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The WEST project: turning Tore Supra into a facility dedicated to ITER tungsten divertor studies

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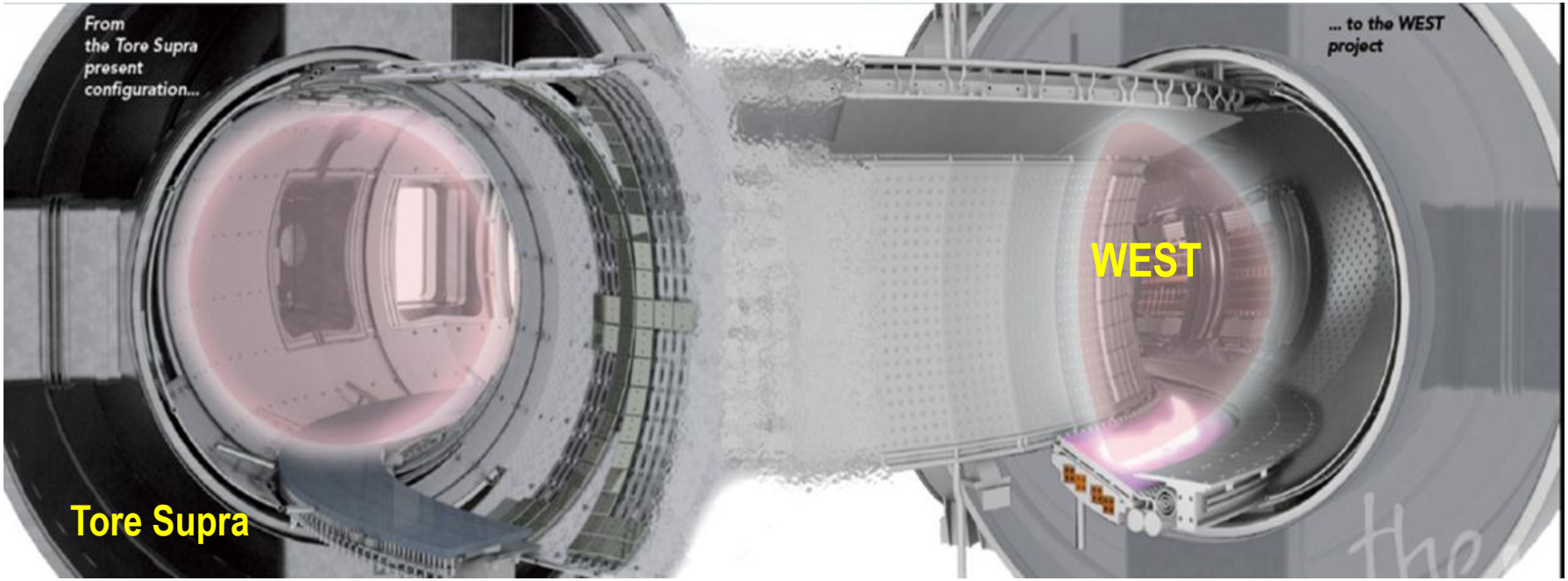
and the WEST PROJECT Team

IFA & CEA JOINT SYMPOSIUM ,

17 & 18 Octobre 2012

The WEST project



WEST Project: operate a full actively cooled tungsten to minimise the technological risk and to prepare the operation of ITER

Getting ready for ITER :

The WEST Project

- ITER W divertor risk analysis
- WEST Implementation
- WEST Plasma Facing Components and Operation Window
- WEST as a multi plat-form device

Getting ready for ITER :

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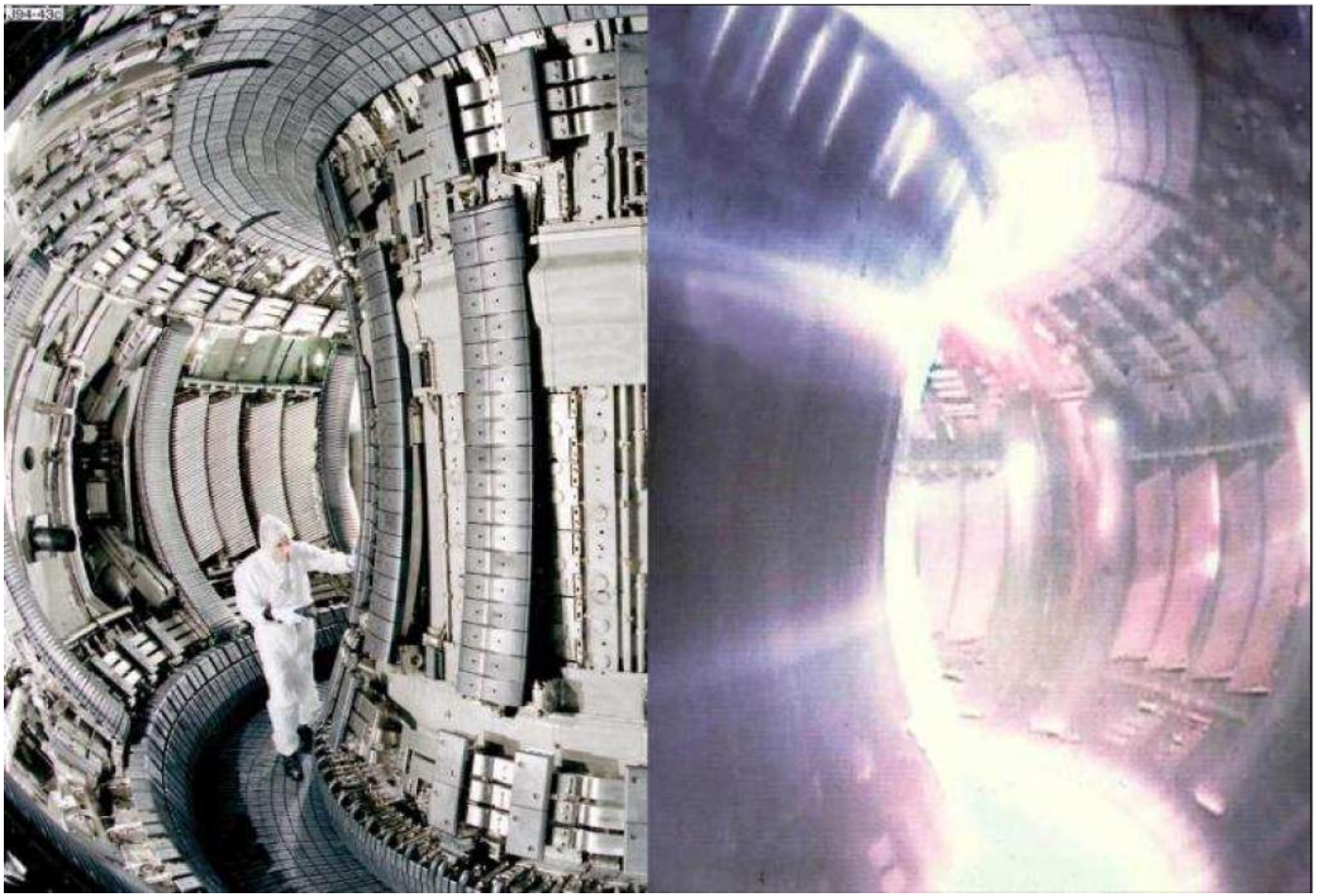
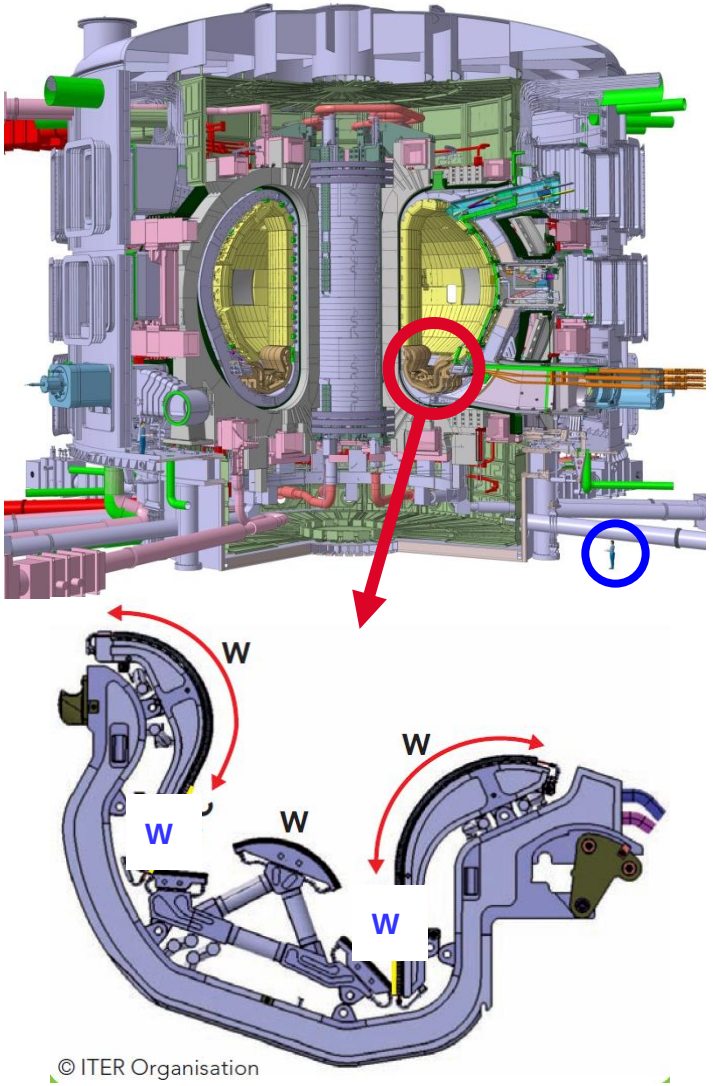
the JET example



A non actively cooled W divertor machine

The WEST Project: in support of the ITER divertor strategy

- The divertor : a key component in fusion devices for power extraction.
- Initial design : carbon on the targets for very high heat fluxes, tungsten elsewhere
- 2007-8 Project Review: full tungsten divertor for the ITER nuclear phase (in order to avoid the trapping of tritium by carbon)
- Current proposal by IO: **starting with a full tungsten divertor from day 1 in conformance with ITER's cost control policy**
- Brings new **scientific, technological and operational challenges**



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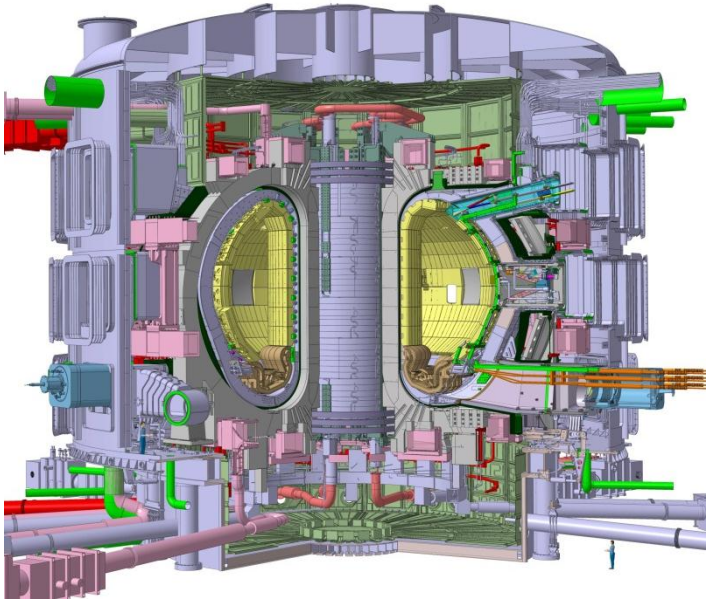


ITER divertor :

- Cost > 100 M€
- Manufacturing: ~6 to 8 years
- Installation and commissioning in nuclear environment: ~1 year

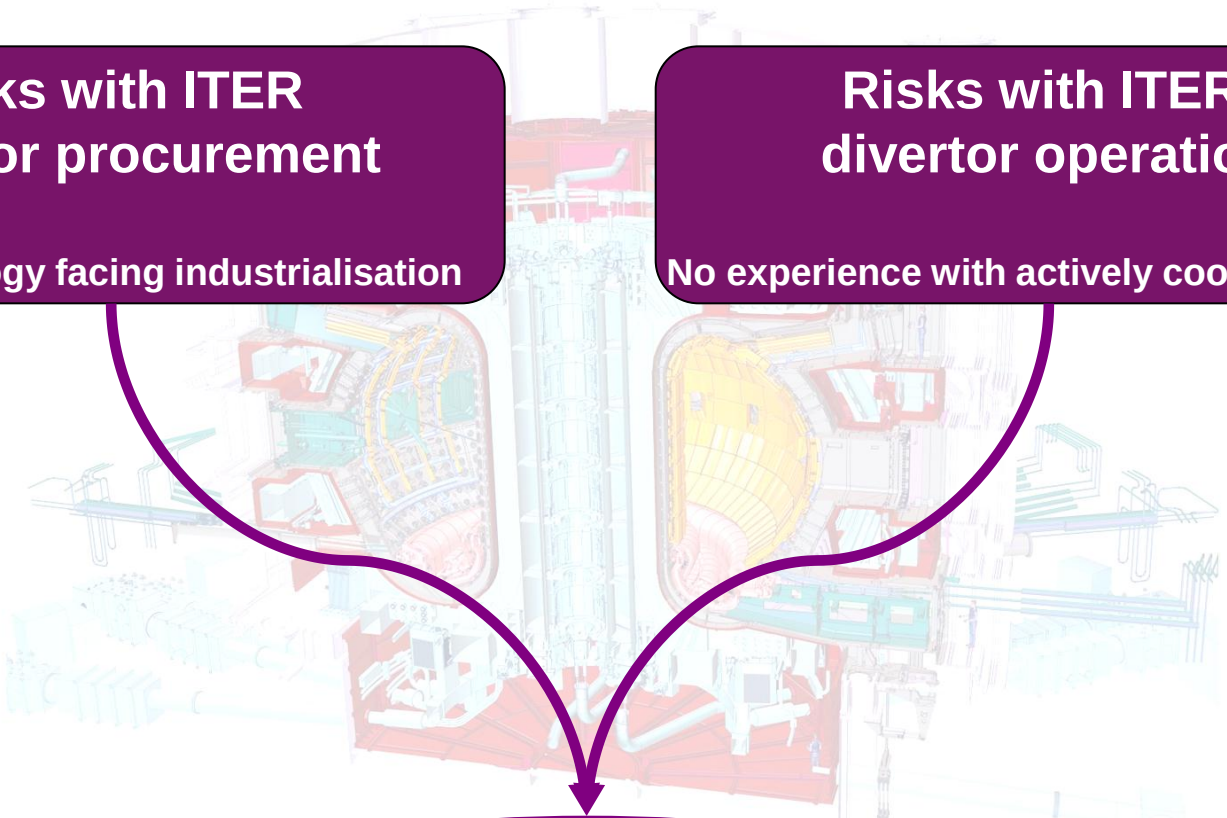
2 risks types for the ITER divertor

Risks with ITER divertor procurement

New technology facing industrialisation

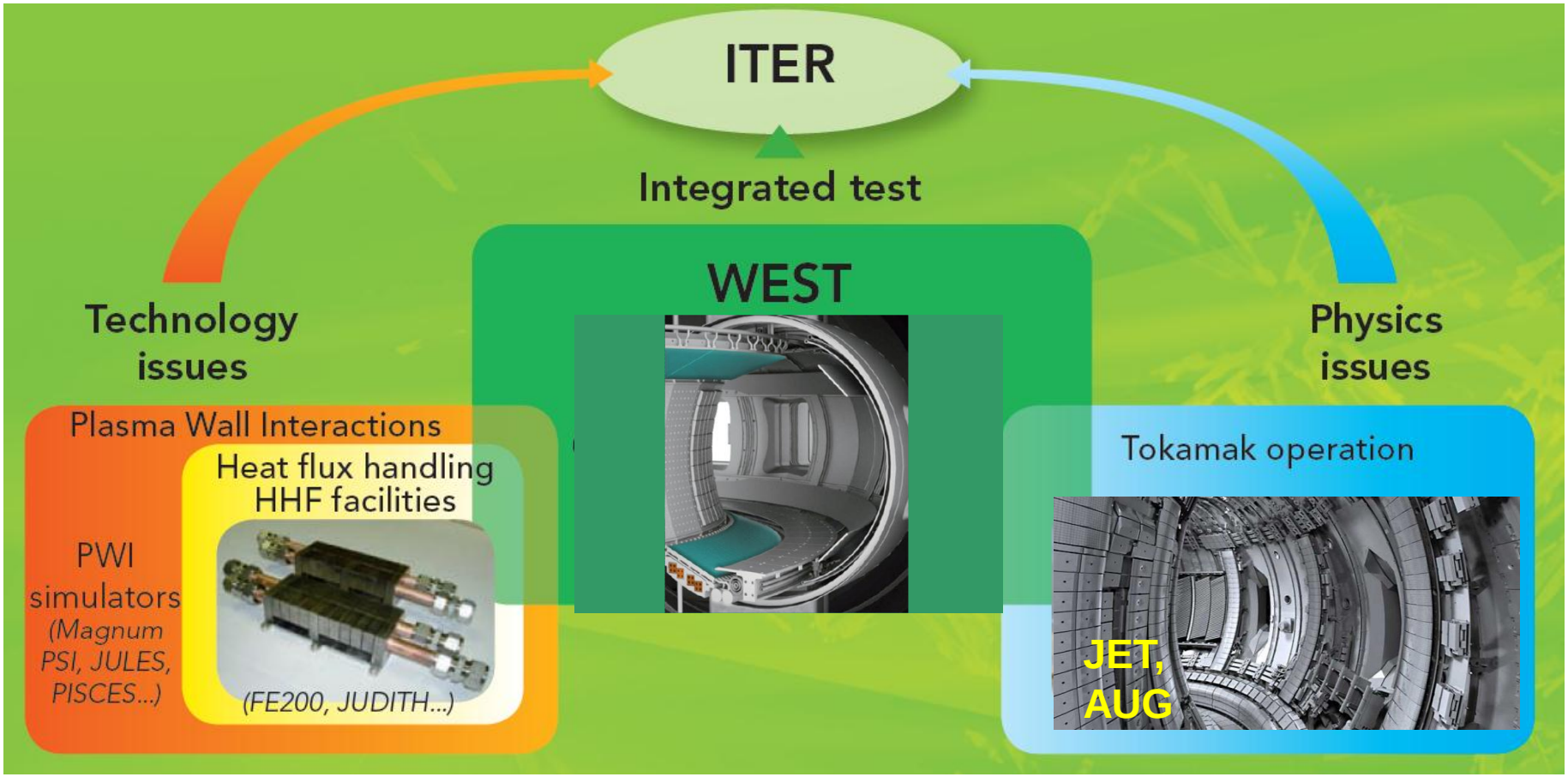
Risks with ITER divertor operation

No experience with actively cooled divertor



WEST

WEST : the “missing link”



First integral test:
Component technology at high flux + tokamak environnement

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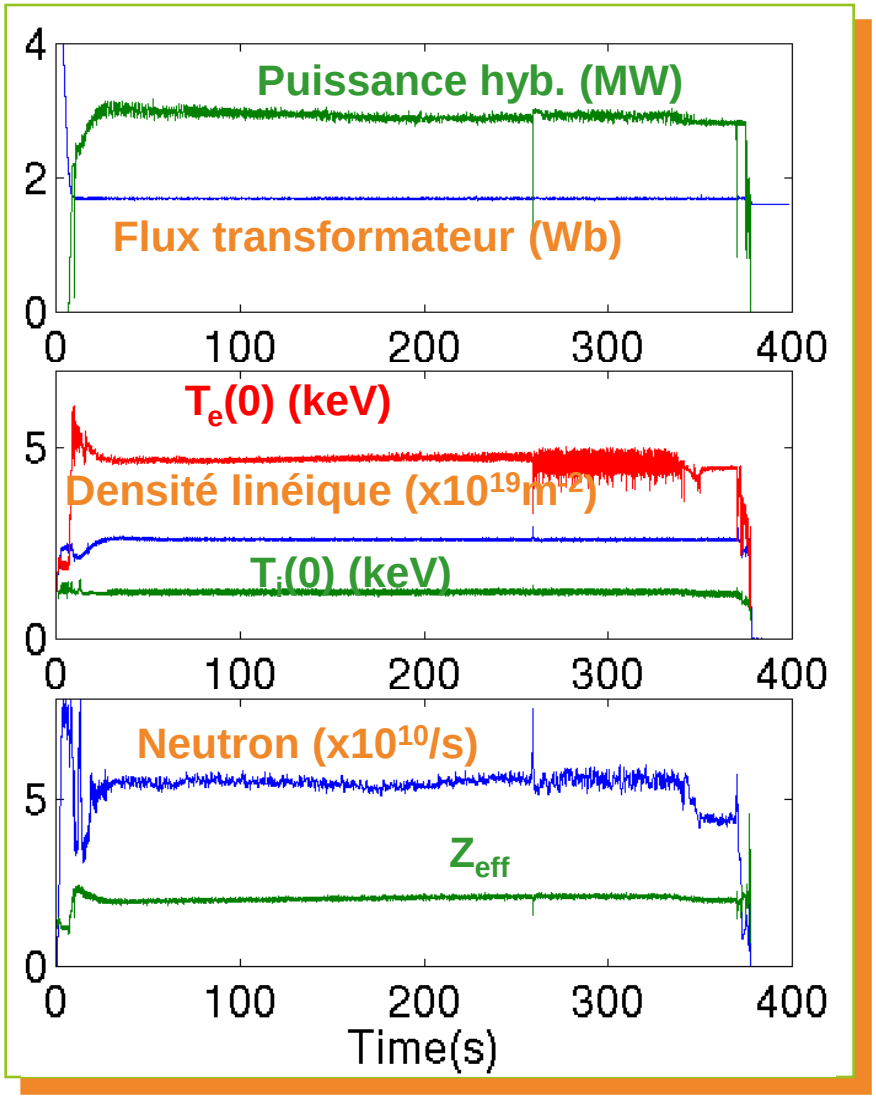
Tore Supra assets : designed for actively cooled PFCs

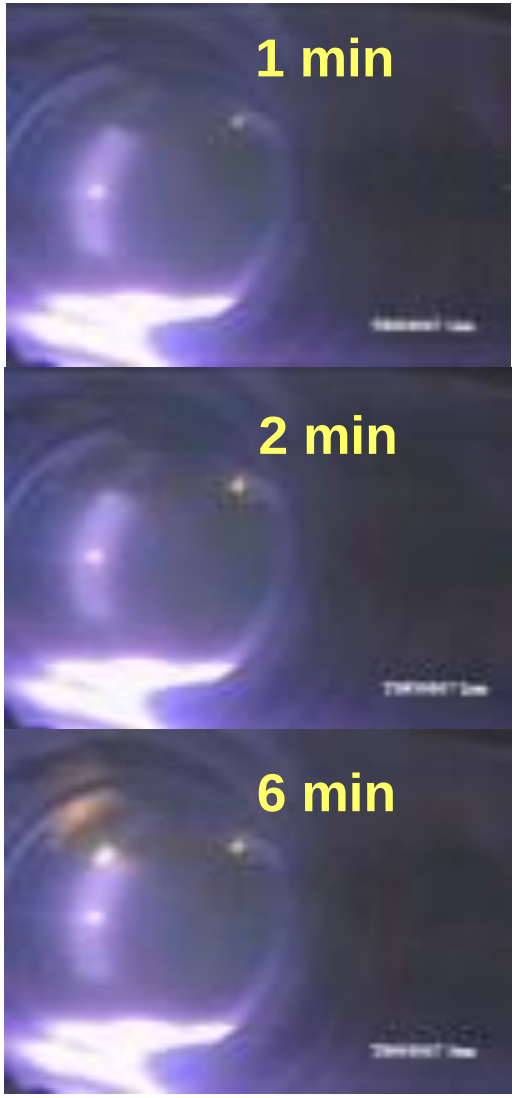
- **Long pulse operations pioneered at the IRFM for more than 20 years**
- **Fully equipped for long pulse operation**
  - Superconducting toroidal coils and cryogenic plant
  - Pressurized water loops
  - 15 MW of RF heating
  - A unique capacity for non-inductive generation of plasma current (LHCD: 7 MW, 1000 s)
  - Fueling systems designed for long pulse
  - Continuous data acquisition system
  - Specific control diagnostics (IR …)


Tore Supra Tokamak

- **Several generations of carbon PFCs designed, manufactured and operated**
- **World record of injected/extracted energy in a tokamak (1GJ)**

1 GJ Injected/Extracted on Tora Supra (>6 min pulses)





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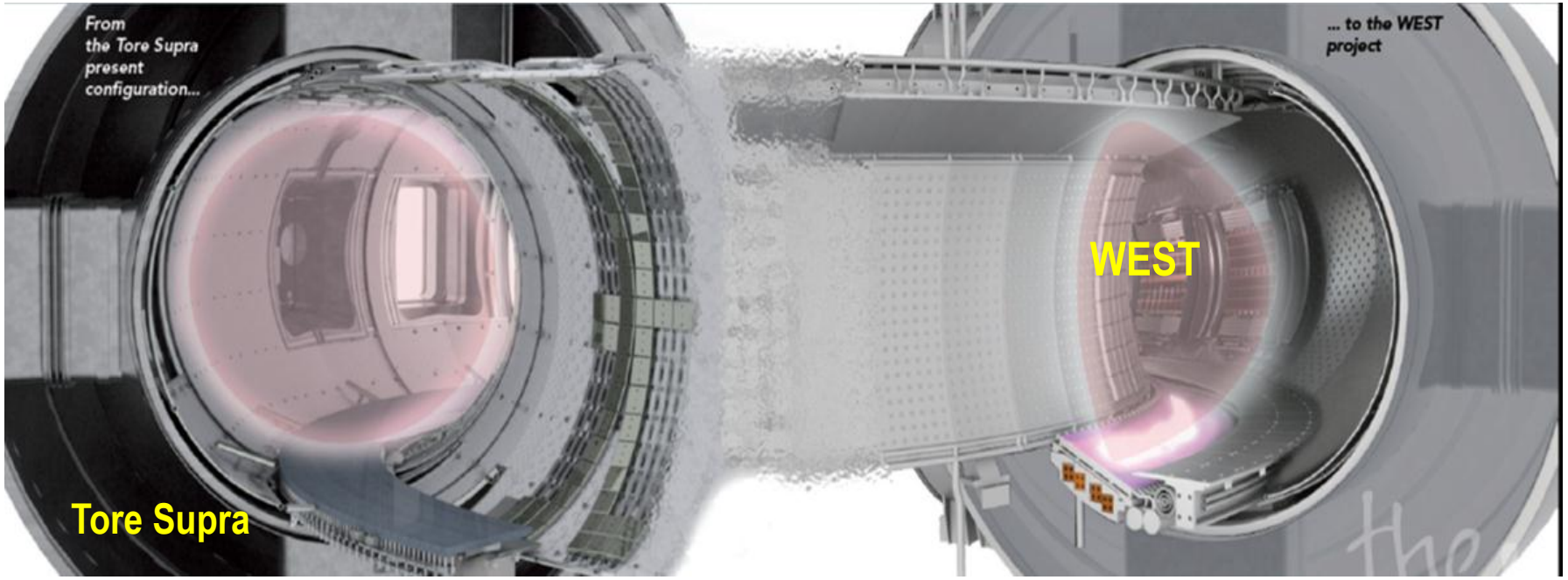
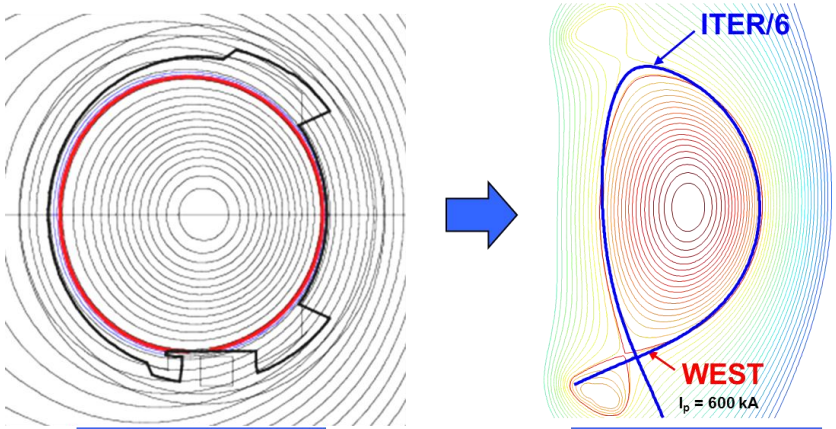
Tore Supra Tokamak

- **Several generations of carbon PFCs designed, manufactured and operated**
- **World record of injected/extracted energy in a tokamak (1GJ)**

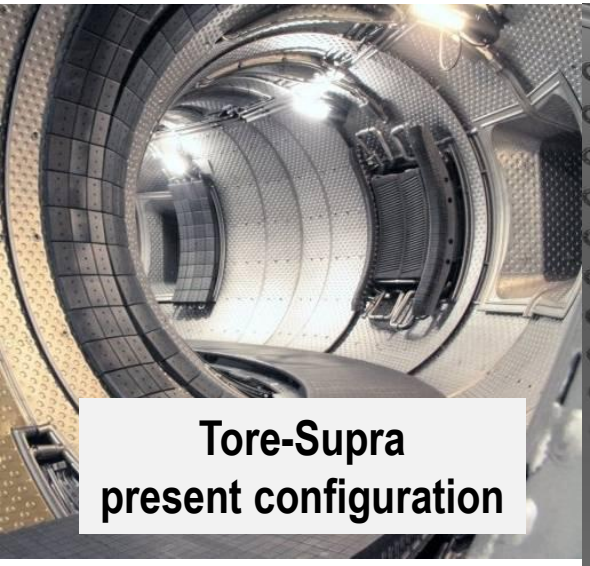
Tore Supra is the most cost effective facility to address high heat flux / long pulse PFC issues

Turning Tore Supra into a facility dedicated to ITER tungsten divertor





FROM TS *(LIMITER)* CONFIGURATION TO THE WEST *(W DIVERTOR)* PROJECT



Tore-Supra
present configuration

Upper target
W-coating

Ripple / VDE
W-coating

~ 1 MW/m² *(steady-state / single null)*
up to 5 MW/m² *(steady-state / double null)*

Bumper
W-coating

Water cooled
stainless steel
panel

Water cooled
stainless steel
panel

Baffle W-coating
up to 3 MW/m2
steady-state

Lower target
« ITER Technologies »

ITER requirement* *(and beyond)*

* 10 MW/m² in steady state
20 MW/m² in slow transient (< 10s)

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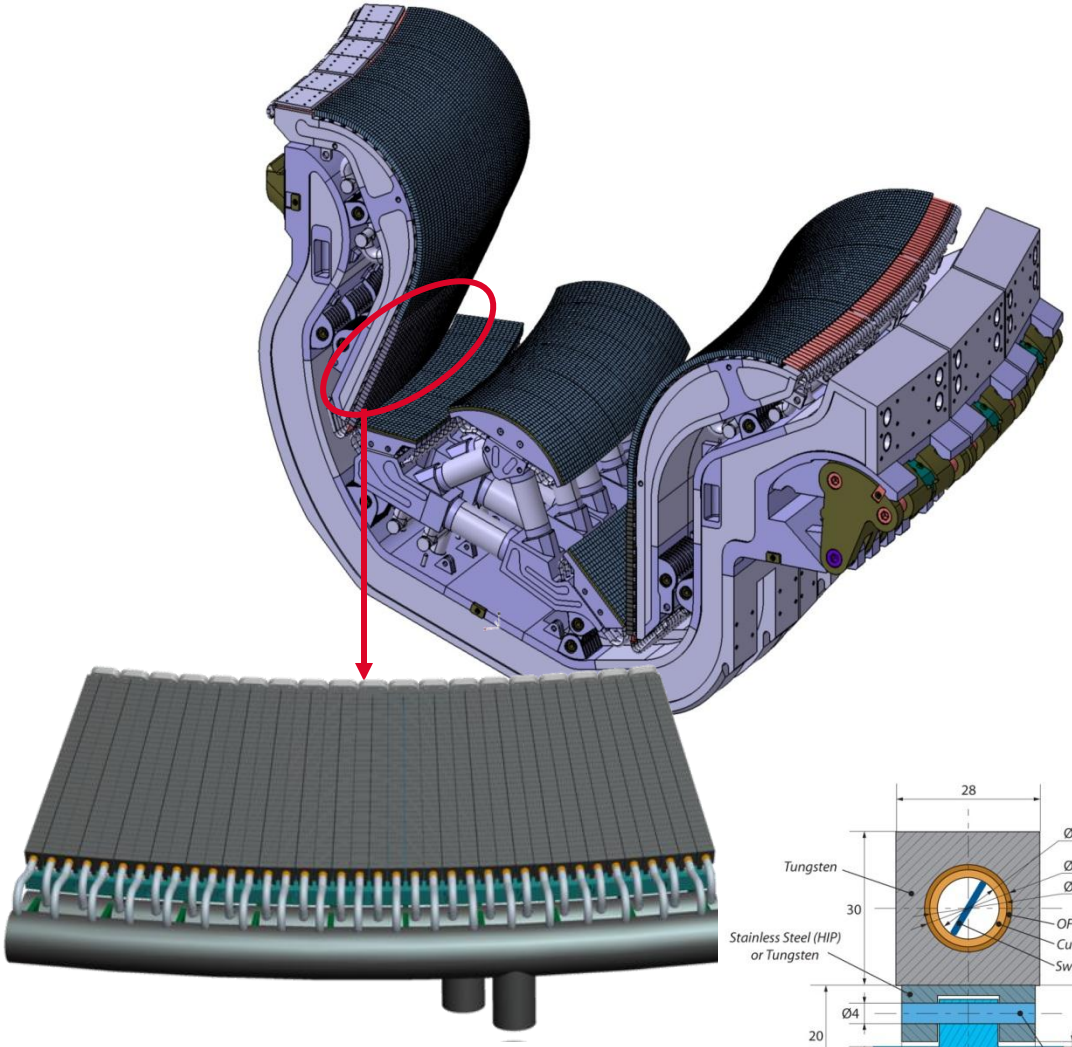
WEST representative of ITER PFCs

	WEST vs ITER
Plasma facing Unit	Identical for high flux flat part
Assembling technology	Identical
Area	~14 % ITER
Length of PFU	Scale 1/3
Number of PFU units	~ 1/2 ITER
Total number of tiles	~14 % ITER
Tile geometry and shape	Identical Trapezoidal
Thermal hydraulic conditions	Identical



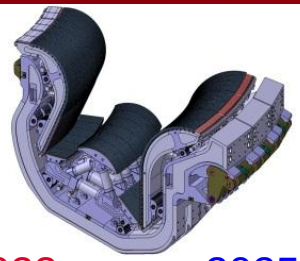
WEST OPERATIONAL DOMAIN : FROM HIGH HEAT FLUXES TO LARGE PARTICLE FLUENCE

SCENARIO	HIGH POWER	STANDARD	HIGH FLUENCE
Plasma current	**0.8 MA**	**0.6 MA**	**0.5 MA**
Toroidal magnetic field	3.7 T	3.7 T	3.7 T
Plasma density	9 $10^{19}m^{-3}$	6 $10^{19}m^{-3}$	4 $10^{19}m^{-3}$
Total radiofrequency heating power	**15 MW**	**12 MW**	**10 MW**
Lower Hybrid Current Drive	6 MW	6 MW	7 MW
Ion Cyclotron Resonance Heating	9 MW	6 MW	3 MW
Plasma current flat-top duration	**30 s**	**60 s**	**1000 s**
Expected heat load*	**6 MW/m²**	**11 MW/m²**	**15 MW/m²**
Expected ELM energy	51 kJ	32 kJ	26 kJ
Expected ELM frequency	59 Hz	76 Hz	77 Hz
Expected ELM load	40 kJ/m²	52 kJ/m²	74 kJ/m²
Expected operation time to reach one ITER pulse particle fluence	**~6 months**	**~2 months**	**~few days**

- **Standard:** long pulse 10 MW/m²
- **High power:** high performance shorter pulse
- **High fluence:** ITER fluence within a few days (6 months of JET!)

WEST in time for ITER

ITER Divertor Installation



2012 2015 2016 2018 2022 2023 2025

ITER

Preparation phase | Production phase | Operation phase

WEST

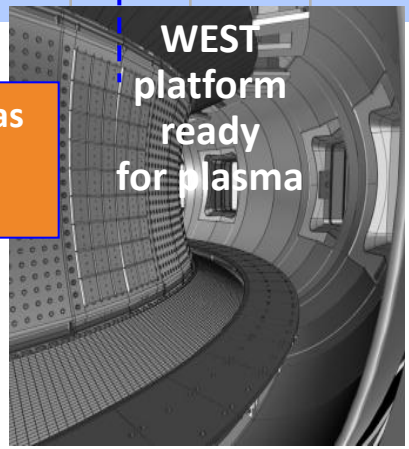
Prep. phase

Production phase

Operation phase I

Operation phase II

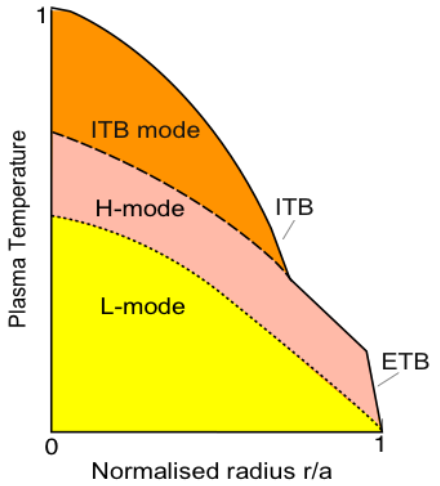
WEST PFC manufacturing as early industrial prequalification

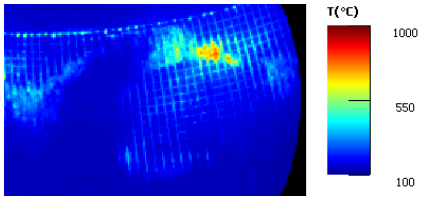


First Outcome from manufacturing 2015
Outcome High Heat Flux 2016
Outcome Long Pulse 2017-2018

Preparing for the physics and operation of ITER

- Possibility of maintaining plasmas over long time periods in the ITER magnetic configuration (divertor) and to study improved confinement modes « H-mode » with tungsten wall (pollution of the plasma)
- Tungsten behaviour study under high flux of the particles in a tokamak environment (intense magnetic field, very high energy particles)
- Development of tools monitoring the surface temperatures of components in a metallic environment.
- Development of tools compatible with the protection of the internal components and that will monitor the performances of the plasma in real time





WEST: a robust and renowned project & a key element in risk mitigation for ITER

- **A project evaluated positively by a panel of international experts**

(IO, F4E, EU, China, US)

- Feasibility study (2010)
- Conceptual design phase (2011)

"The CEA/IRFM team plays an exceptional role for ITER, moving even closer to ITER objectives with the WEST project, contributing to steady state physics and technology."
Professor F. Wagner, IPP Greifswald; Germany.

« WEST would undoubtedly offer ITER **substantial benefit in terms of risk mitigation** concerning the divertor material and operational strategy, provided the platform can be implemented in the proposed timescale. » Pr Motojima, Head of IO

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WEST: a multi-purpose platform

A structuring tool

- Brings the **scientific community** together around a **relevant instrument**

➔ Prepares for the operation of ITER in fields of unique competence in Europe (cooled W components, long pulses, superconductivity) « ITER Generation »

Industrial qualification

- A platform designed for the **validation of industrial components** destined for ITER and other projects (mirrors, diagnostics, heating systems…)

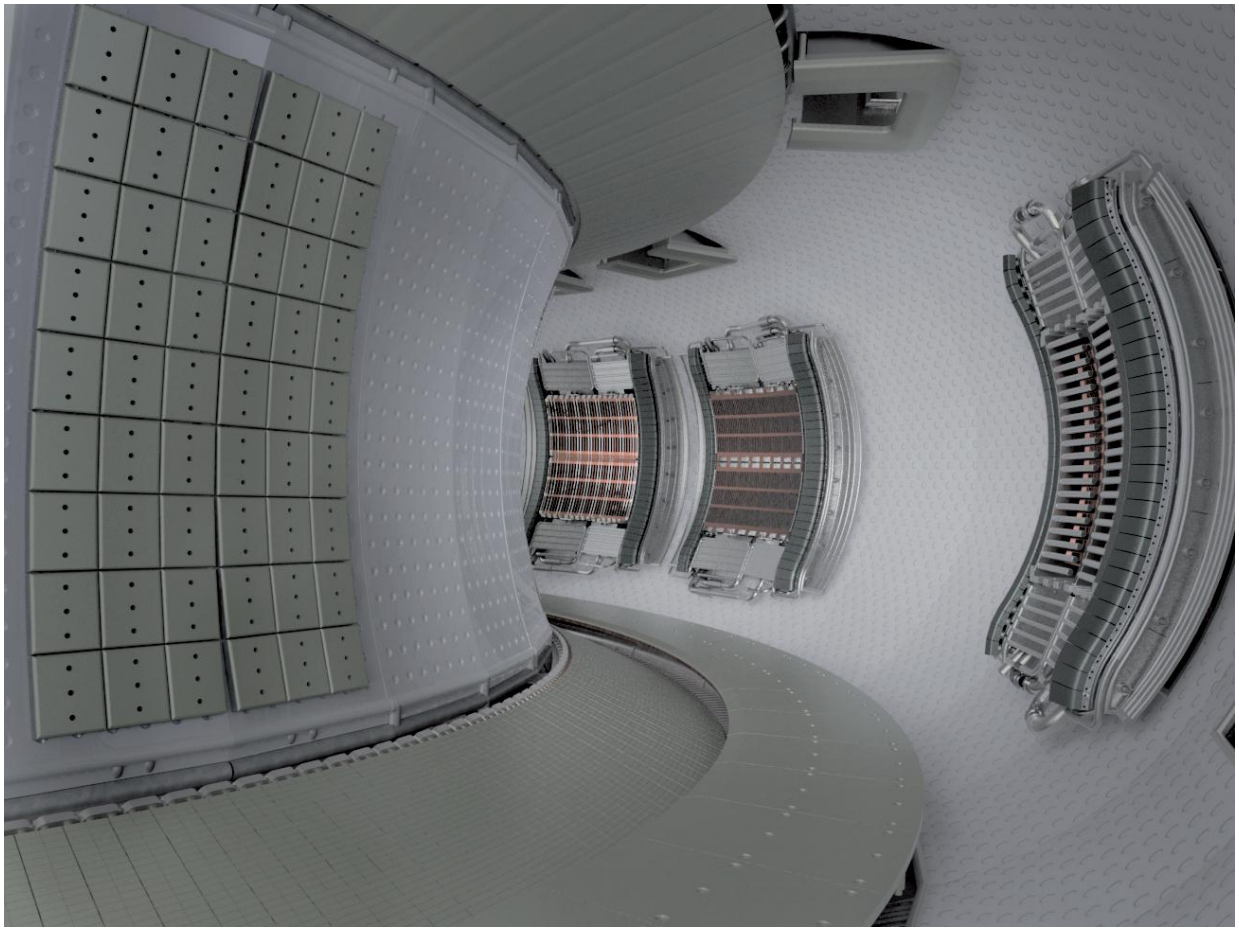
A collaboration open to the international community

- Laboratories of the FR-FCM
- European collaborators
- ITER partners (JA, CN, US …)

WEST and the fusion community

- PFC coating
- Diagnostic for program achievements
- Safety issues:
  - Fuel trapping and control
  - Dust open issues (collection, analysis)

Conclusions



Minimize risks of ITER divertor procurement and operation

Transform Tore Supra into WEST platform offered for collaboration to the ITER partners

(Domestic Agencies, Industry, Fusion Community)