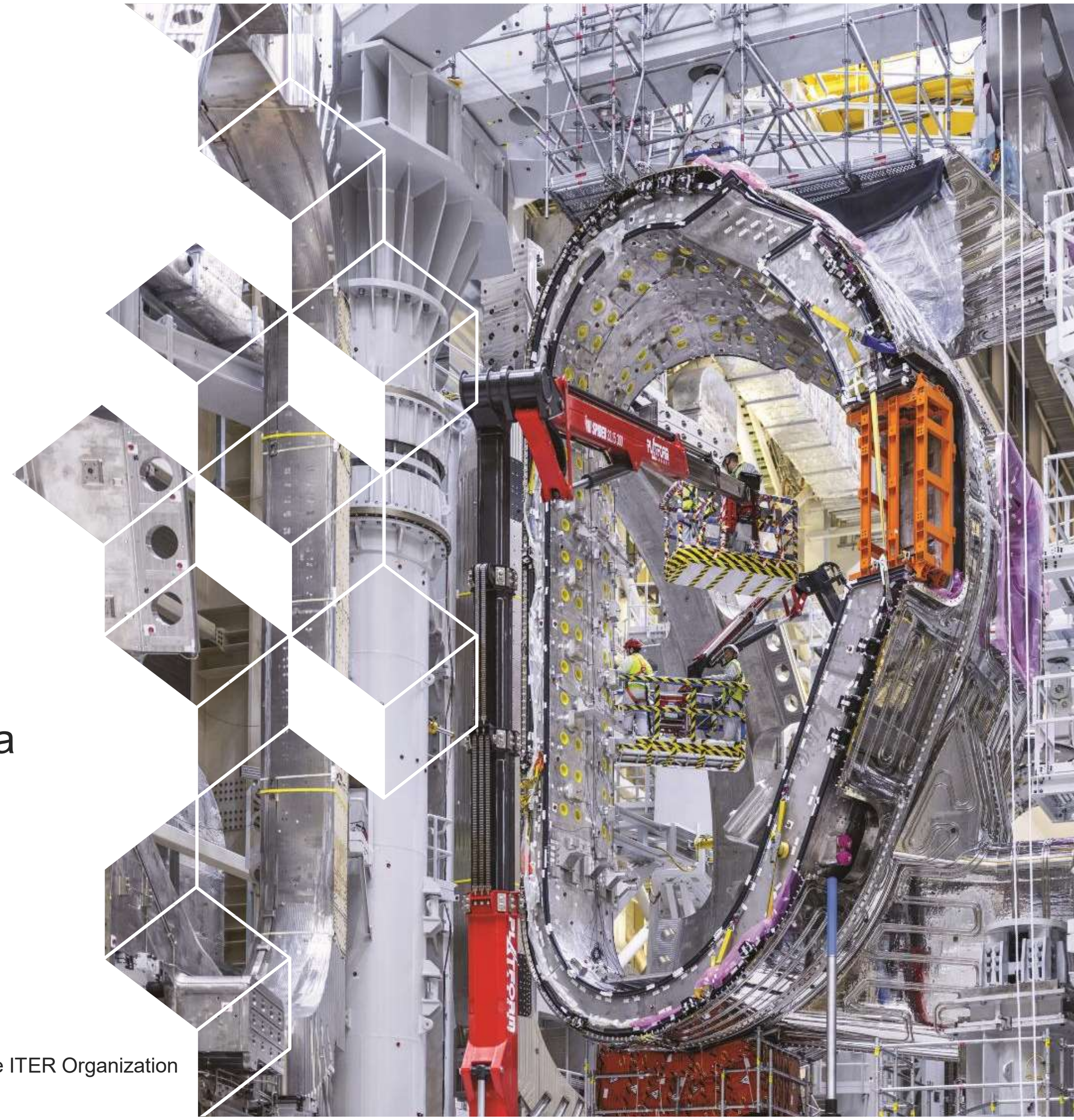
INTERNATIONAL
ITER BUSINESS FORUM



FUSION@

avs
added value solutions

Miguel Angel Carrera

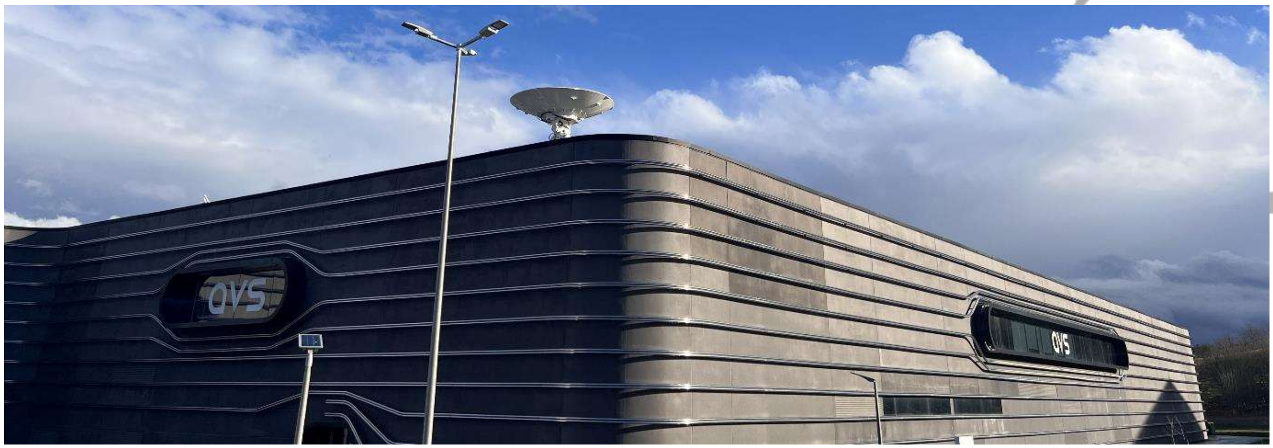
CEO

THURSDAY APRIL 24th

Disclaimer: the views and opinions expressed herein do not necessarily reflect those of the ITER Organization

A BROAD APPROACH

1. **DIAGNOSTICS**
2. **HEATING SYSTEMS**
3. **VACUUM VESSELS**
4. **REMOTE HANDLING**
5. **FUELING SYSTEMS**



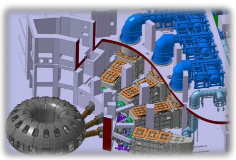
MITICA: The HNB 1:1 prototype

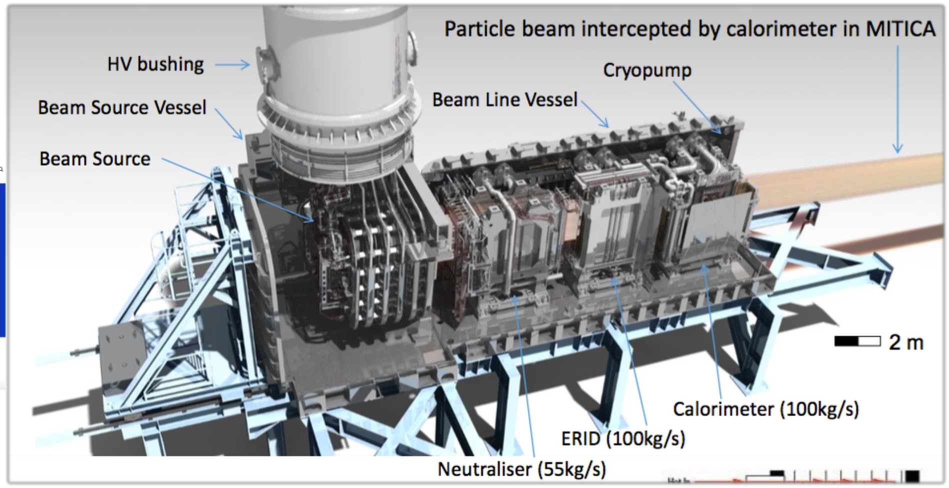
1. DIAGNOSTICS
2. **HEATING SYSTEMS**
3. VACUUM VESSELS
4. REMOTE HANDLING
5. FUELING SYSTEMS

WORLD most powerful NBI System

P_{beam}	17 MW (33-40 MW)
I_{acc}	40-50 A
V_{acc}	1 MV
t_{pulse}	3600 s
Weight	50 T

FUSION FOR ENERGY iter





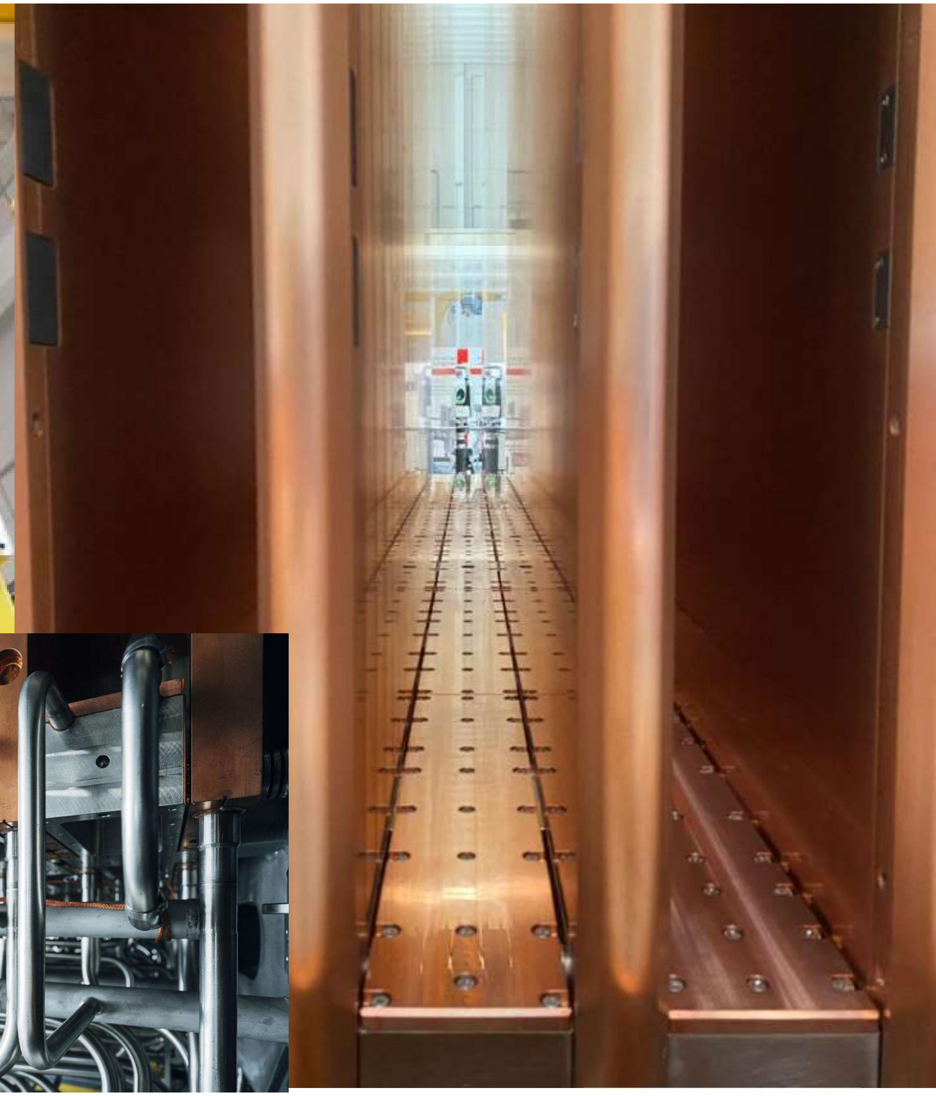
ISO 9001 EN 9100

Sounds like a challenge...


avs

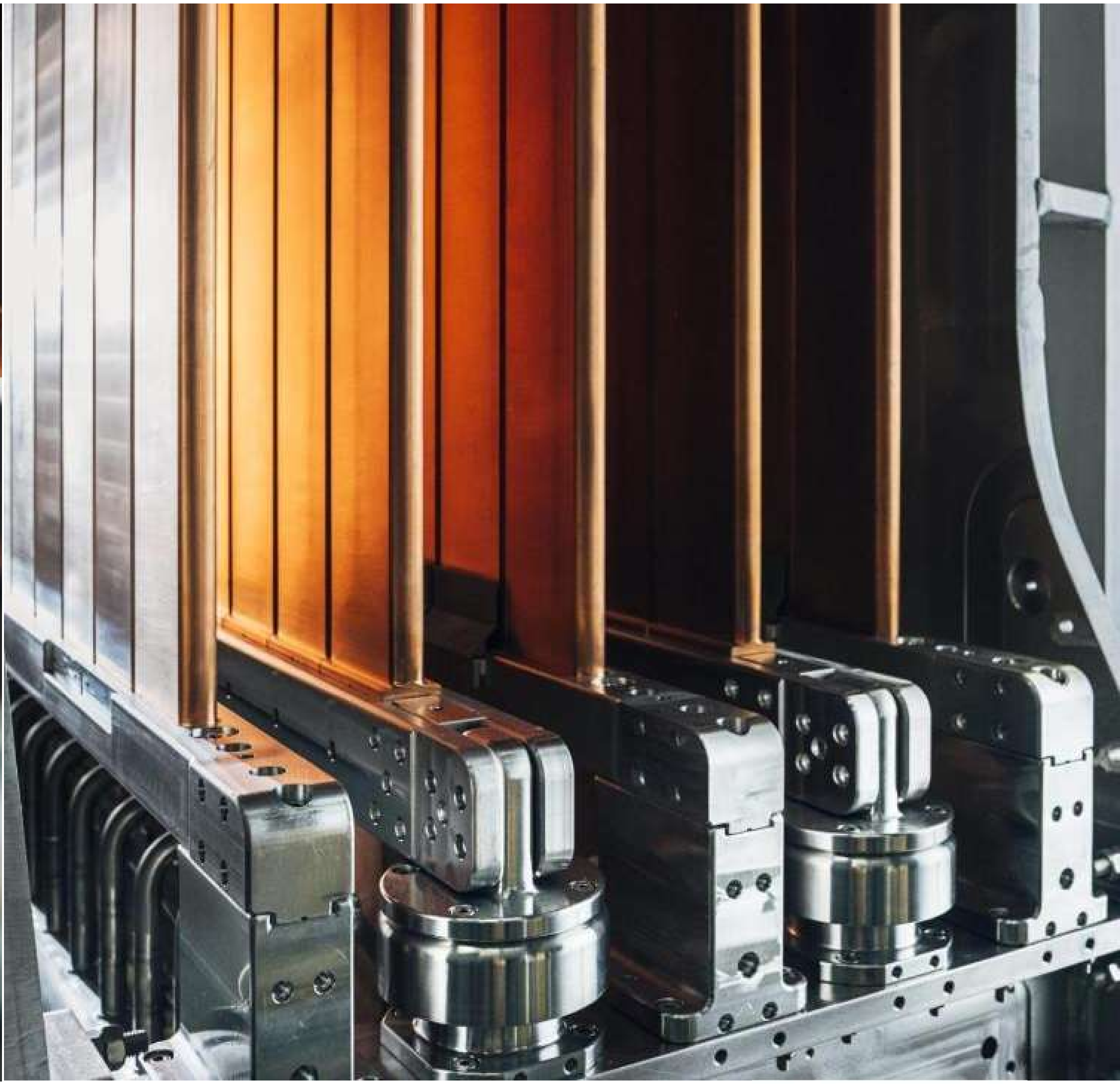

avs
added value solutions


MITICA
avs



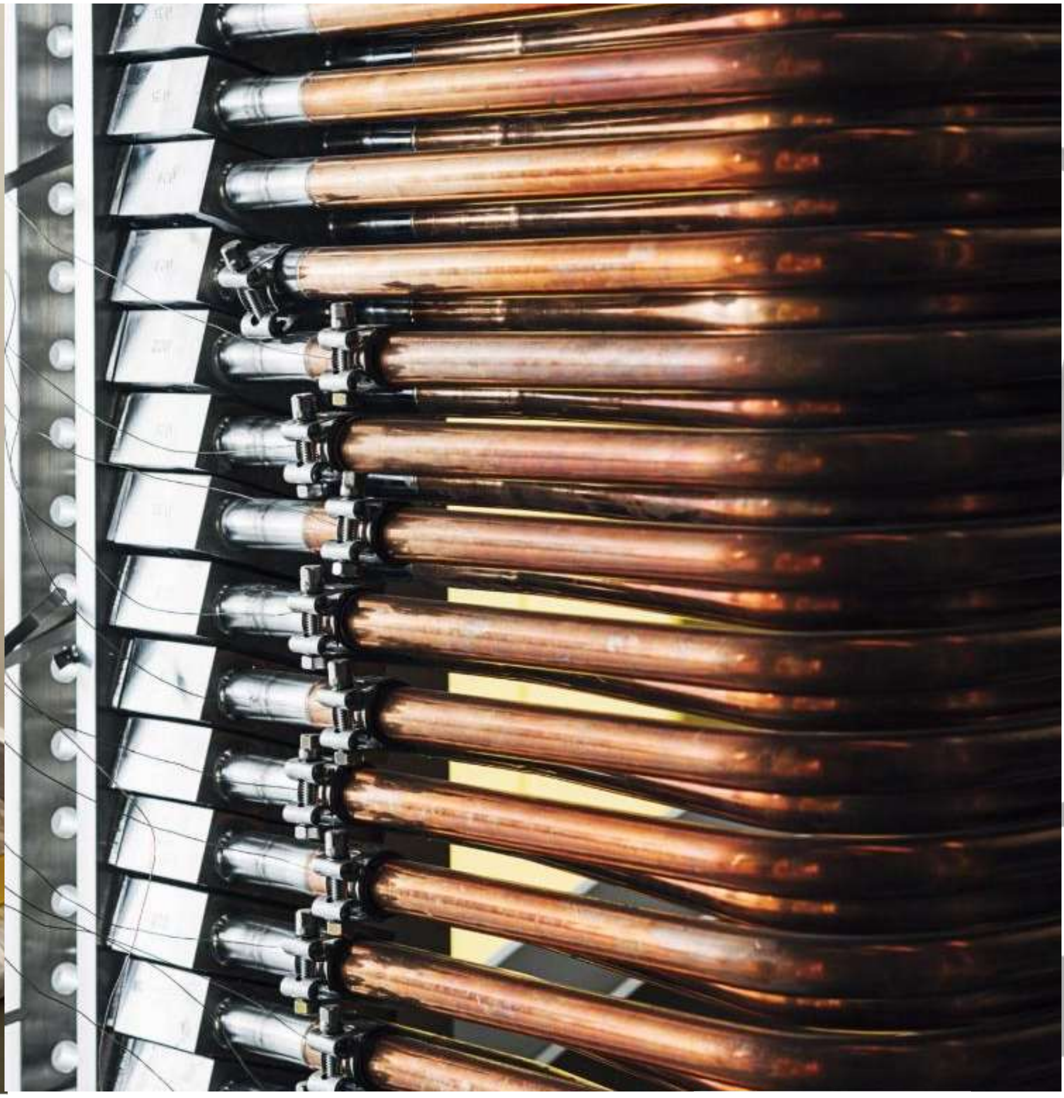
Neutralizer

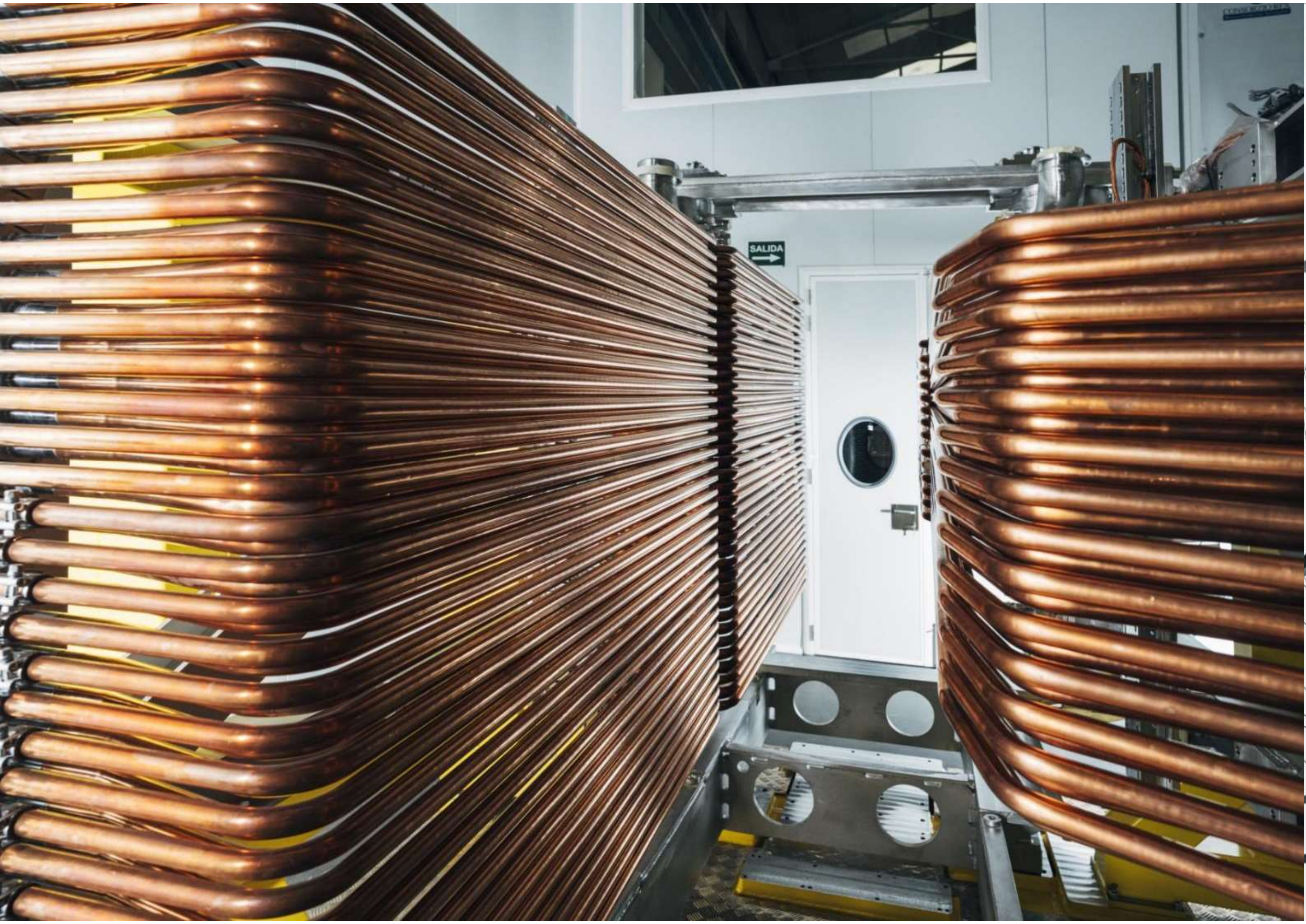
NED



Electrostatic Residual Ion Dump

ERID




SALIDA


Calorimeter

CAL

- Challenges
  - On components and subASSYs: Hetereogeneous joints, distortion mitigation strategies, CuOF and CuCrZr machining & tolerance chain, deep drilling, inspection…
  - On ASSY: pressure/global A1 leak test for the whole ASSY, Class 1 geometrical tolerances, installation & inspection-validation of optical sensors, SEM & probes diagnostics and instrumentation, and more…
- Risk mitigation strategies: proved to be key
  - Fair and secured relationship with subcontrators
- Key points:
  - Flexibility, commitment, integrated team inc F4E and IO, openness, early implementation of sound risk mitigation strategy

THANKS

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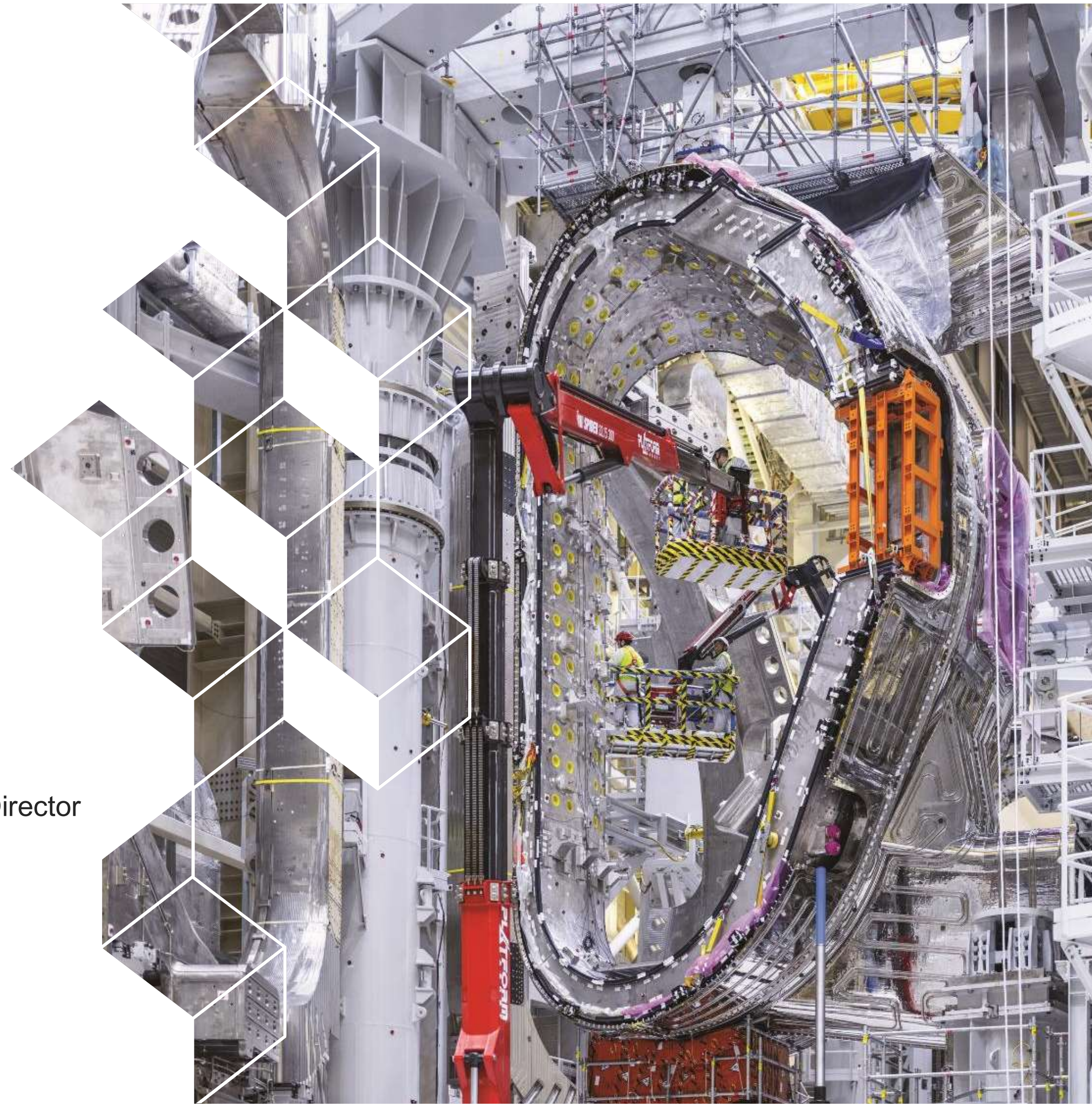
THALES MICROWAVE & IMAGING SUB-SYSTEMS

MAJOR PLAYER IN PLASMA HEATING SYSTEM



Antoine Loidreau

THALES
Building a future we can all trust

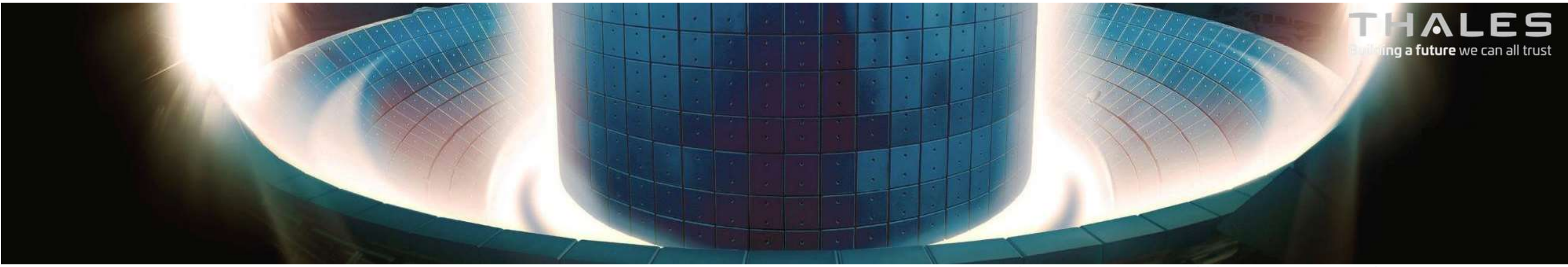
Defense and Science Business Segment Director

Thales Microwave & Imaging Sub-Systems

WEDNESDAY APRIL 23rd

THALES
MICROWAVE & IMAGING SUB-SYSTEMS

1. **Our science solution**
2. **Fusion | Plasma heating system**
3. **Fusion | Main programs & Thales gyrotron**
4. **Fusion | Thales strategy for ECRH**
5. **Fusion | ECRH turnkey system**



Our science solution

- Sources RF for **particle accelerators** and **fusion reactors**
- **KEY PRODUCTS:** Gyrotron, Klystron, multi-beam Klystron, grid tubes (Diacrode, Tetrode, Triode, IOT) & Cavities
- **KEY REFERENCES**:
  - **Fusion** : ITER (170GHz, 1 MW), DTT (170 GHz, 1 MW), W7X (140 GHz, 1,5 MW), CEA (105GHz, General MW) Atomics (117GHz, 1MW), ASIPP (170GHz, 1MW)
  - **Particle Accelerators** : CERN (400MHz, 300kW), ESS (704MHz, 1,5MW), DESY (1300MHz, 10MW, Soleil, Los Alamos (200MHz, 3MW), Brookhaven (500MHz, 300kW)
  - Big Science Instruments : EPURE, LMJ

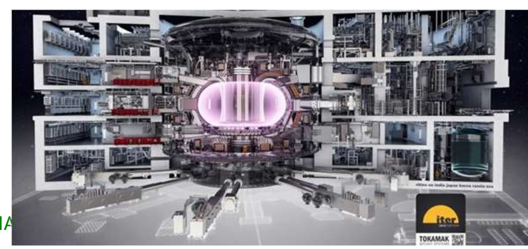
MULTI BEAM KLYSTRON

TÉTRODE

KLYSTRON

GYROTRON

THALES, A LONG-STANDING PARTNER TO THE MOST PRESTIGIOUS
LABORATORIES ANS RESEARCH CENTRES



Fusion | Plasma heating system

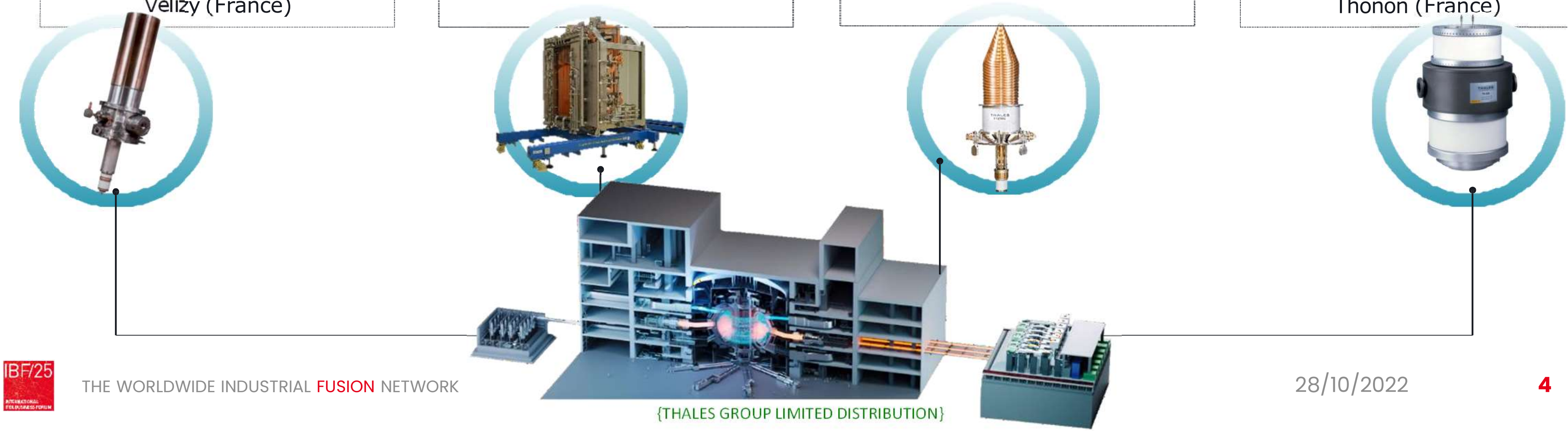
- Thales MIS contribution through RF plasma heating sources of four kinds: ECRH – gyrotron, ICRH – grid tubes, LHCD – klystron and NBI

Electron cyclotron resonance heating (ECRH) system with Thales gyrotrons manufactured in Vélizy (France)

Neutral-Beam Injection (NBI) system with SPIDER, Thales (Vélizy, France)

Lower Hybrid Current Drive (LHCD) with Thales klystrons manufactured in Vélizy (France)

Ion cyclotron resonance heating (ICRH) system with Thales tetrodes & diacrodes manufactured in Thonon (France)



Fusion | Main programs & Thales gyrotron

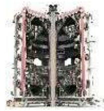
ITER

6x TH1509U
170GHz
1MW
3600s

WEST

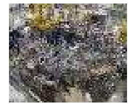
3x TH1511
105GHz
1MW
1800s

STEP



Gyrotrons
development
plan

W7-X



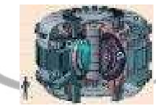
10x TH1507
140 GHz
1800s

4x TH1507U
World record 1,3MW
Up to 1,5MW

TCV EPFL

3x TH1511
84/126GHz
1/1MW
2s

DTT

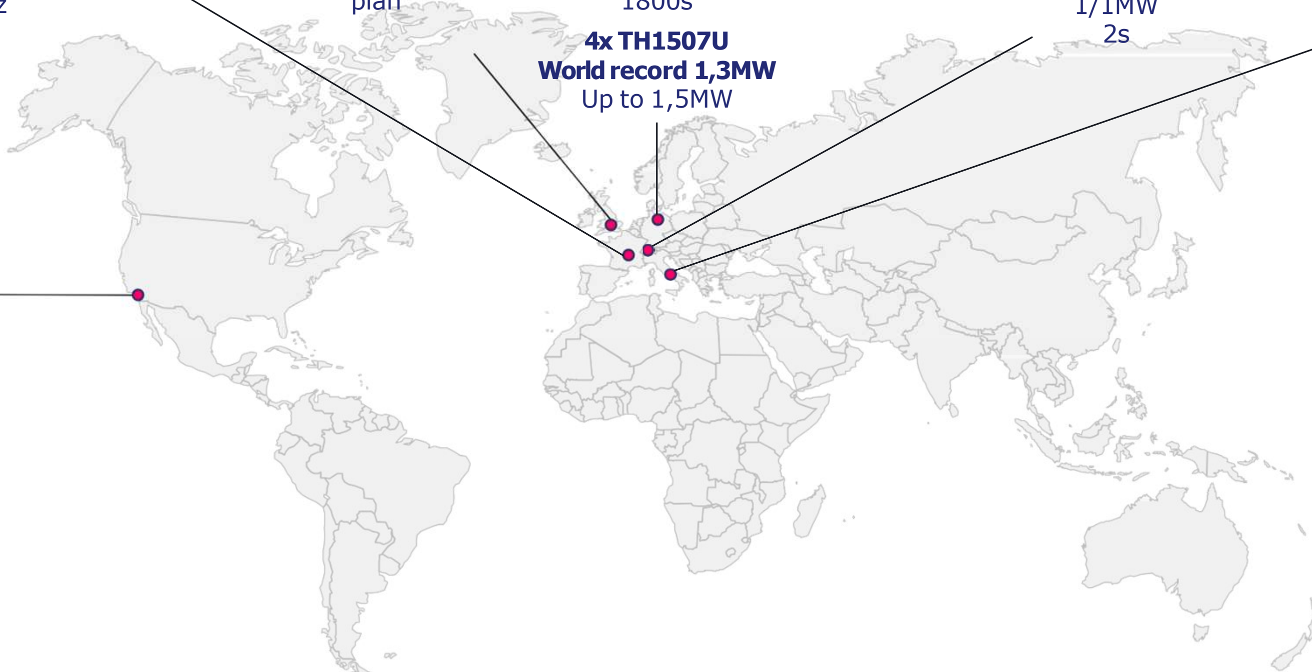


16x TH1509U
170GHz
1MW
3600s

DIII-D

GENERAL ATOMICS

3x TH1512
117,5GHz
1MW
10s



EUROPEAN GYROTRON CONSORTIUM

EPFL KIT ISTP Politecnico di Torino POLITECNICO MILANO

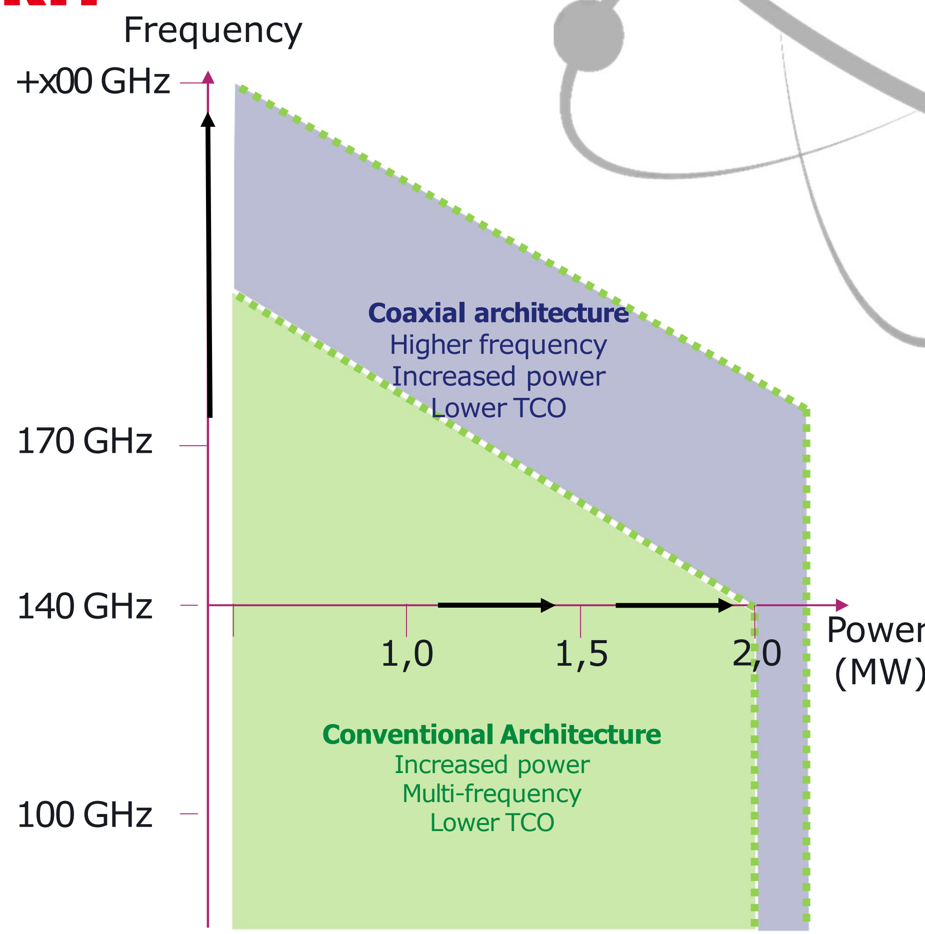
Fusion | Thales strategy for ECRH

1. Production ramp-up

- Main issue for the Fusion community:
  - Worldwide gyrotron production: 15 gyrotron per year (incl. Thales)
  - Future need of gyrotron for public & private actors: 500 gyrotrons for the next decades
- Thales launched an ambitious plan to ramp-up gyrotron production to 5, 10 then 15 gyrotrons per year
- Takin into account all industrial aspects: Human ressources, supply chain, tools and industrial means for manufacturing and outgassing, test station upgrade

2. New roadmap to answer all future needs

- Four critical needs identified for the Fusion community
  - Increased gyrotron power: 1,5 and 2MW
  - Multi-frequency gyrotrons
  - Total Cost of Ownership reduction: Higher efficiency, serie production
  - Higher frequencies (200-300GHz)
- Two main architectures to answer it all
  - Conventional architecture
  - Coaxial architecture



Fusion | ECRH turnkey system

Complex ECRH system will be required for future fusion plants

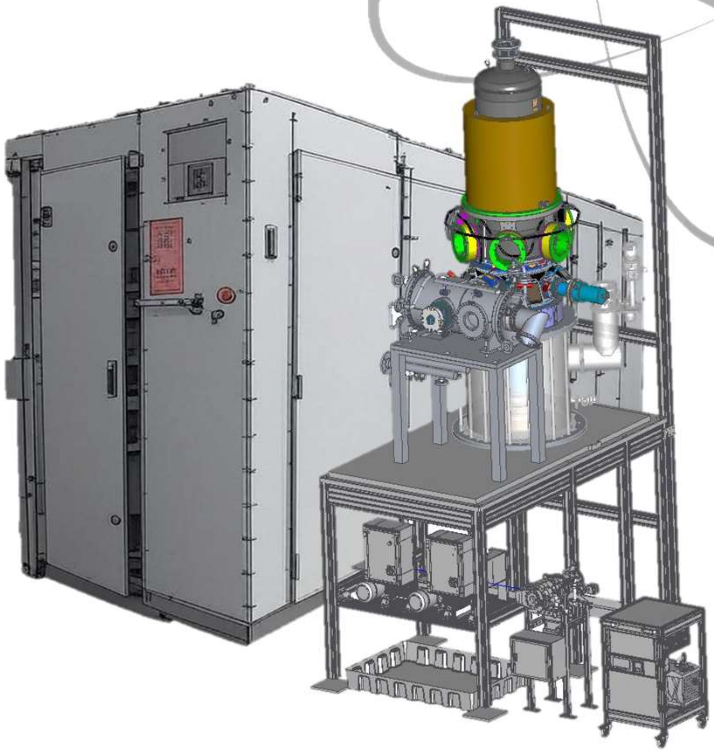
- New projects with high number of gyrotron requiring an industrial know-how to deliver, operate and maintain a complete solution
- New Fusion: Clear need for turn-key solutions from private actors

Thales as central enabler of all fusion actors

- Key provider of integrated ECRH system for fusion power plants
- Thales gyrotron and key partners: High Voltage Power Supply, transmission lines, dummy load, Control Command, etc.

Main benefits:

- Facilitate system of systems integration, operation & maintenance for critical projects
- Complete ECRH solution with services (maintenance, operation)



THANKS

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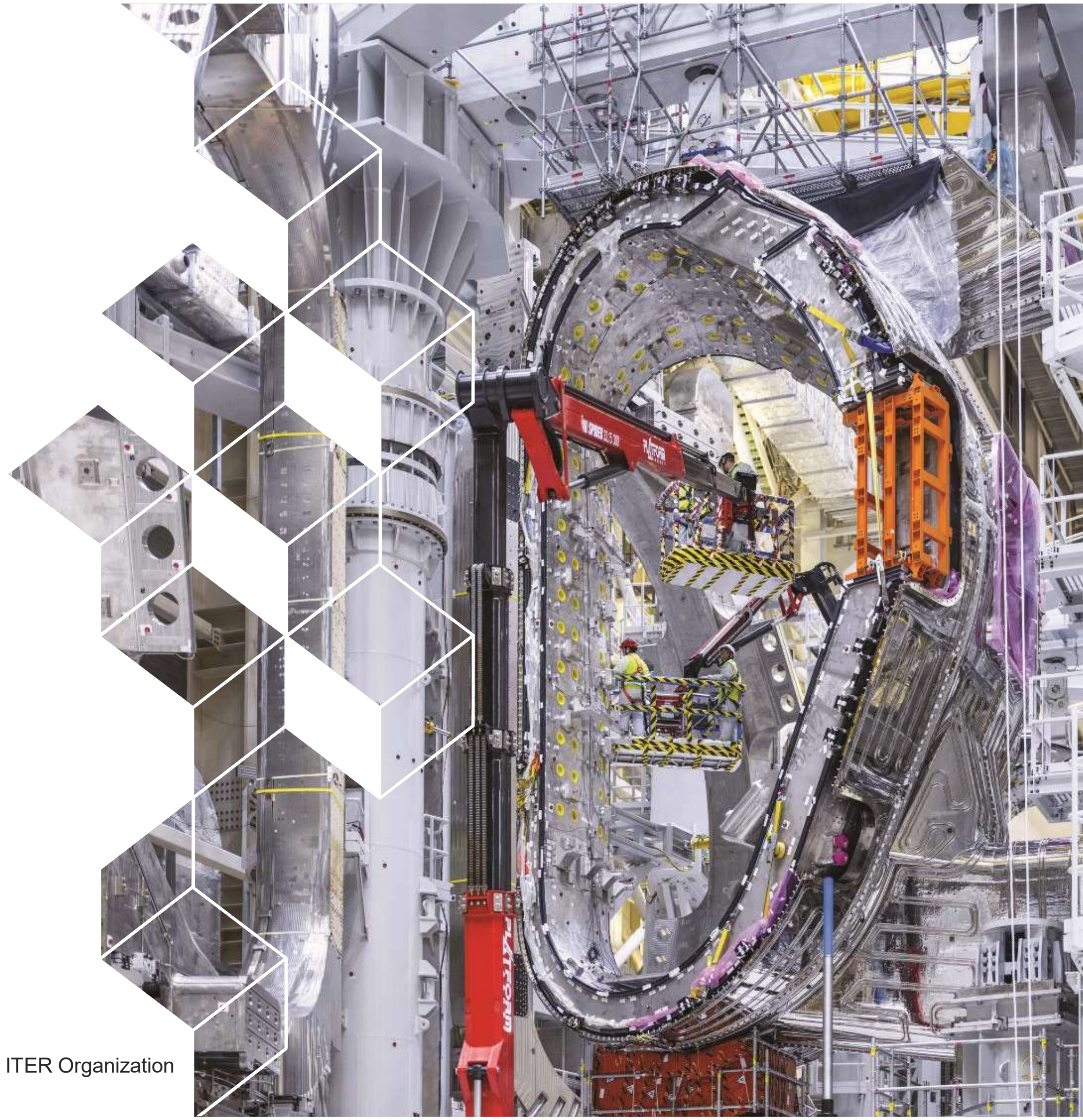


NBI AND ICRH SYSTEMS EXPERIENCE

De Pretto industrie

Diego Ruaro

De Pretto Industrie,

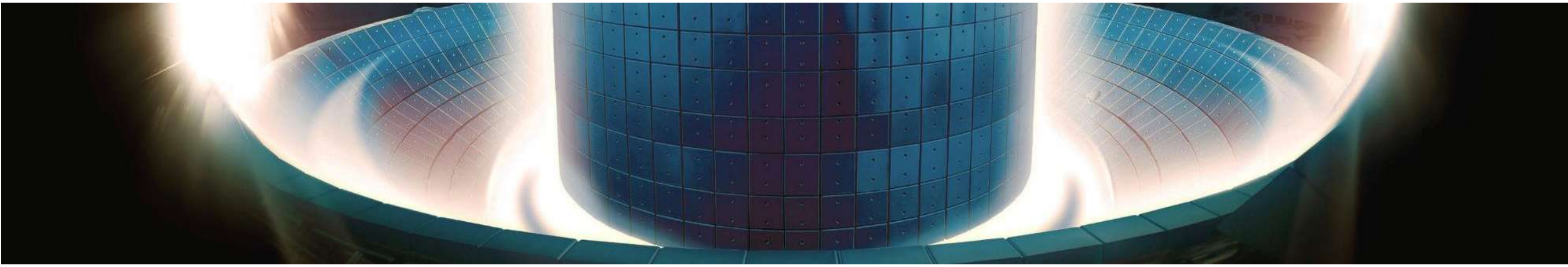
Sales Manager

WEDNESDAY APRIL 23rd

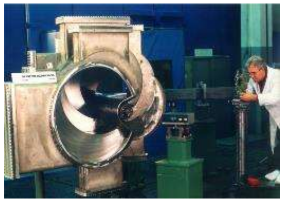
SUMMARY

1. **Introduction to De Pretto Industrie**
2. **Heating systems experience**
3. **Challenges Faced and Lessons Learned**
4. **Future Prospects and Developments**
5. **Conclusion: Key Takeaways and Impact**

1. Introduction to De Pretto Industrie



De Pretto Industre: supporting Fusion Tecnology sine more than 50 years!



1980 TJ II

1985 JET

1991 RFX

1995 TCV

2020 ITER – Mitica VV

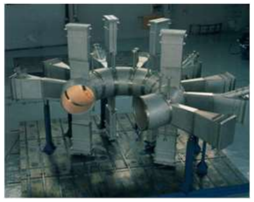
De Pretto – Escher Wyss

De Pretto Industrie

1972 Eta Beta

1981 Weldenstein VII

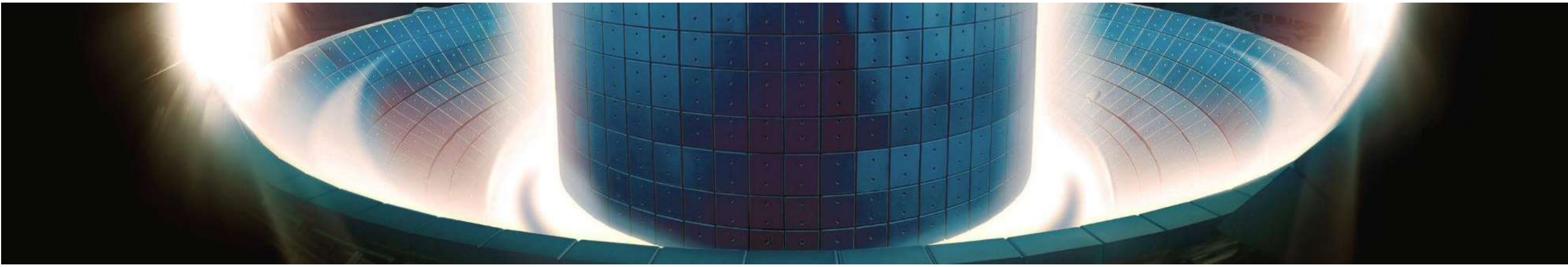
1989 FTU



1996 COMPASS

2022 ongoing ITER - IVT

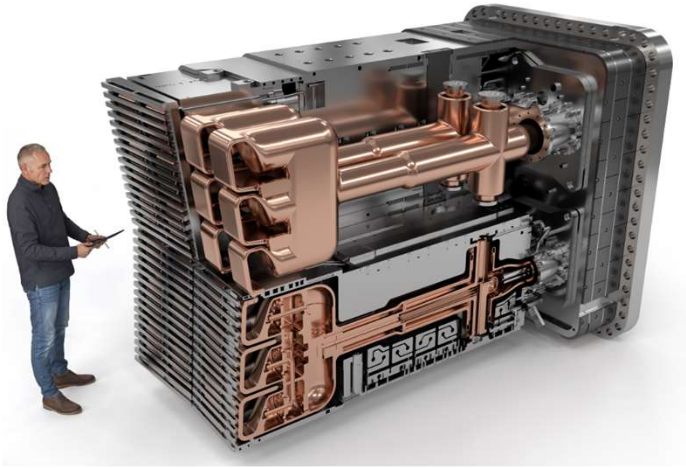
2. Heating systems experience



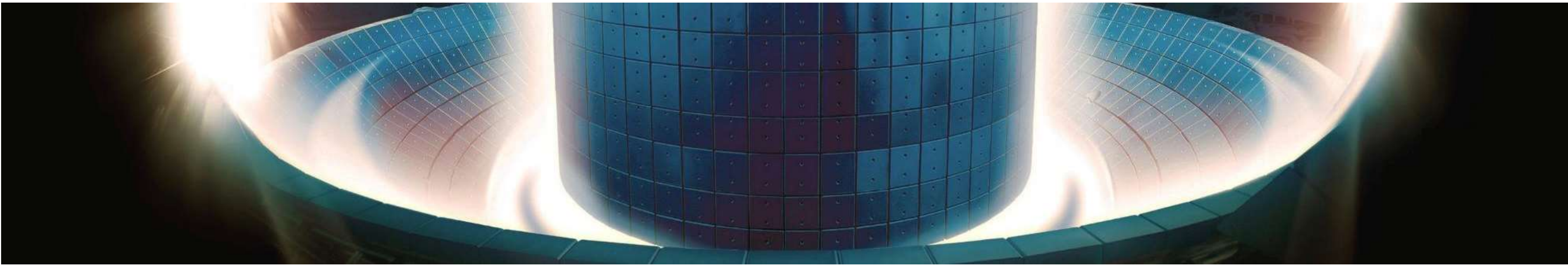
HNB Vaccum Vessels

HNB Assembly Tools

ICRH Antenna



3. Challenges Faced and Lessons Learned



Technical Challenges

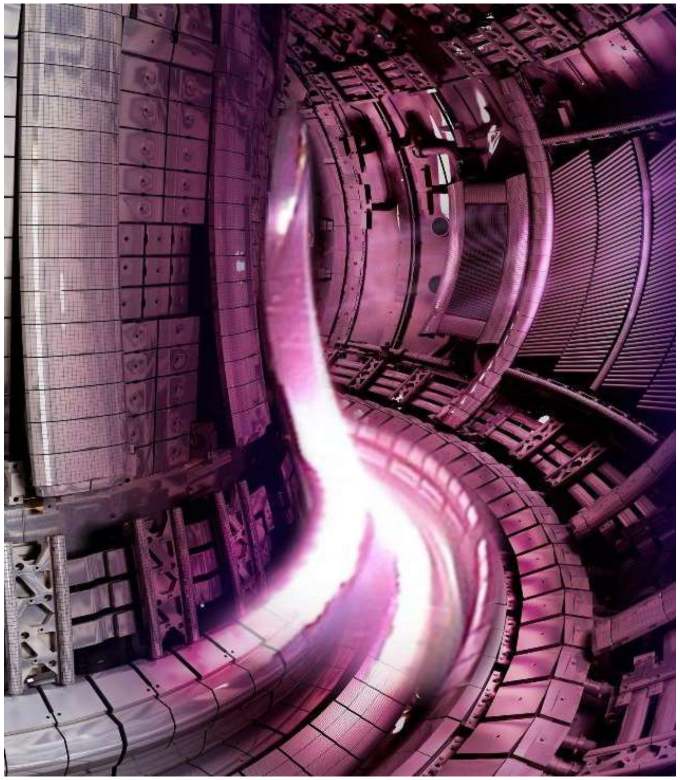
Iterating designs and solutions to meet stringent technical specifications while ensuring performance and safety in operating under extreme conditions presents ongoing challenges during the project's development.

Project Management

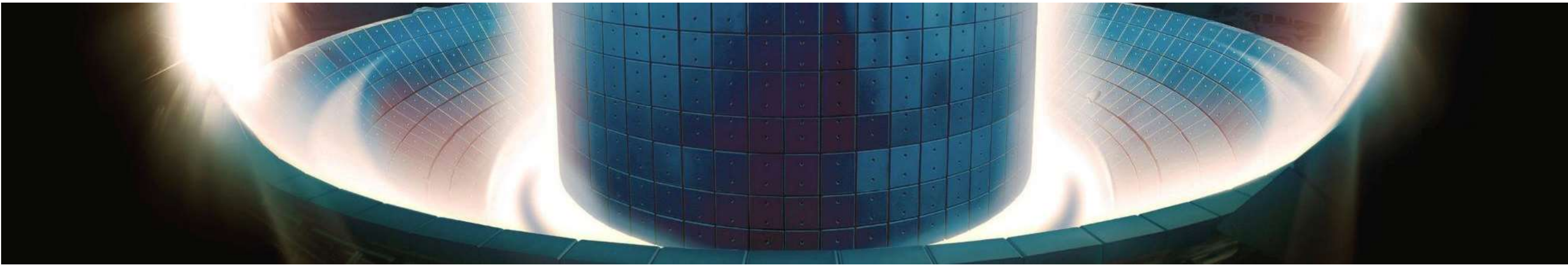
Effectively managing timelines, resources, and personnel across international teams requires adept project management to address unforeseen challenges and ensure smooth collaboration.

Innovative Solutions

Creative problem-solving strategies have emerged as the team works to address technical issues, reflecting the importance of innovation in engineering as well as collaboration for successful outcomes.



4. Future Prospects and Developments



Next Steps in ITER

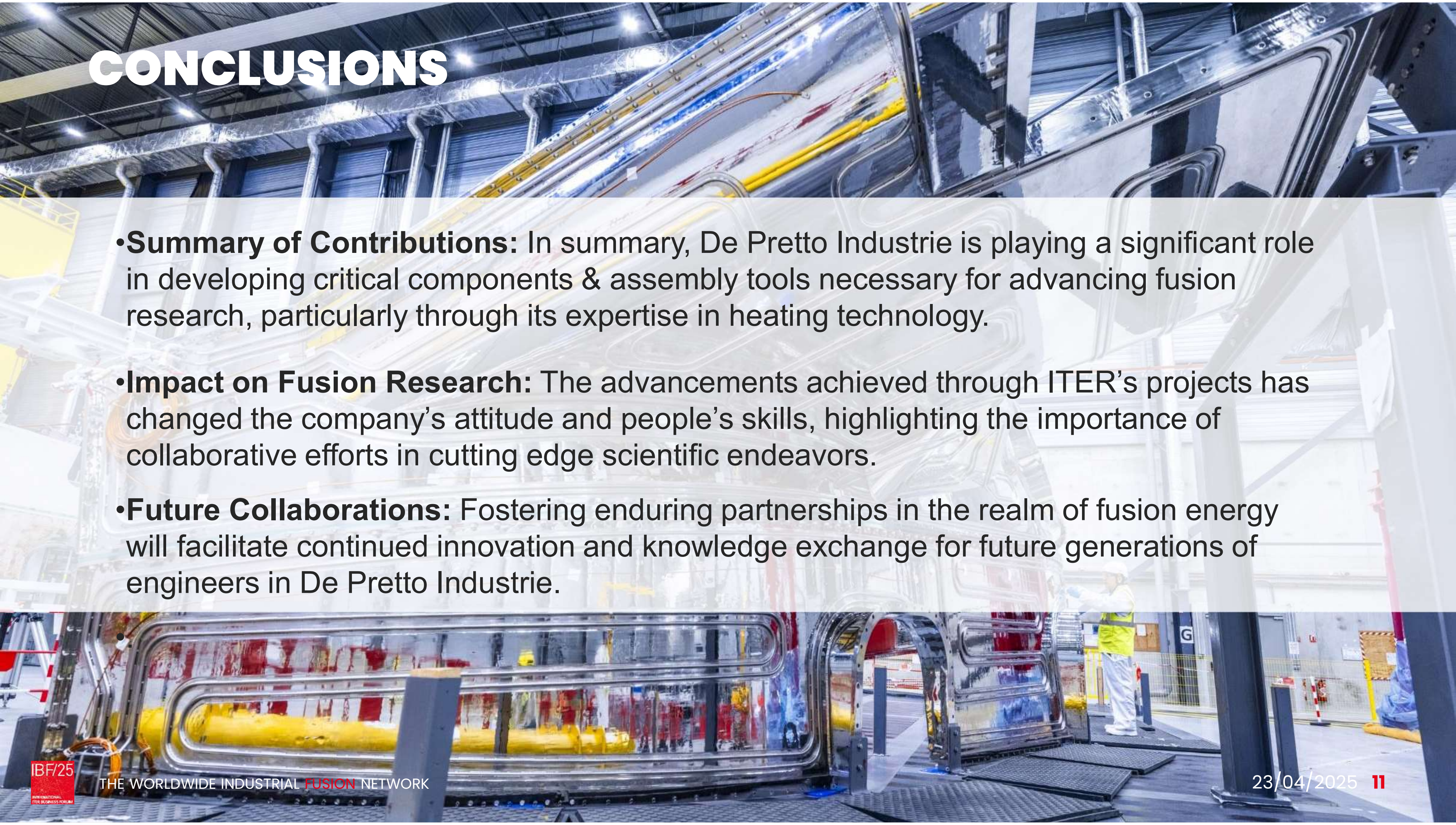
After successful completion of initial phases, DPI team is focusing on critical next opportunities that will advance toward the first plasma and operational achievements, which are pivotal in validating fusion technologies.

Potential Innovations

Exploring cutting-edge innovations across multiple fronts: materials technology, fabrication methods and remote handling applications, to assist the performance and reliability of future systems.

Long-term Goals

The long-term objectives of the team is to support the path of achieving commercially viable fusion energy, extending the experience of ITER milestones to other nuclear fusion and fission projects for future energy sustainability and safety.



CONCLUSIONS

- **Summary of Contributions:** In summary, De Pretto Industrie is playing a significant role in developing critical components & assembly tools necessary for advancing fusion research, particularly through its expertise in heating technology.

- **Impact on Fusion Research:** The advancements achieved through ITER's projects has changed the company's attitude and people's skills, highlighting the importance of collaborative efforts in cutting edge scientific endeavors.

- **Future Collaborations:** Fostering enduring partnerships in the realm of fusion energy will facilitate continued innovation and knowledge exchange for future generations of engineers in De Pretto Industrie.

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