INVESTIGATION OF PLASMA WALL INTERACTIONS BETWEEN TUNGSTEN PLASMA FACING COMPONENTS AND HELIUM PLASMAS IN THE WEST TOKAMAK

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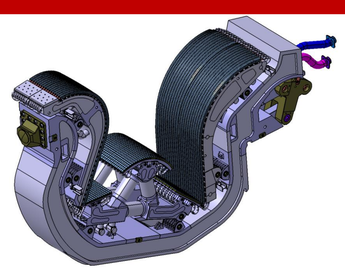
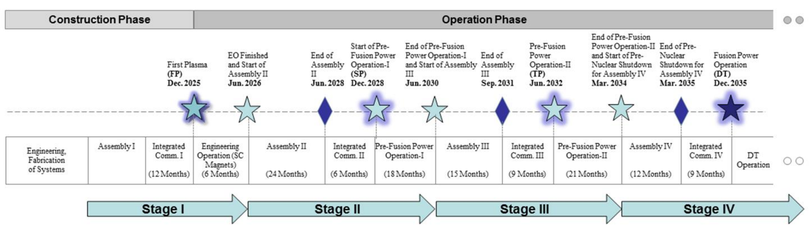
MOTIVATION





► **ITER actively cooled tungsten divertor scheduled for ~10 years/more than 2000 hours of operation from PFPO1 up to FPO**

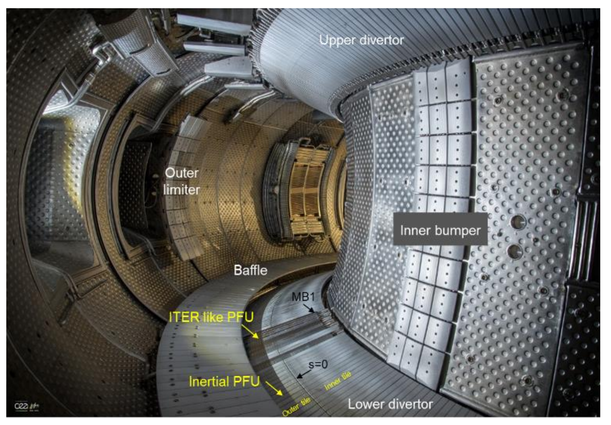
► **Helium operation planned in ITER : He plasmas in PFPO1 for access to H mode w/o activating the vessel + He in FPO as ash from D-T reaction**

► **Tungsten is known to exhibit surface morphology changes under Helium exposure, which can affect its thermal/mechanical properties**

► **Investigating interactions between tungsten plasma facing components and helium plasmas in a tokamak environment is therefore a key point to consolidate predictions for the ITER divertor performance and lifetime**

➔ **A dedicated helium campaign was performed in the full tungsten WEST tokamak**

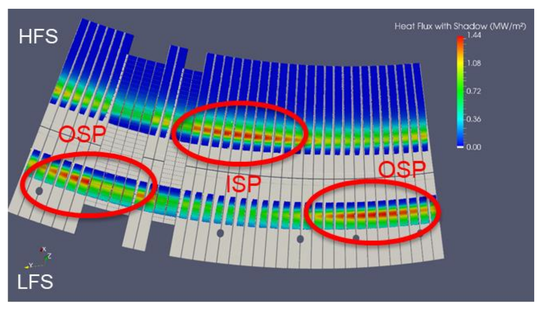
WEST : A FULL TUNGSTEN TOKAMAK

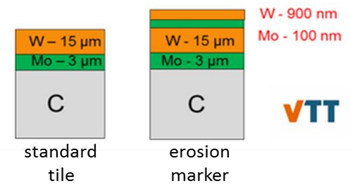


► **WEST : a MA class superconducting device targeted at testing ITER tungsten divertor in a tokamak environment**

► **WEST phase 1 : lower divertor equipped with a mix of ITER like Plasma Facing Units and inertially cooled W coated Plasma Facing Units (including erosion markers)**

► **Divertor heat load modulated by ripple**



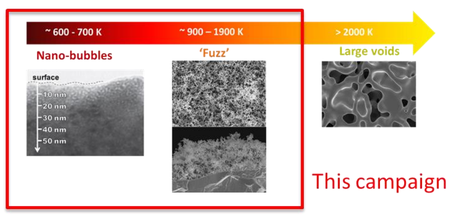


► **Large set of plasma edge and divertor diagnostics available : Langmuir probes (LP), infrared (IR) thermography, thermocouples (TC), Fiber Bragg Grating (FBG)**

THE HELIUM CAMPAIGN IN WEST

Main objective :

► **investigate W surface morphology changes under He plasma exposure in medium to high surface temperature range**



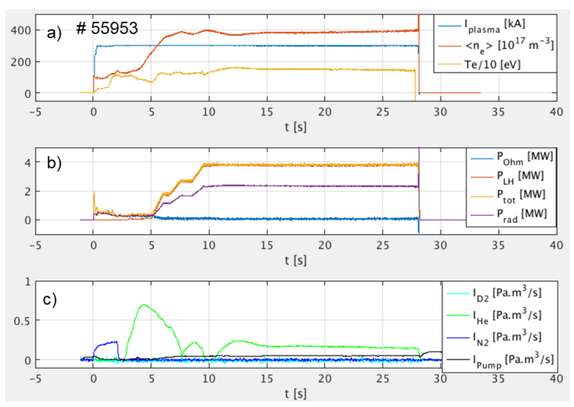
► **He campaign targeted to reach parameters allowing for W fuzz formation in the max OSP area :**

- incident He energy above 20 eV (but lower than ~350 eV to avoid competition with erosion)
- PFU surface temperature above 900 K (and below 1900 K)
- He fluence above the seed fluence required for W fuzz formation (> 10^{24} He/m^2)

[G. De Temmerman et al., PPCF2018]

► **~ 1 week of He operation at the end of the C4 campaign (2019) to allow for PFC post mortem analysis**

Robust L mode scenario developped

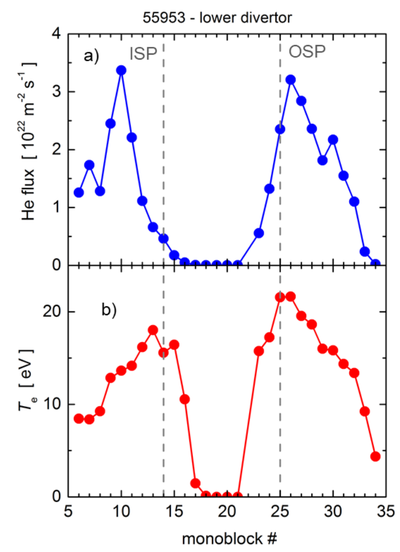


► Repetitive pulses : I_p=300 kA, nl~4, P_{LH}~4 MW, 20-30 s

► D prefill, N injection in stratup phase (MHD control), no boronisation during the week

► ~140 shots, ~2000 s of plasma, 4.4 GJ of energy coupled

Divertor parameters



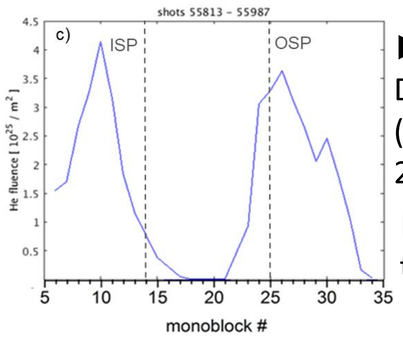
► Te ~20 eV / particle flux ~3.5 10^{22} He/m^2/s (He^+ assumed) @ max OSP

TUNGSTEN FUZZ FORMATON IN WEST CONDITIONS ?

Target for fuzz formation : E_{inc} > 20 eV, fluence > 10^{24} He/m^2, T_{surf} > 700°C

✓ **He incident energy (2Ti+3ZTe) : 100-200 eV**

✓ **He fluence : 3.5 10^{25} He/m^2 (pure He^+ assumed)**

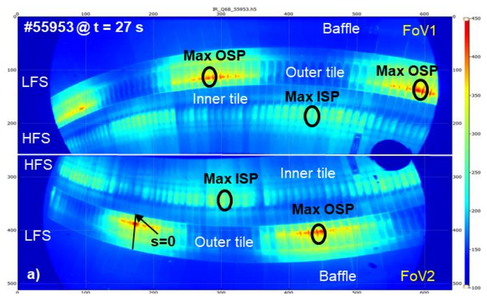


► Taking into account D (~10%) + impurities (few %) ↘ fluence by 20%

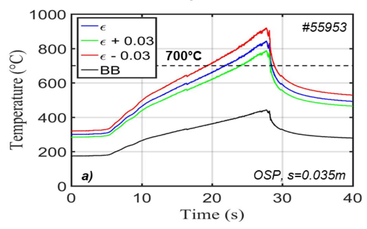
► Impact of % of He^{++} to be worked out

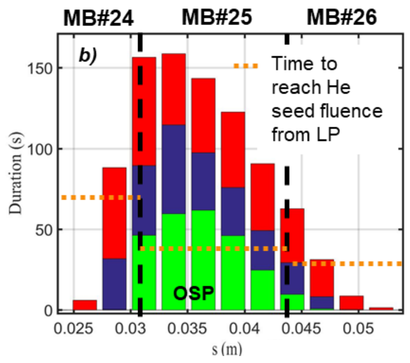
► **Question : which fraction of He fluence impacted divertor at temperature > 700° C ?**

✓ **Tsurf > 700°C after ~20 s**



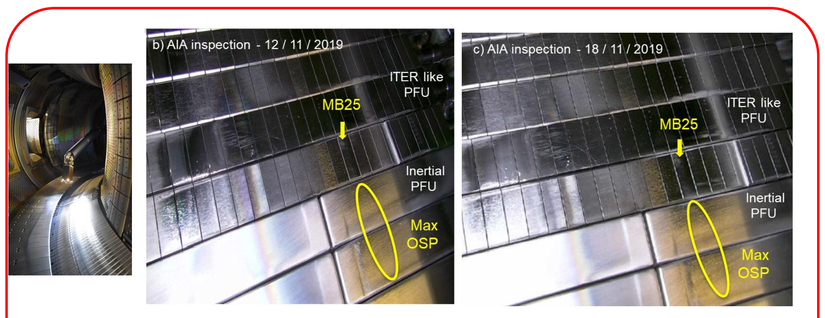
► W emissivity : ε = 0.15 ± 0.03





► Fraction of He fluence impacting max OSP at Tsurf > 700°C only slightly above seed fluence (factor ~2) ➔ limited tungsten fuzz thickness

► **Even under worst case assumption, threshold for W fuzz formation reached in area of ~1 cm around OSP**



► **Articulated Inspection Arm : no macroscopic sign of surface modification**

► **Post mortem analysis ongoing : no indications of W fuzz formation from SEM imaging / FIB cutting at this stage. From RBS and SEM, OSP = net erosion zone**

► **Speculation : in WEST conditions, erosion dominating process over W fuzz formation**

CONCLUSION

- **Dedicated He-W PWI experiment performed in WEST, with 2000s of repetitive pulses / fluence up to 3.5 10^{25} He/m^2 on the lower divertor.**
- **Conditions for W fuzz formation as derived from linear devices (E_{inc} > 20 eV, fluence > 10^{24} He/m^2, T_{surf} > 700°C) met @ OSP of the inertial PFU. However fraction of He fluence impacting divertor at Tsurf > 700°C only a factor ~2 above seed fluence required for W fuzz formation.**
- **Preliminary inspection of the components after the campaign did not show visible signs of surface modification. Extensive post mortem analysis now ongoing.**

➔ **In tokamak conditions, complex balance between W erosion (in particular from impurities) /redeposition (from W eroded from the main chamber or from prompt redeposition) and W fuzz formation. Data obtained ➔ modelling effort for predicting W fuzz formation and growth in ITER**

WEST phase 2 starting in 2021 : full actively cooled ITER like divertor ➔ further dedicated campaigns at significantly higher fluence in both deuterium and helium plasmas.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.