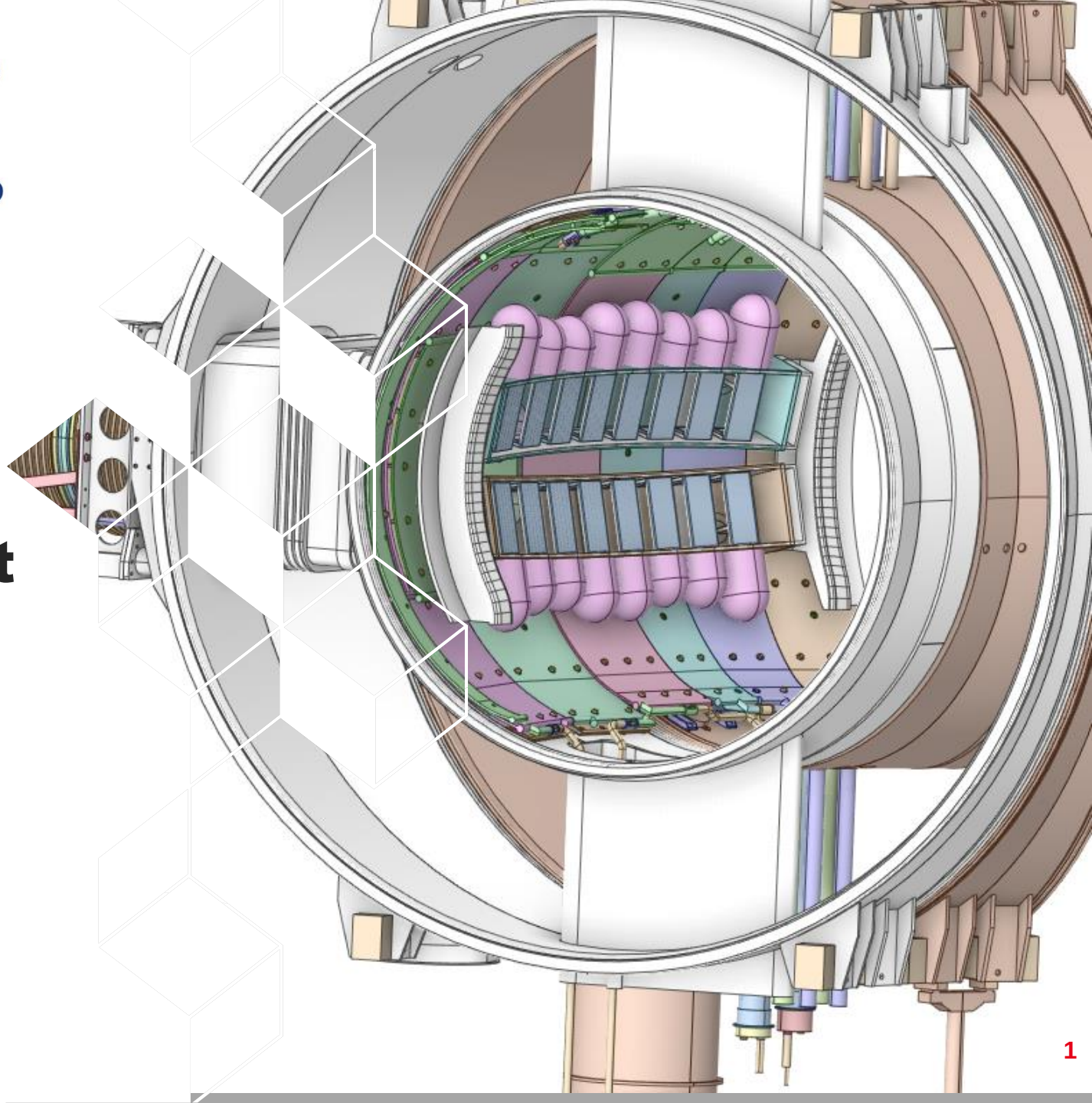
ENR-TEC.02.CEA
WEST ICRH TWA Project 2024 Activities

8th SB.ENR-TEC

Monitoring of 2024 activities

05/02/2025

J.Hillairet for the WEST TWA team



Introduction

Current Ion Cyclotron Antennas have Several Drawbacks

While ICRF has been proven to be a relevant tool in fusion experiments due to

- No density limit (high-density plasmas)
- Excellent absorption
- Proven experience in relevant scenarios (heating, wall-conditioning, breakdown)
- Proven technology for CW and modest price/MW (compatible with high field experiments)

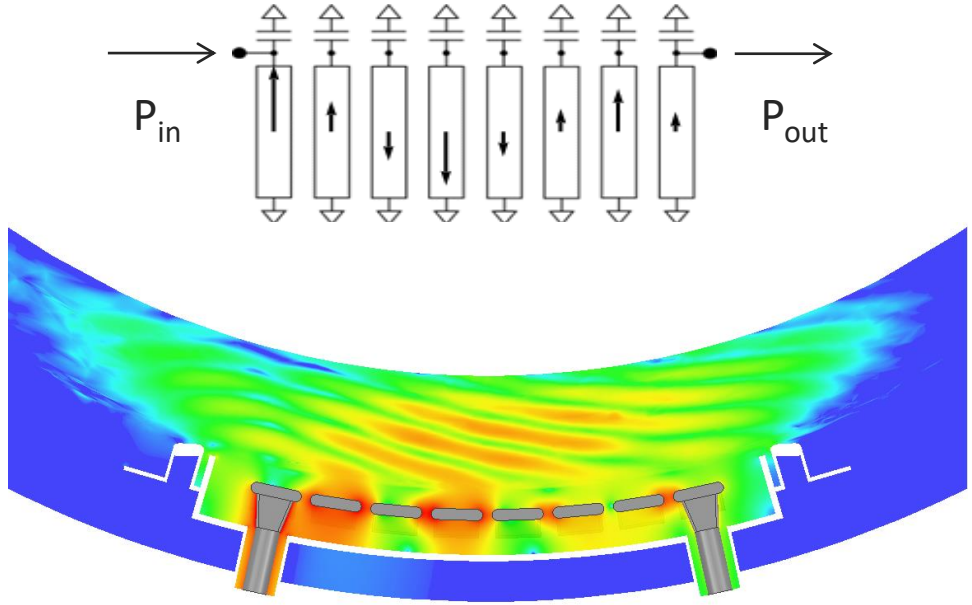
Current ICRF Antennas suffer from drawbacks making them incompatible with fusion plants

- Low coupling conditions (Large antenna to fast-wave cut-off distance)
- Undesirable Large Voltages and Currents inside the antennas (Arcs)
- Metallic Impurity production (RF Sheaths)
- Low Reliability, Availability, Maintainability and Inspectability (RAMI)
- Large antenna volume and weight (Tritium breeding requirements)

Traveling Wave Array (TWA) Antennas for ICRF

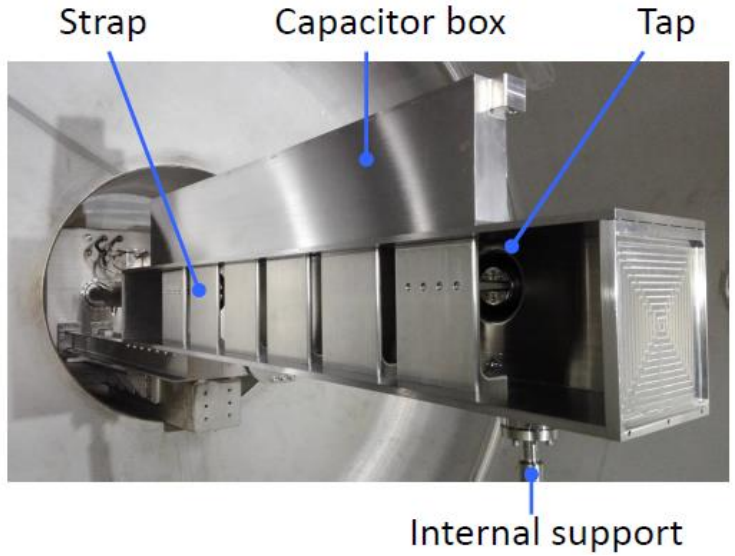
An innovative antenna concept for the ICRF

- Array of tuned straps
- RF Current is induced by mutual coupling between elements
- No direct feeding of each element
- "*Slow-wave*" RF structure (exciting plasma fast-wave)
- Power *leaks* to the plasma



High-power mockup successfully tested in 2021 in Vacuum

- 2 MW / 3 s (limited by RF generator only) and 1.75MW/5s
- 500 kW / 60 s
- No pressure increase during long pulses
- Thermal & Electrical responses as expected by modelling



[Chiu 1984 Nucl. Fus. 24]
[Moeller 1994 AIP Conf. Proc 289]
[Ragona 2016 Nucl. Fus. 56]

[Ragona 2022 *Nucl. Fus* 62]

Motivations: Demonstration of ICRF TWA antenna in WEST

Advantages of operating a TWA antenna in a W-environment

- Provides mechanical simplicity (no tuning elements in vacuum)
- Increased RF coupling ($k_{//}$ spectrum narrower and of lower value)
- Fusion power plant compatibility:

  → Materials, reliability, efficiency
- Lower Electric Field

  → Reduced risk of Arcs and Impurity Production during long pulse operation
- Enhanced directivity

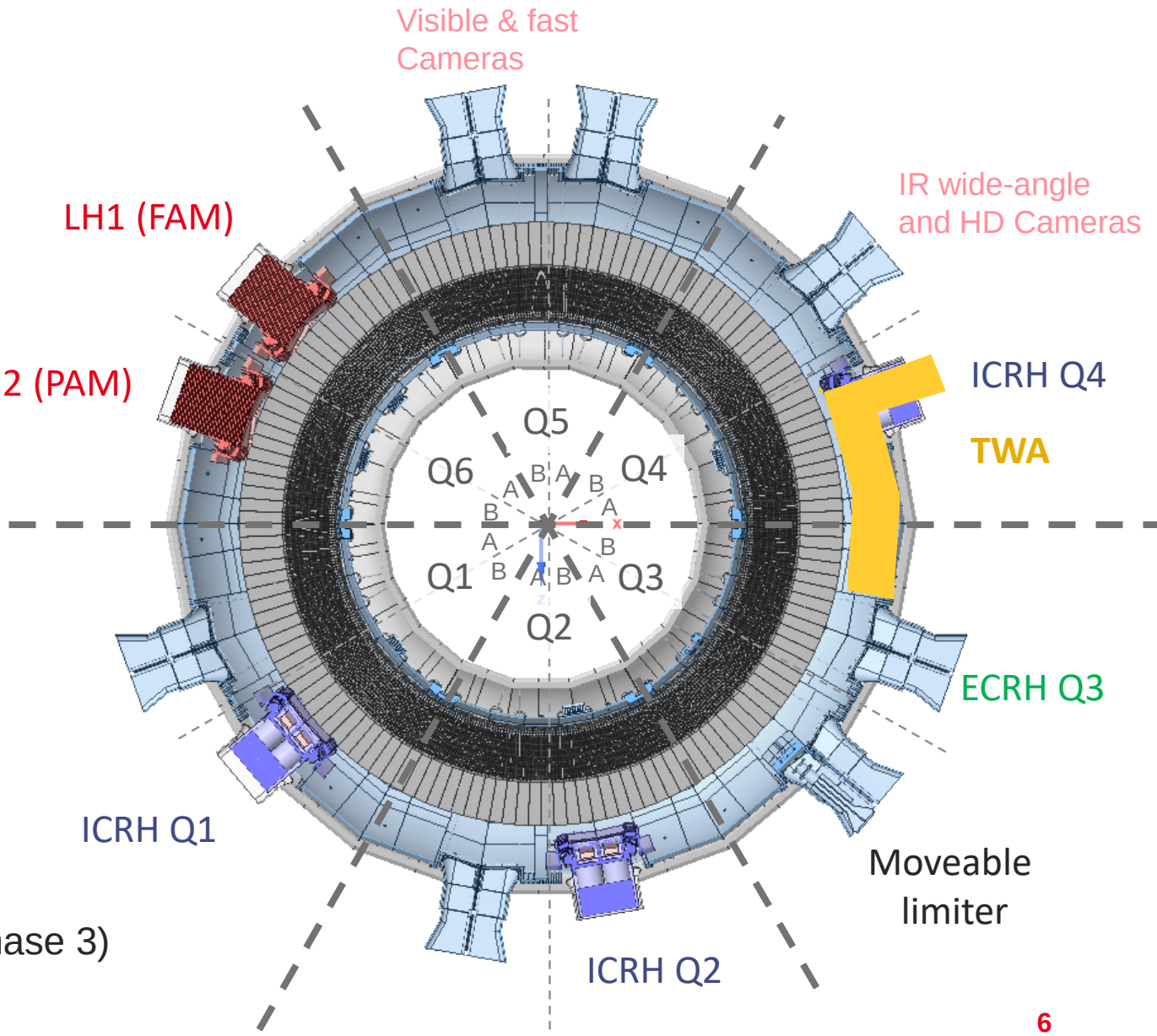
  → Reduced Parasitic Coaxial Mode Excitation (reduced impurity)
- If possible: assess the requirements of a Faraday Screen

  → Comparing one TWA with and one without Faraday Screen
- Large bandwidth: allows to change the RF frequency (power deposition) in real-time

  → New operational scenarios!

Objectives of the TWA Antennas Project

- Two poloidal rows
  - Current preferred implantation in port Q4A
  - Replacing Q4 antenna
- CW Antenna
- Same plasma scenarios than currently
- RF power scenarios goals (2 rows):
  - Limits on max power & durations takes into account plant/lines/feedthroughs
  - 4 MW peak coupled power (duration *tbd)*
  - 3 MW coupled power 30 s
  - 1 MW coupled power/1000 s
  - ICWC to be investigated
- Material: bare Stainless-Steel
  - No coating (fusion plant relevance)
- Faraday Screen
  - One antenna without
  - One antenna with if possible
- Eventually integrated inside the wall/blanket (WEST Phase 3)

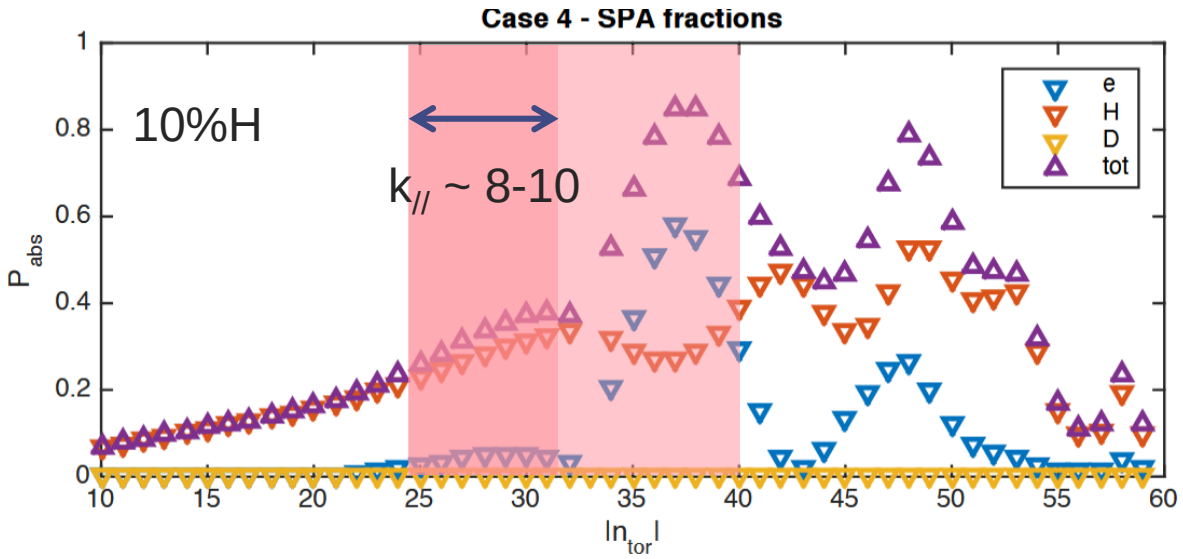


ENR Activities

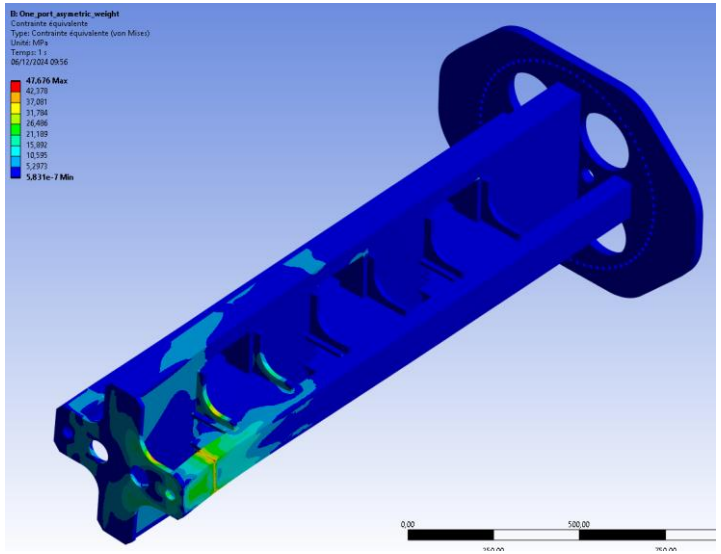
ENR-TEC.02.CEA 2024 Activities

- **Project Started: May 2024**

- **Scenario Development**
  - EVE and TOMCAT ICRH scenarios
    - 57 +/- 5 MHz bandwidth
    - Parallel wavenumber between 8 and 10 rad/m
      - (Avoid damping too much on electrons)



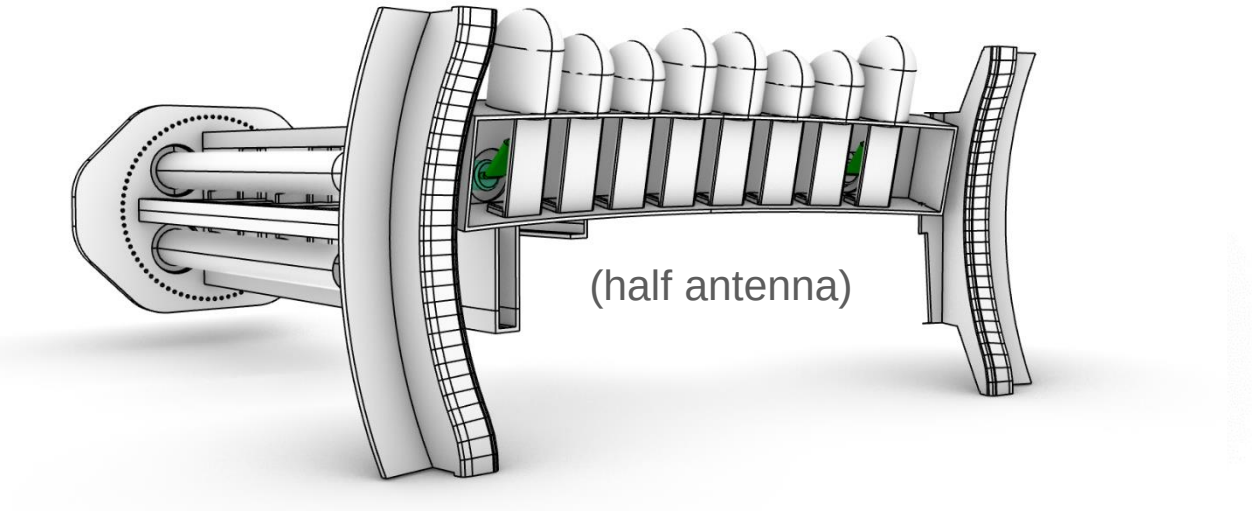
- **WEST ICRH TWA system System Specifications**
  - Actively cooled launchers
  - 3 MW/30s and 1 MW/1000s (2 rows)
  - From one equatorial port of WEST
- RF Design mostly achieved
- Load Specifications
  - Plasma and RF thermal fluxes
  - Structural and electromechanical loads
- Mechanical design started

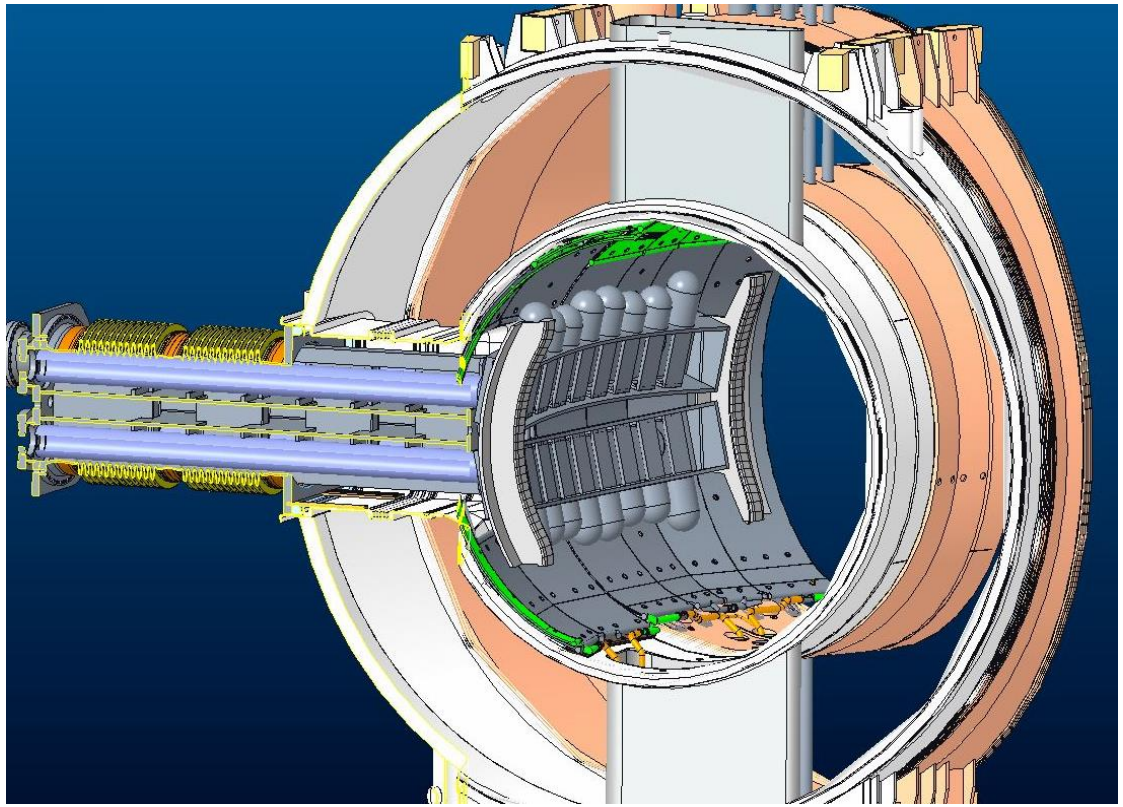


WEST Travelling Wave Array system Conceptual Design Review Passed

11th & 12th of December 2024

- Review of the current design of the WEST TWA by an international panel
- Main points (“Chits”) to address for the future Preliminary Design Review (PDR) mid-2025:
  - Faraday Screen feasibility
  - Assess launchers radial position
  - Finalize the antenna boxes and inner connections
  - Consolidate the in-vessel assembly sequence

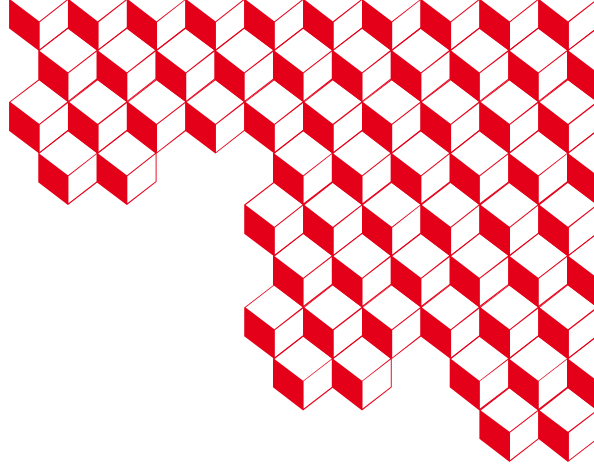




Project Current Status (2025-01)

- Antenna RF design mostly completed (ERM + DTU)
- Mechanical design on-going (IRFM/GCIF)
  - Conceptual mechanical modelling (structural, EM, thermal) done or on-going

- CDR 11&12/12/2024 Passed
  - No showstoppers have been identified by the CDR review panel.
- The work will continue towards a Preliminary Design Review by the middle of 2025
- No modifications to the project for 2025 for the moment



Questions?

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