

# OVERVIEW OF ITER DIAGNOSTICS

## and their contribution to ITER Research Plan

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with contributions from DAs, Research Centers, Universities, and private industry

iter

china eu india japan korea russia usa

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# Presentation Outline

- SRO objectives
- SRO diagnostics
- Contribution to SRO activities
- Standardization
- Innovative solutions
- Synthetic diagnostics
- Summary



# Presentation Outline


**SRO objectives**

SRO diagnostics

Contribution to SRO activities

Standardization

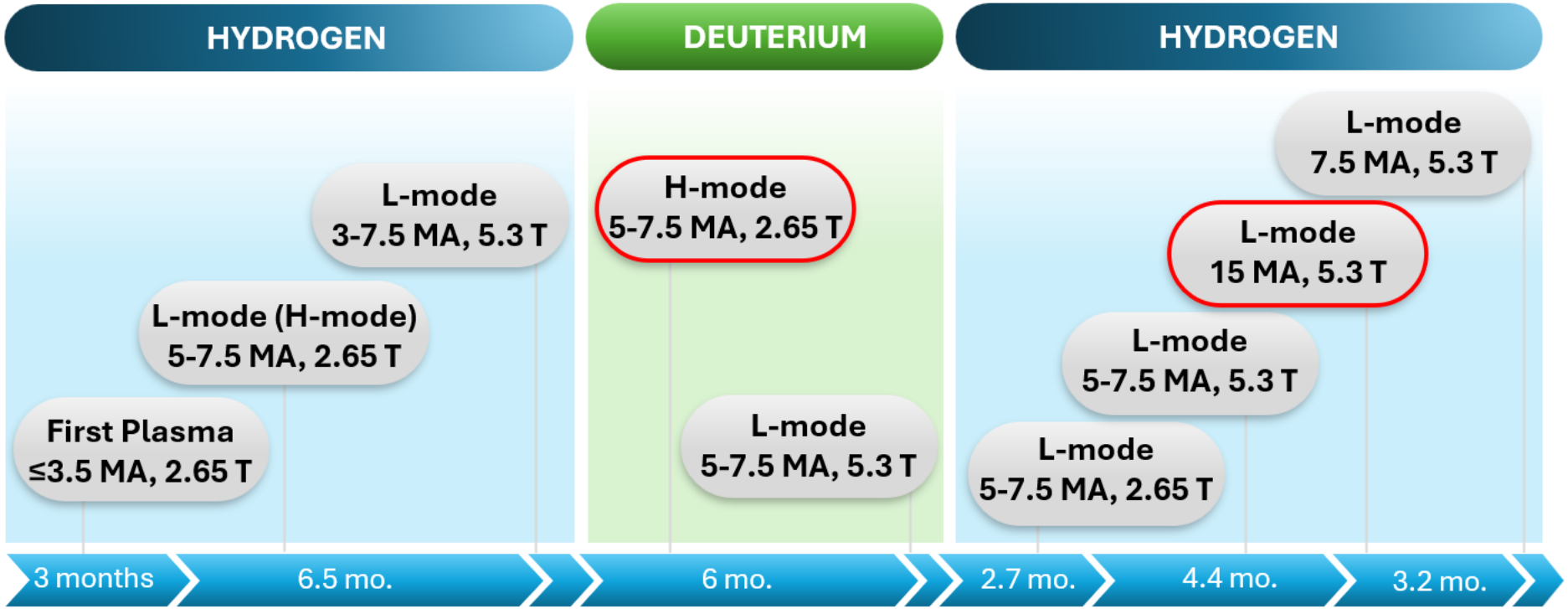
Innovative solutions

Synthetic diagnostics

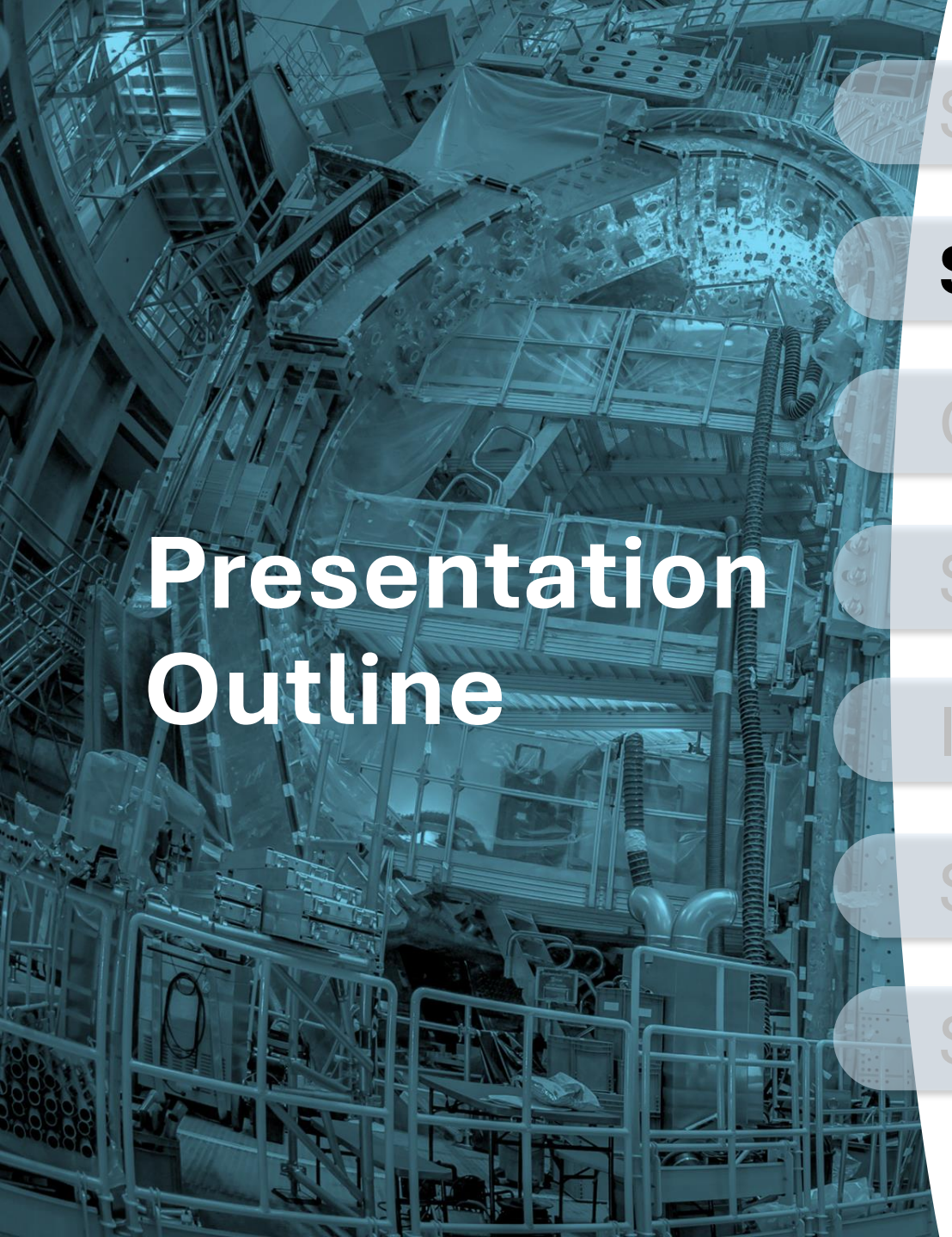
Summary

# Start of Research Operation – main objectives

1. H-mode* up to 7.5 MA / 2.65 T in D plasma for a target flat-top of at least 30s
2. L-mode** up to 15 MA / 5.3 T in H plasma for a target flat-top of at least 30s
3. Disruption loads characterization and mitigation before D-T operation




*High-confinement mode
**Low-confinement mode



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SRO objectives

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Standardization

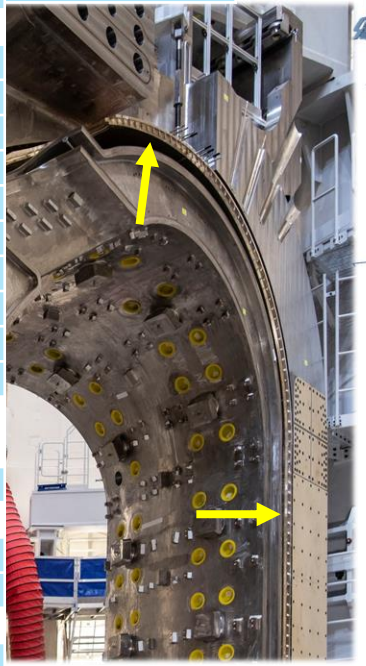
Innovative solutions

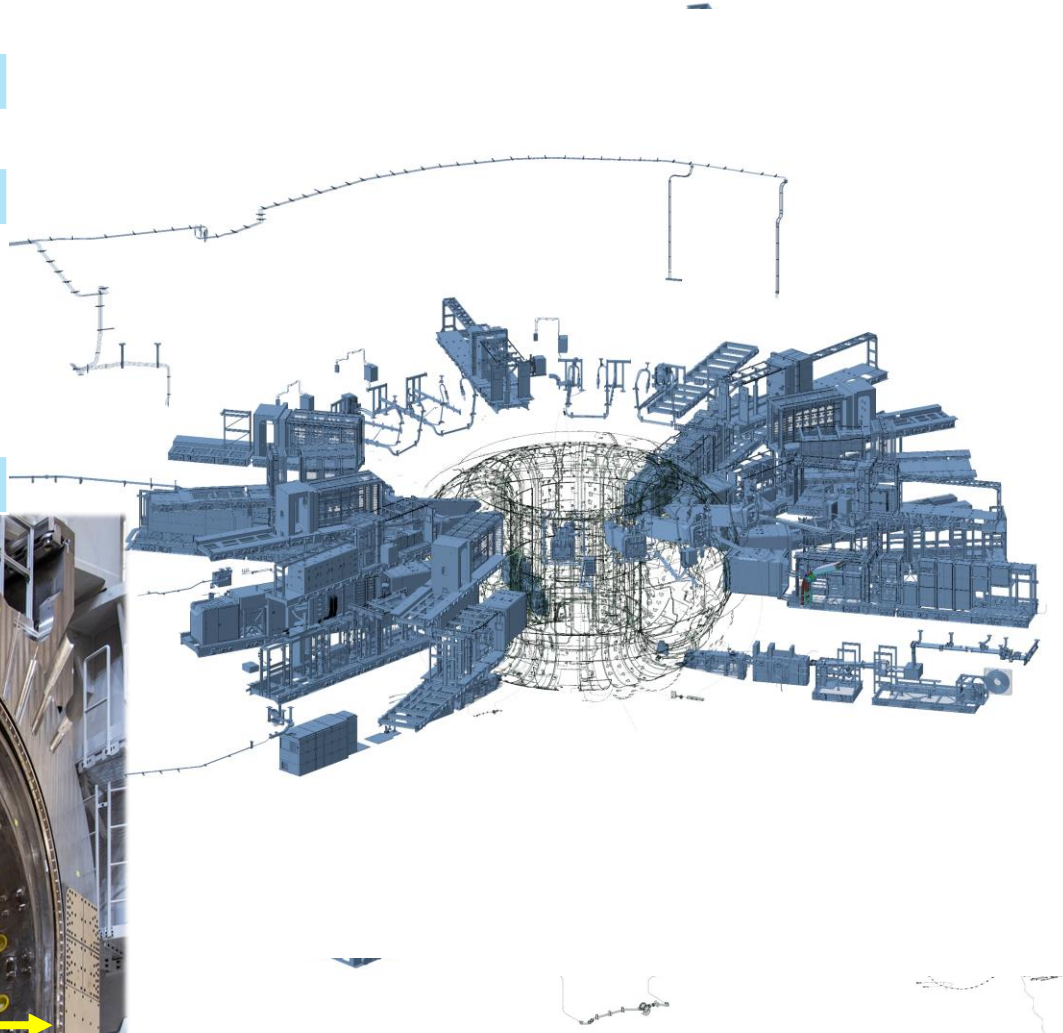
Synthetic diagnostics

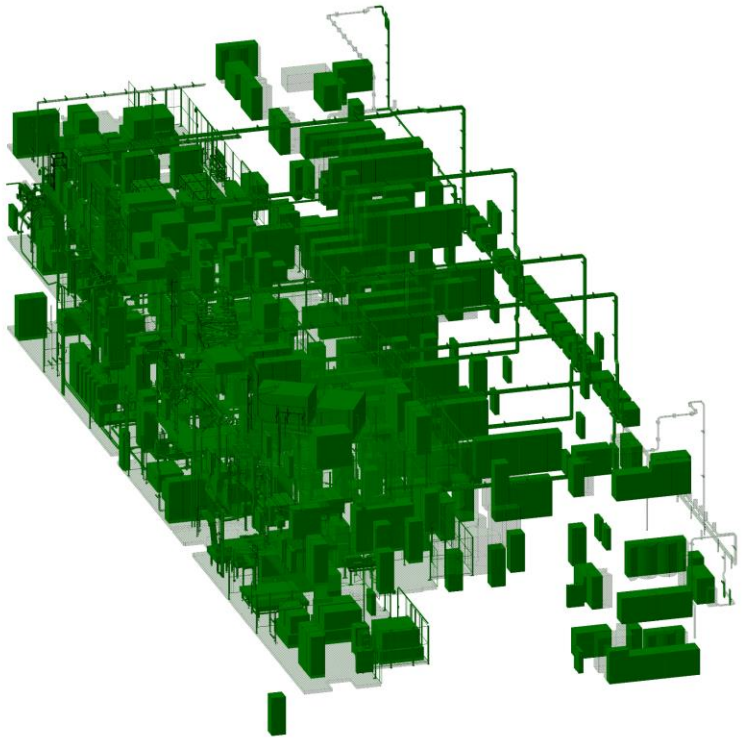
Summary

# >2/3 of ITER diagnostics installed for SRO

- Magnetics
- Plasma Current Monitor
- Neutron Activation System
- Divertor Neutron Flux Monitor
- Bolometers
- High Field Side Reflectometry
- Pressure Gauges
- Dust Monitor
- In-Vessel ECH Detectors
- Core Thomson Scattering
- Edge Thomson Scattering
- Toloidal Interfometer Polarimeter
- Poloidal Polarimeter
- H-alpha & Vis Spectroscopy
- Vacuum Ultraviolet Survey
- Divertor Impurity Monitor
- Core Imaging X-ray Spectrometer
- Visible Continuum Array
- Radial X-ray Camera
- Neutral Particle Analyzer
- X-Ray Crystal Spectro. Survey
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- Vacuum Ultraviolet Divertor
- Vacuum Ultraviolet Edge Imaging
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- Density Interfometer Polarimeter
- Visible / IR in Equatorial Ports
- Thermocouples
- Residual Gas Analysis
- Divertor IR Thermography
- Langmuir Probes
- Visible / IR in Upper Ports
- Tritium Monitor
- First Wall Samples
- Boundary Imaging System
- In-Vessel Viewing System

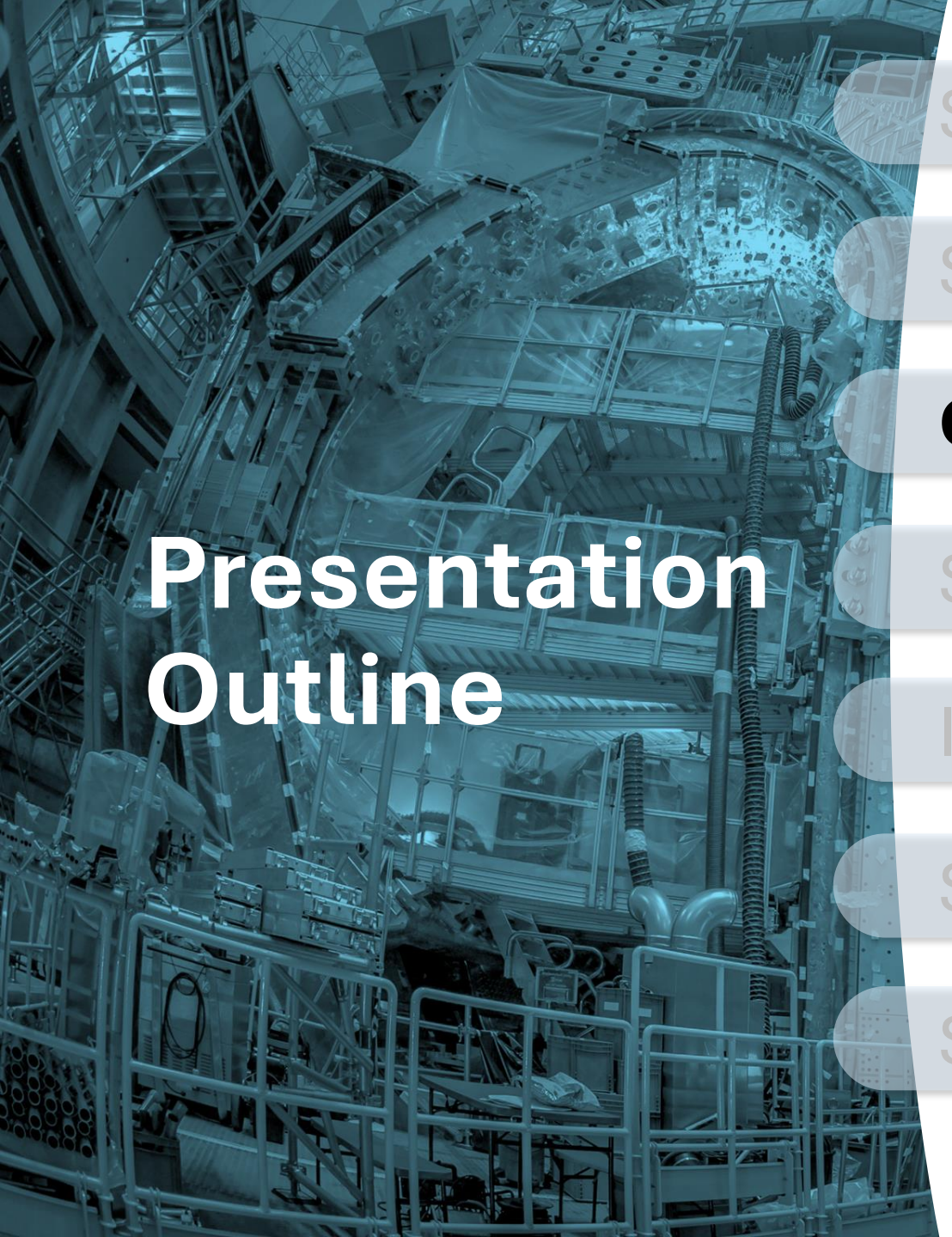






## After SRO

| | | |
|---|---|---|
| Radial Neutron Camera | High Resolution Neutron Spectrometer | Charge Exchange Recomb. Spectr – Edge |
| Vertical Neutron Camera | Divertor Thomson Scattering | CXRS Pedestal - Beam Emission Spectroscopy |
| Neutron Flux Monitor | Collective Thomson Scattering | XRCS Edge Imaging |
| Radial Gamma Ray Spectrometer | Charge Exchange Recomb. Spectr - Core | Calorimetry |
| Lost Alpha Monitor | Motional Stark Effect | Microfission chambers |



# Presentation Outline

SRO objectives

SRO diagnostics

**Contribution to SRO activities**

Standardization

Innovative solutions

Synthetic diagnostics

Summary

| |
|---|
| Magnetics |
| Plasma Current Monitor |
| Neutron Activation System |
| Divertor Neutron Flux Monitors |
| Core Thomson Scattering |
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| Toroidal Interfometer Polarimeter |
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First plasma demonstration ($I_p \leq 2MA$)

Initial operation up to 3.5 MA in hydrogen

Plasma Control System

Advanced Protection System

Safety knowledge acquisition program

Plasma Wall Interaction Characterization

Disruptions characterization

Other SRO research activities*

* MHD characterization, Wall cleaning, neutron fluence, ICH coupling optimization, boronization effect, pedestal screening, control of First Wall W sources, etc.

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Plasma Current Monitor
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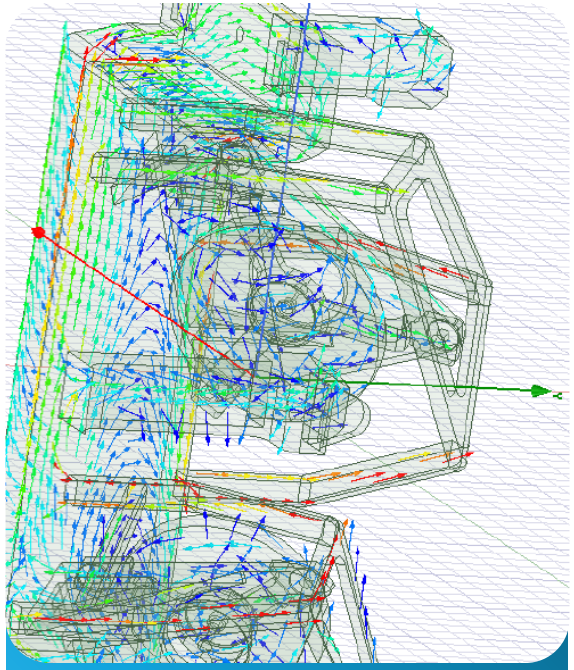
**Plasma Wall Interaction Characterization**

**Disruptions characterization**

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# ITER Diagnostics – status snapshot



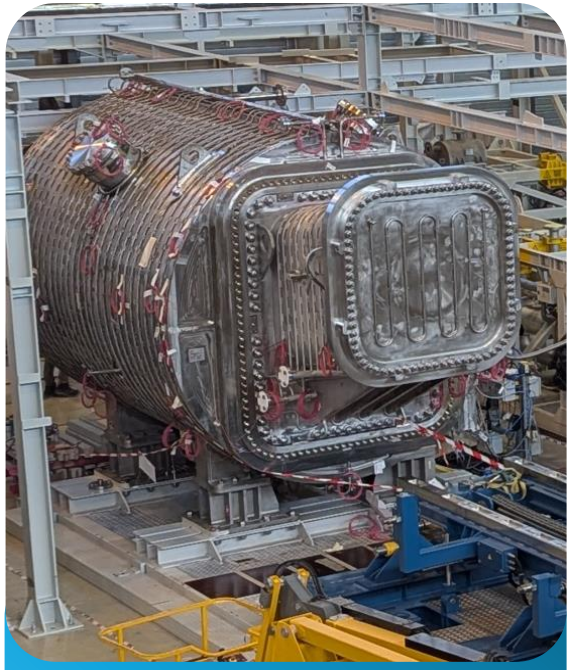
**300+**

Diagnostic design reviews held



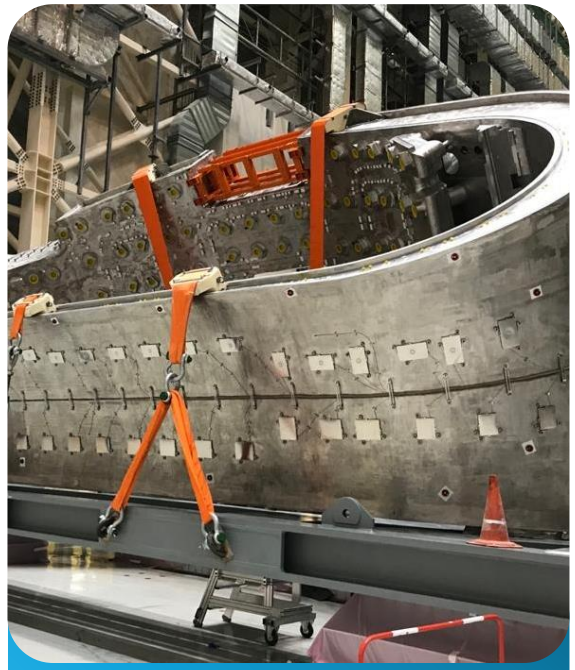
**61+**

Diagnostic projects currently in manufacture



**58+**

Diagnostic projects fully or partly delivered



**22+**

Diagnostic projects fully or partly installed

# Installation of Magnetics

- Continuous Rogowski
- Outer vessel coils
- Control cubicles
- Outer vessel toroidal loops
- Fiber optics current sensor*
- Hall sensors
- Hall sensor electronics
- In-vessel sensors
- Partial flux loops
- MHD saddle coils
- Divertor pick-up coils

*vessel-mounted components

100% by end of 2026

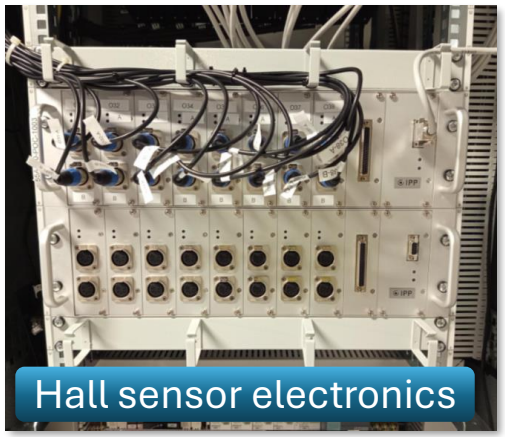
% delivered % installed

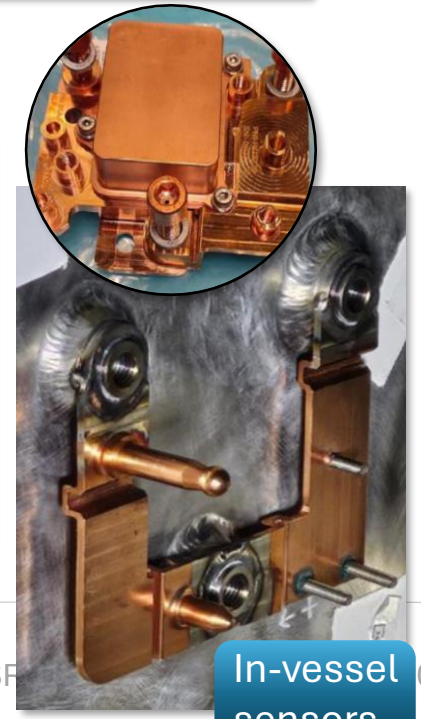


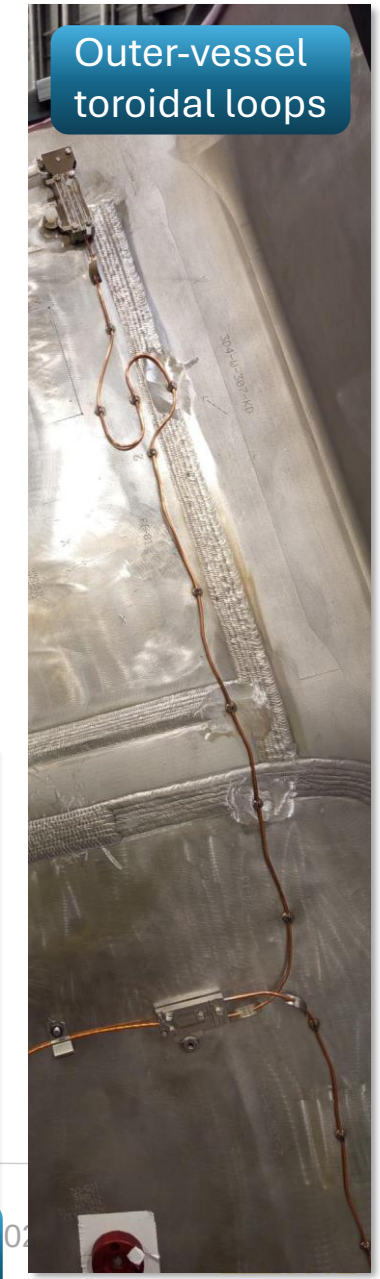


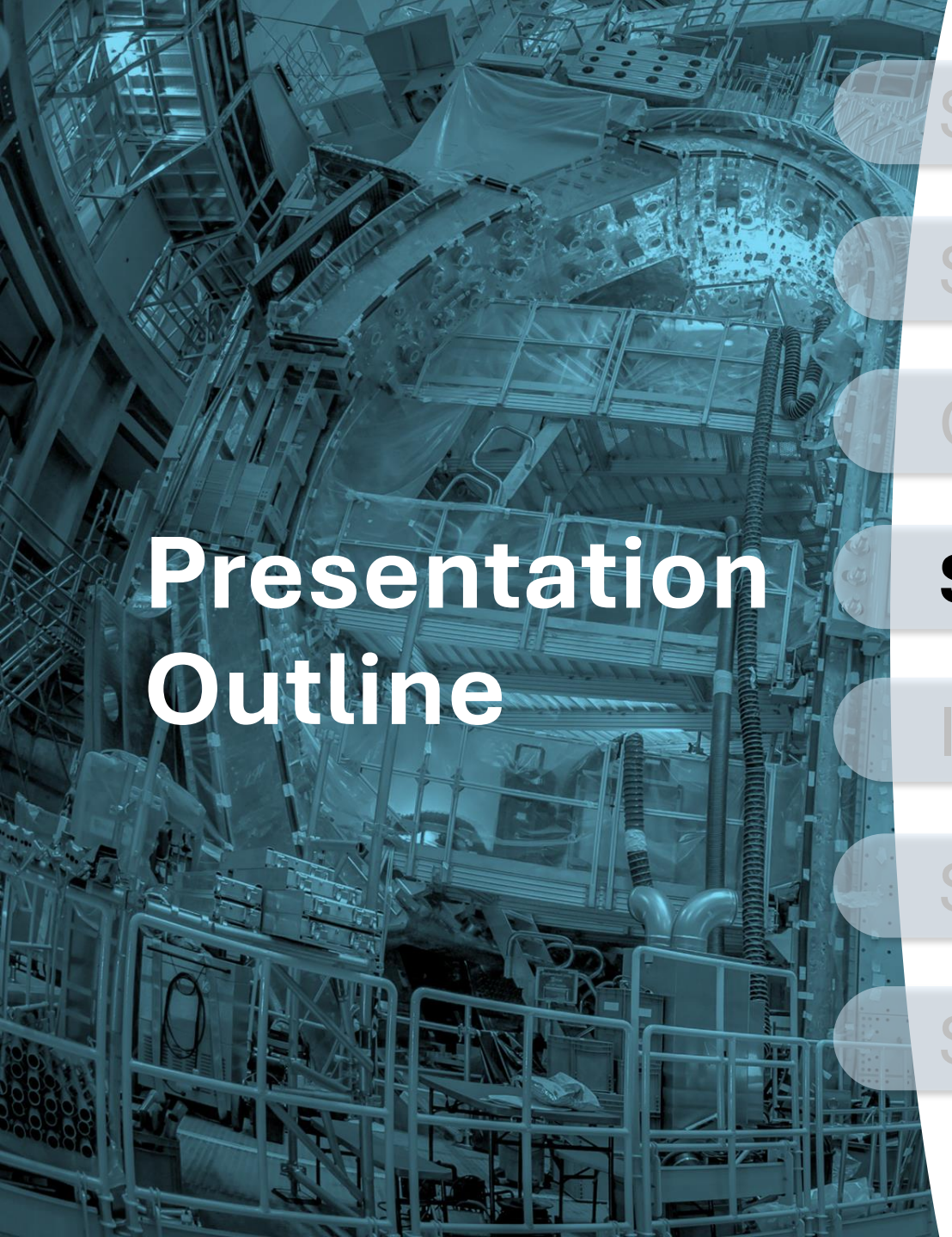






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SRO diagnostics

Contribution to SRO activities

**Standardization**

Innovative solutions

Synthetic diagnostics

Summary

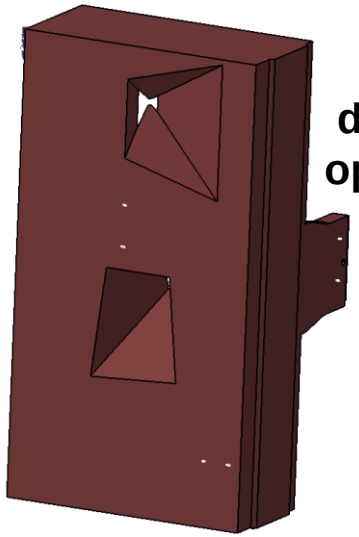
# Standardization of ITER diagnostic components

**ITER Project Requirement:** *Standardization shall be privileged when selecting multiple numbers of similar components that can be used by several diagnostics systems or ports in order* ***to reduce the number of required spare parts, tools, skills, procedures, storage spaces and associated costs****.*

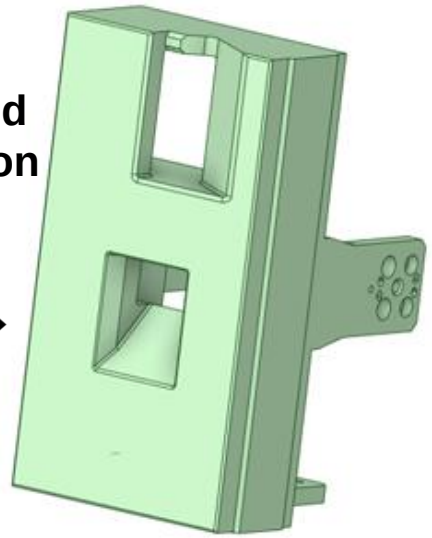
**Standardized design used for:**

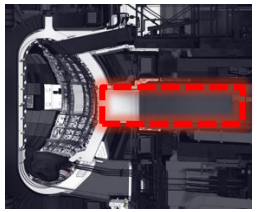
- Diagnostic port structures
- Diagnostic attachments to vacuum vessel
- Mirror enclosures for optical diagnostics
- Vacuum windows
- Electrical feedthroughs
- Shielded cabinets for electronics
- Control cubicles
- Mirror cleaning systems
- Cameras
- Shutters
- Actuators
- …

# Port structures - common architecture, tailored functionality

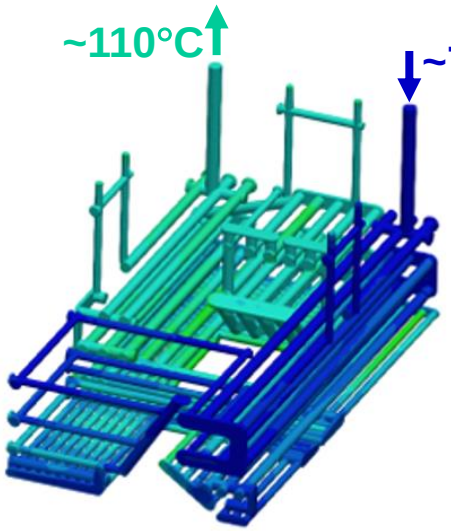


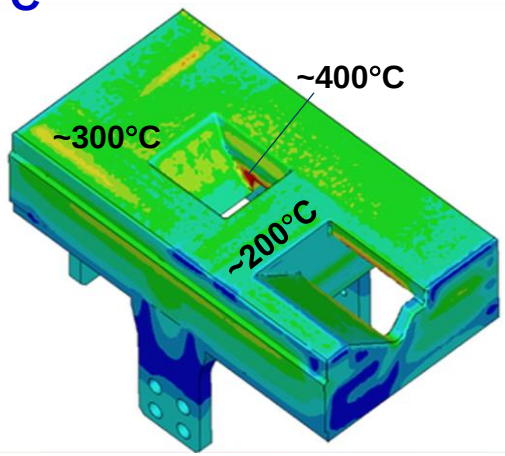
Cooling network design and optimization







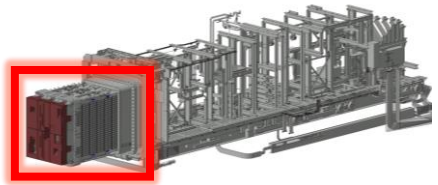



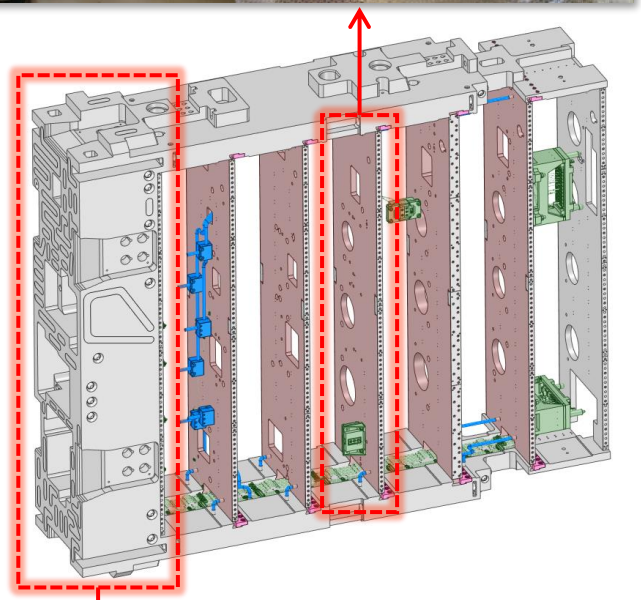



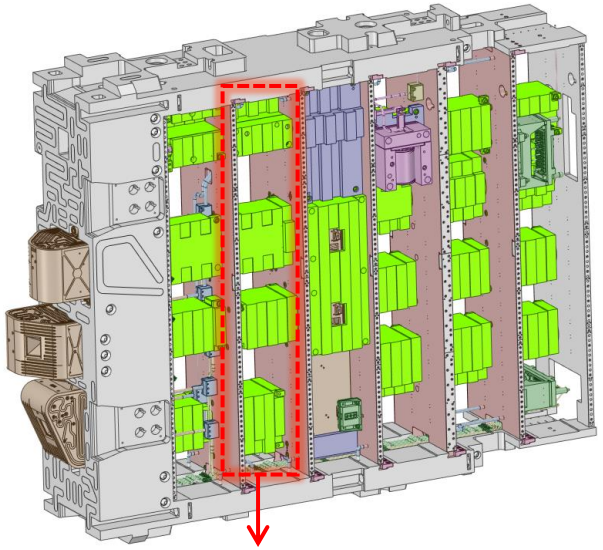


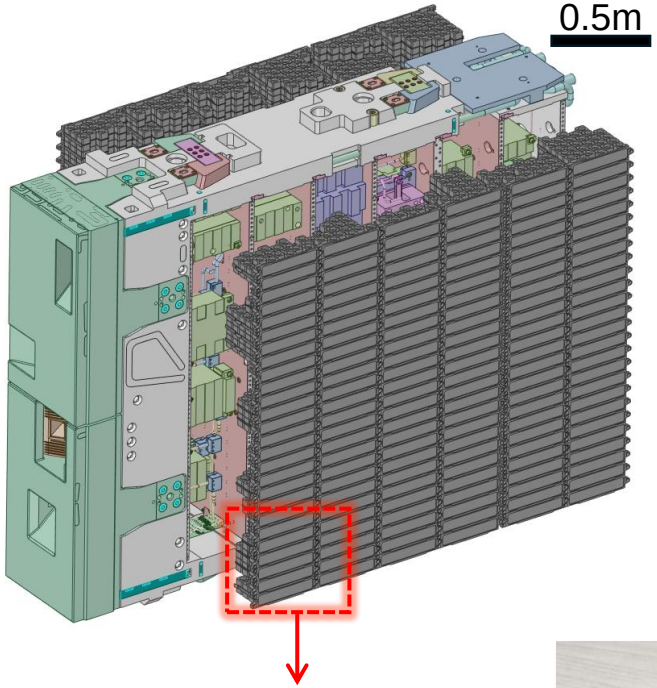

# Port structures - common architecture, tailored functionality







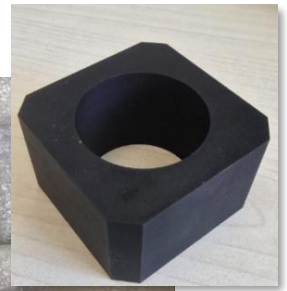




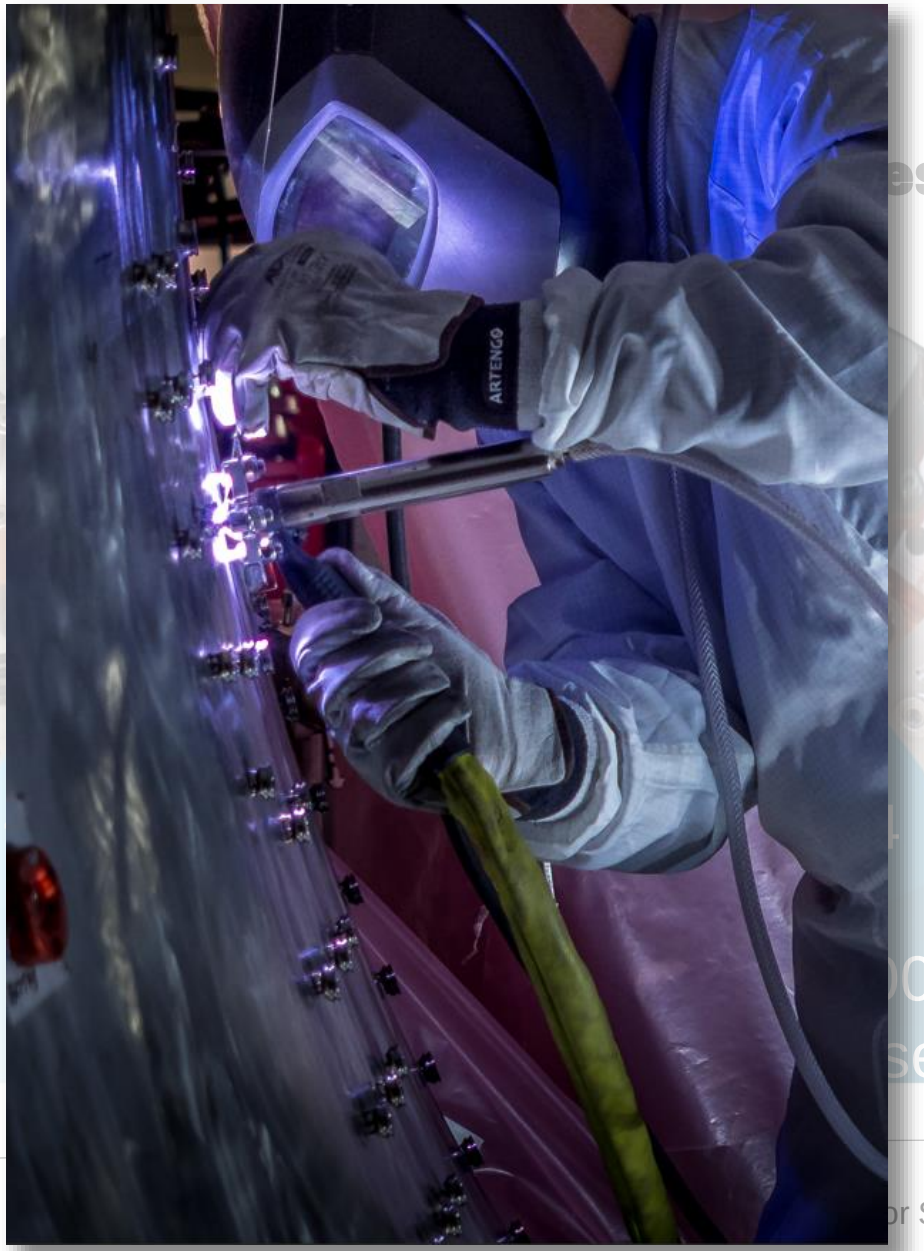






# Diagnostic attachments to vacuum vessel



Hall sensors

In-vessel coils

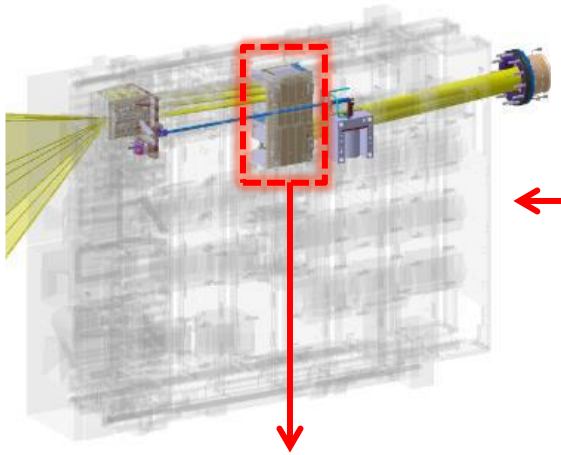
Bolometers

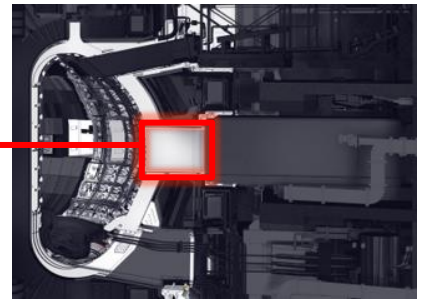
Ex-vessel coils

Divertor equilibrium coils

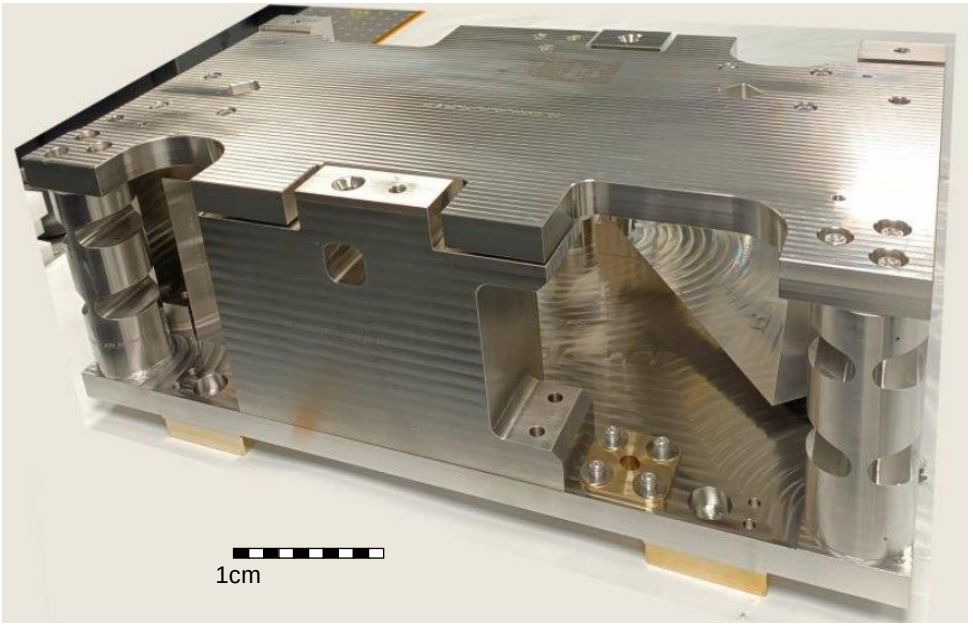
Diagnostic electrical looms

# Enclosures for optical diagnostics

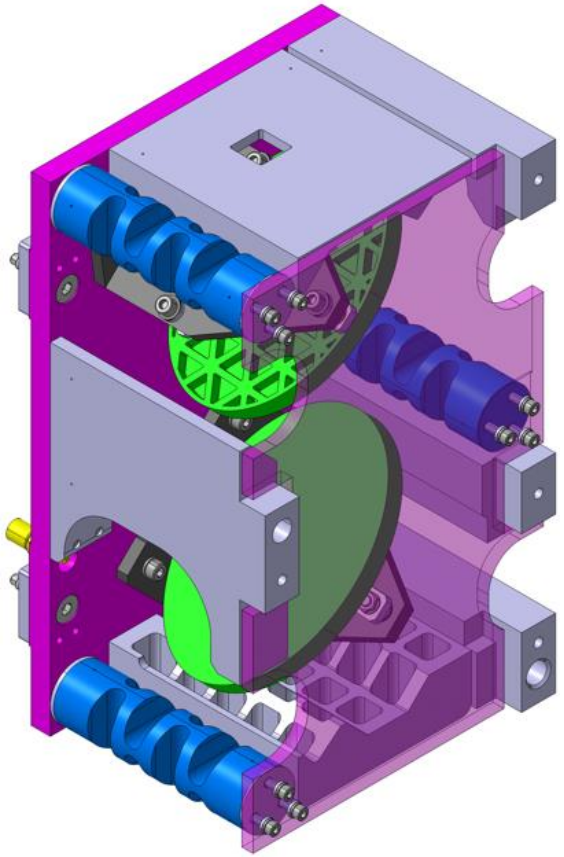




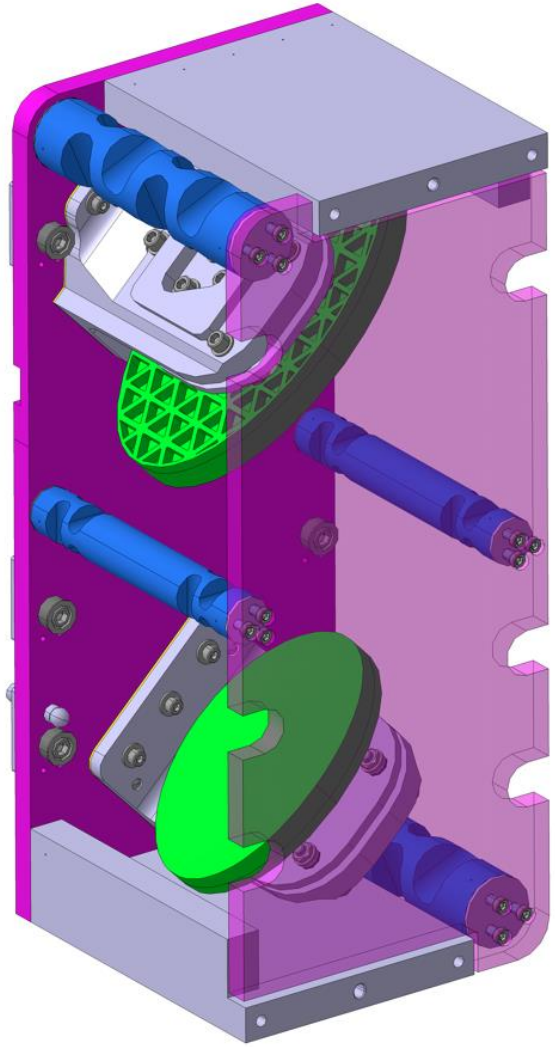
Hα diagnostic



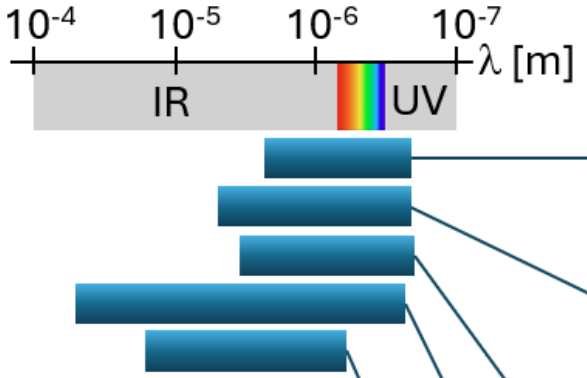

Boundary imaging system

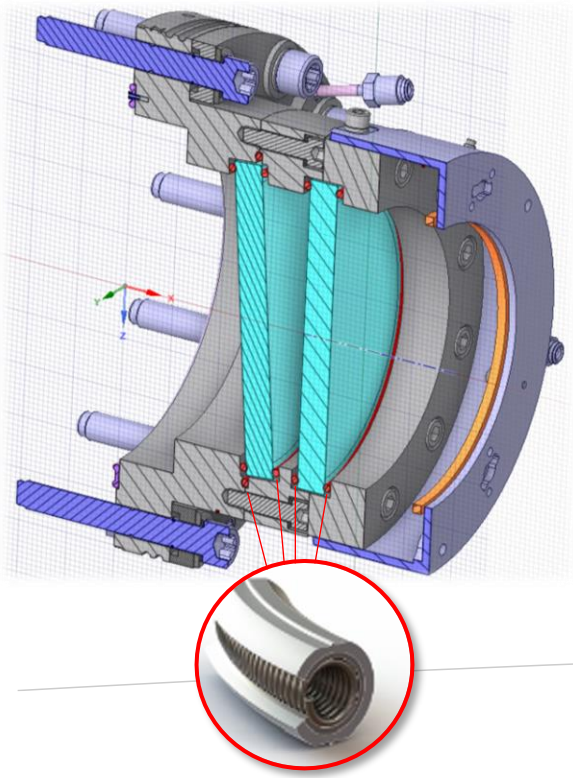


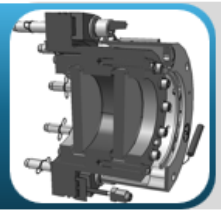
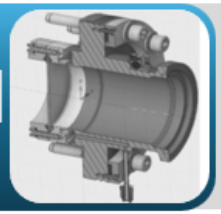
Lost alpha monitor

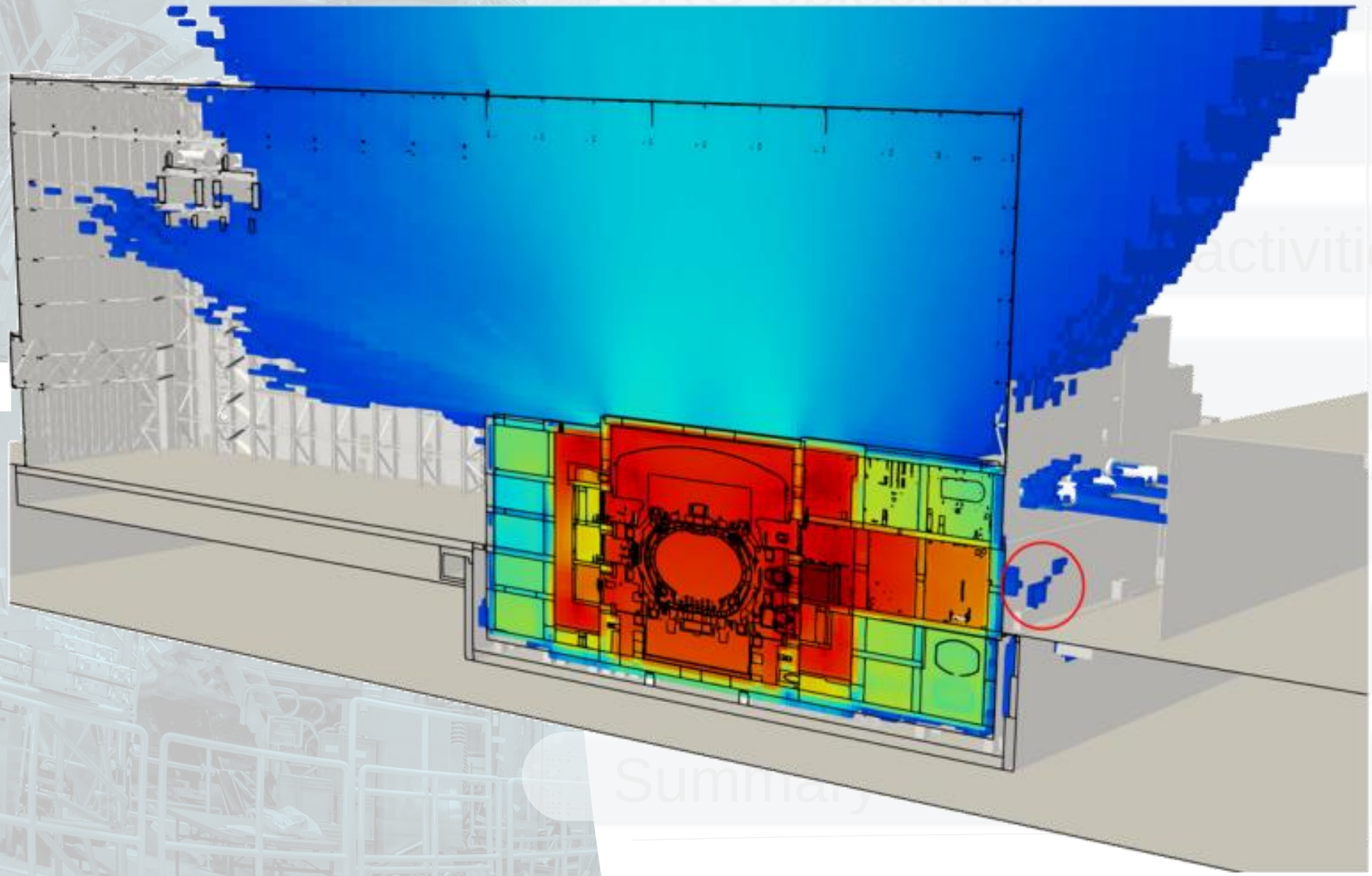


# Vacuum windows



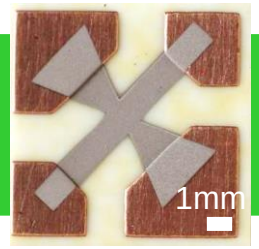



| | QUANTITY | VARIANTS | DIAGNOSTICS |
|---|---|---|---|
| Fused Silica  | 57 | 11 | Thomson Scattering, Vis/VUV/CX Spectro., Reflectometers, etc. |
| Sapphire  | 22 | 2 | Vis-IR cameras |
| Quartz  | 15 | 2 | Polarimeter, ECE |
| ZnSe  | 7 | 1 | Interferometers |
| CVD Diamond  | 1 | 1 | Collective Thomson Scattering |

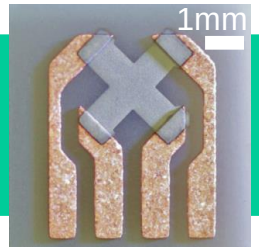

1.0e+10
1e+9
1e+8
1e+7
1e+6
100000
10000
1000
100
10
1
0.1
1.0e-02
Dose (uSv/h)

# Benefiting from technology advancement – ITER Hall sensors

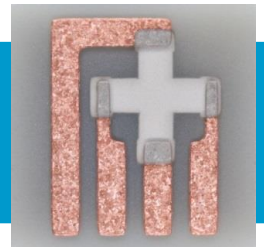
1. Bismuth. First prototype. R&D phase.




2. Bismuth. Miniaturized and symmetric. R&D phase.



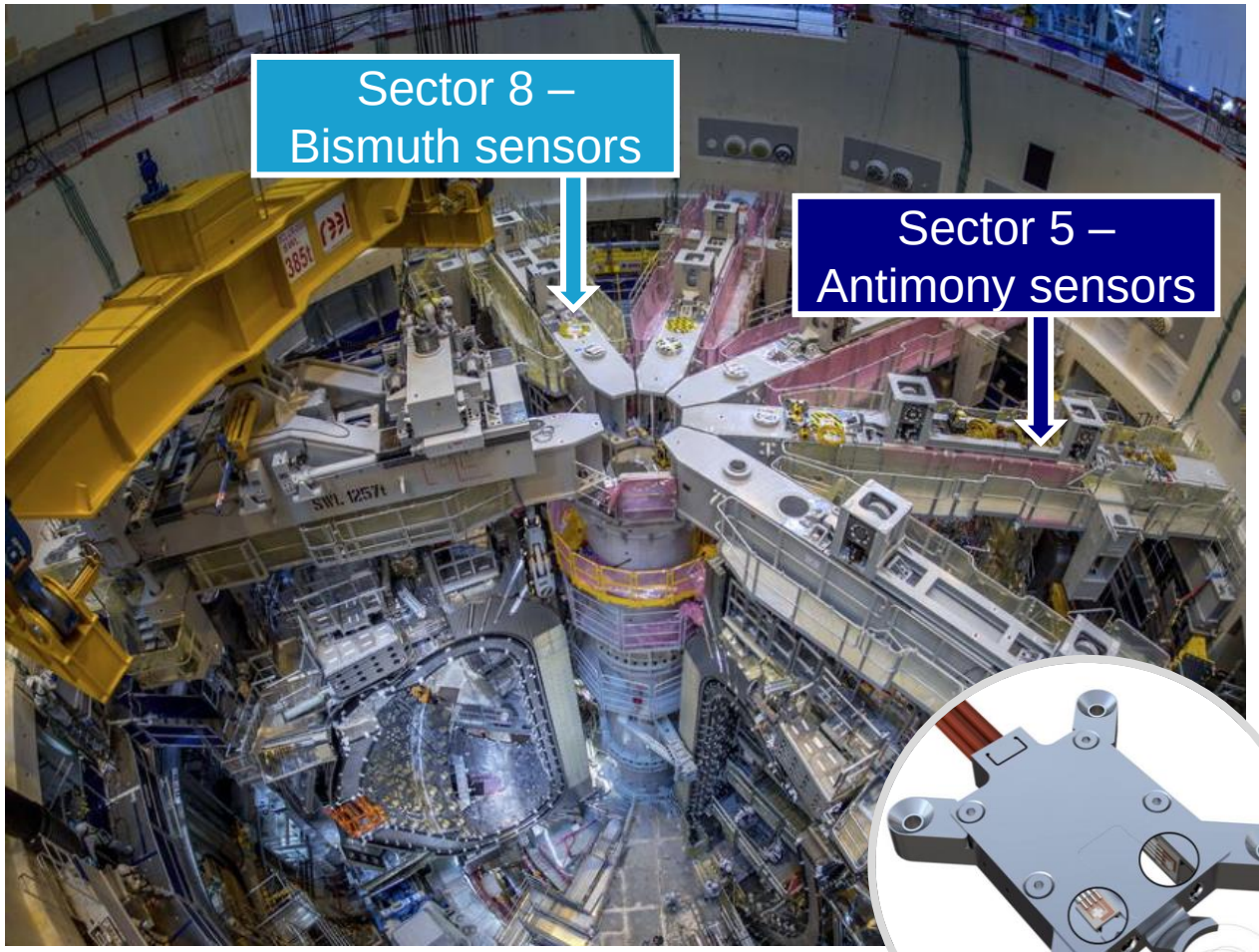

3. Bismuth. Reduced planar Hall effect. **Installed in Vacuum Vessel sector 8**



4. Antimony. More rugged. Less affected by temperature. **VV sectors 5 and 2.**



I. Duran, this conference
M. Ivanek, this conference

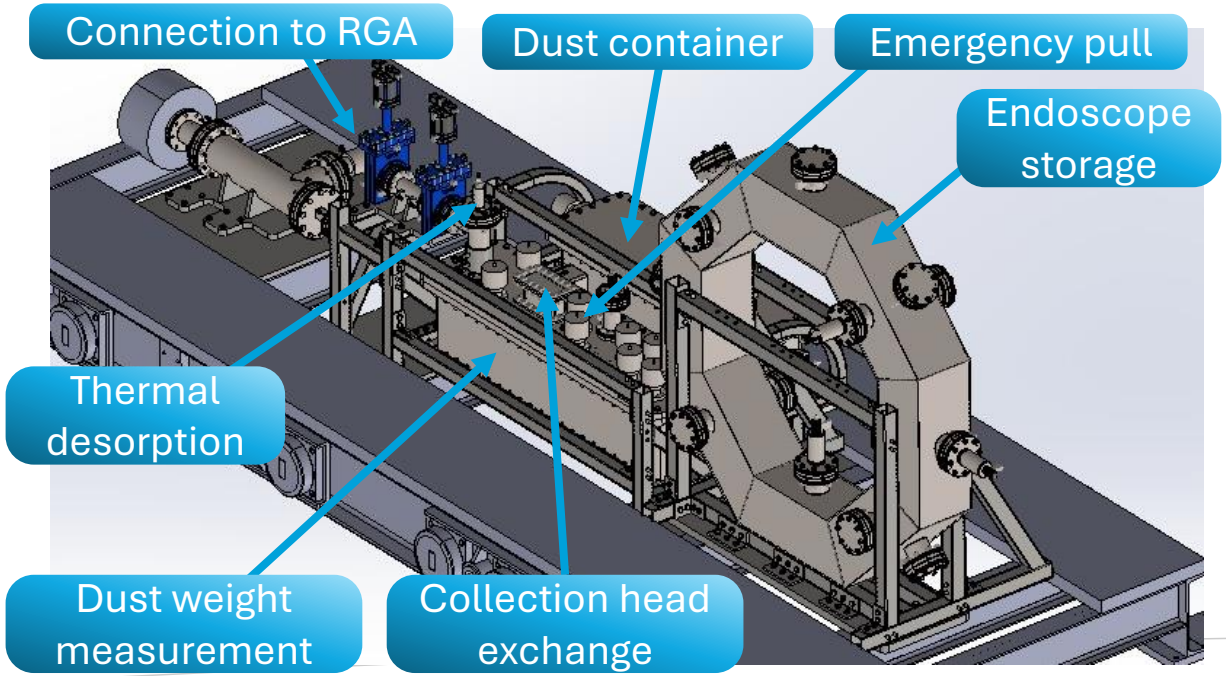





24 per VV sector

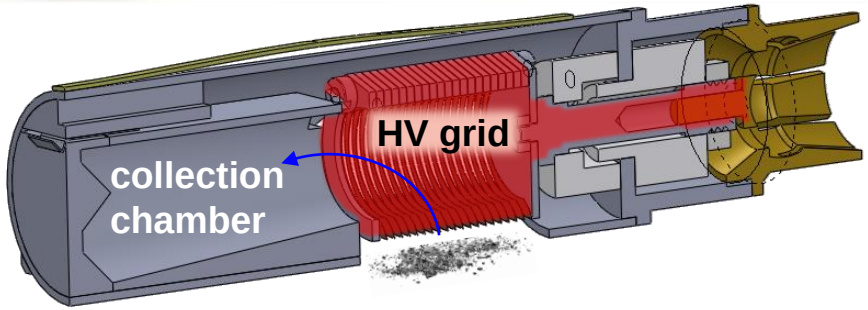
# Dust monitor for safety knowledge acquisition



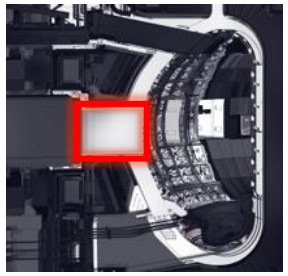


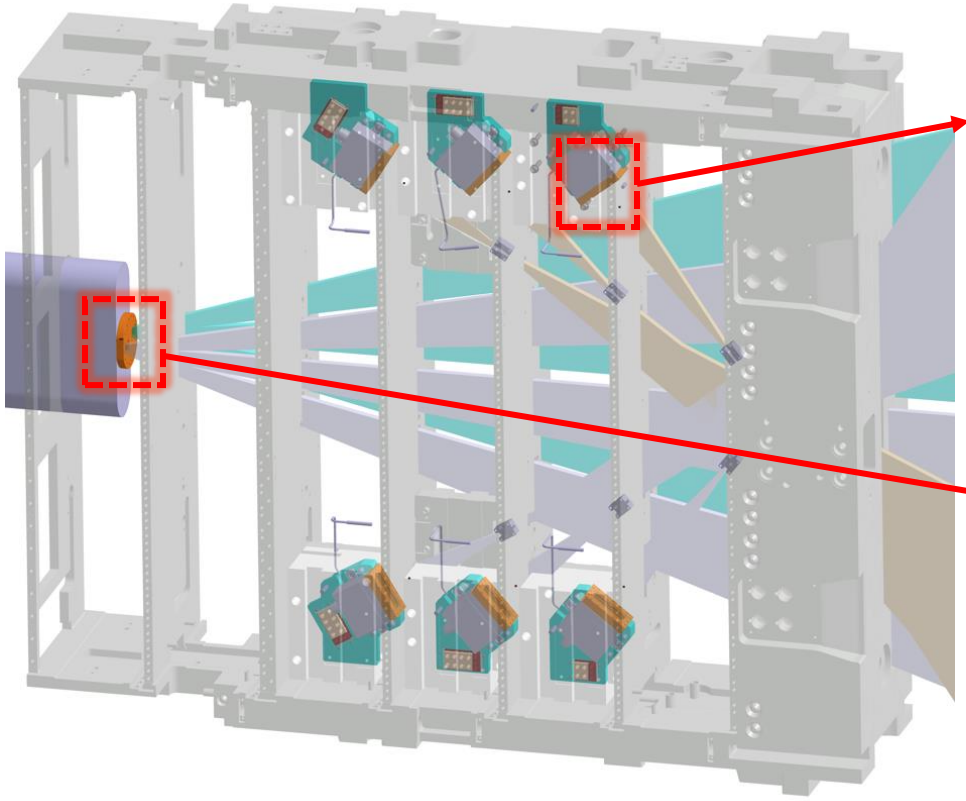


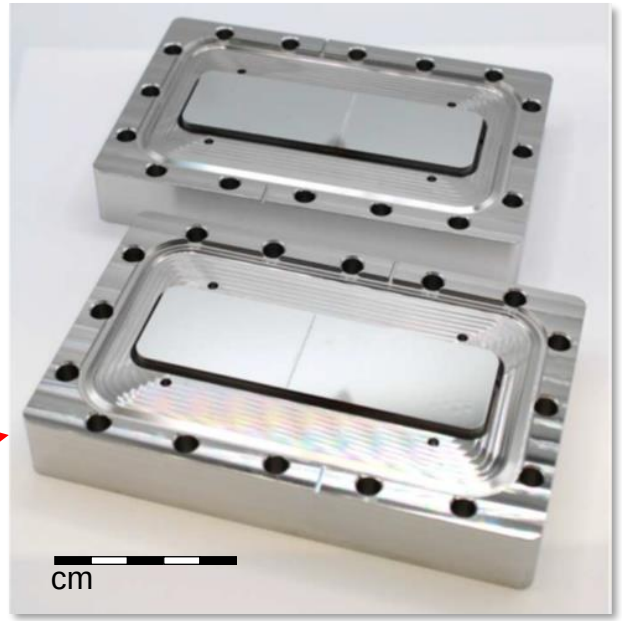





# Diamond windows/filters for Radial X-Ray Cameras














# Presentation Outline

SRO objectives

SRO diagnostics

Contribution to SRO activities

Standardization

Innovative solutions

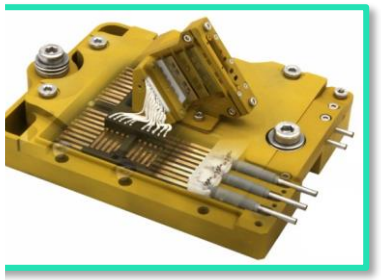
**Synthetic diagnostics**

Summary

# Synthetic diagnostics in support of the design

Synthetic diagnostics modelling guides the design and selection of hardware

20+ synthetic diagnostics implemented in ITER **Integrated Modelling and Analysis Suite (IMAS)**



This conference: E. Agus Poletti, M. Helene-Aumeunier, D. Nébouy, F. Pesamosca

K. Munechika, et al. “3D Synthetic Bolometry and Radiation Asymmetry Analysis for ITER SPI-Mitigated Disruptions,” 27th PSI Conf.

K. Munechika et al., Cherab Add-on Module for IMAS (https://github.com/cherab/imas)



# Summary

- **47 diagnostics and 16 diagnostic port structures targeted for SRO, covering >2/3 of the ITER diagnostics infrastructure**
- **Designs and hardware in full compliance with nuclear safety requirements**
- **Standardization of key components is improving efficiency and reducing manufacturing time and costs**
- **Novel engineering solutions are applied to meet ITER requirements**
- **Overall Program performance is ahead of plan with**
  - Magnetics installation well advanced
  - Large number of projects is currently being manufactured
  - Many fully or partly delivered to site already
  - Port assembly activities planned through the next five years

# SOFT 2026 contributions on ITER diagnostics

| Diagnostic Type | # Abstracts | Main Authors |
|---|---|---|
| Neutron Diagnostics | 14 | An, Di Sarra, Dojko, Fortuna, Fujiwara, Hagg, Kantor, Koning, Morawski, Occhiuto, Ollus, Potiron, Seo, Yoo |
| Plasma-Facing Component and Boundary Diagnostics | 6 | Baross, Bohm, Bourgade, Meister, Park, Quinlan |
| Optical / Spectroscopic | 6 | Cholleton, Hidalgo-Salaverri, Kim, Marques, Pokorny, Sapna |
| Collective Thomson Scattering | 4 | Blanco, Rechena, Ronconi, Varela |
| Magnetics | 3 | Di Grazia, Duran, Ivanek |
| Infrared | 2 | Agus-Poletti, Nébouy |
| Bolometry | 1 | Banos |
| Tokamak Systems Monitor | 1 | Iglesias |