WP PFC.SP8: *WEST Activities & Plans* *(2020&2021)*

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Outline

- Status of analysis of the 2019 EF experiments
- Next experimental campaign in WEST (C5)
- Future plans (2021)

2020 WEST activities

- WEST operation stopped in November 2019 and will resume in November 2020
- This talk : focus on deeper analysis of 2019 experiments

- SP8.1 / WEST-1: Qualification of PFC diagnostics and λ_q studies
- SP8.2 / WEST-4: High Power test of ITER PFC, including damaged or below specification components
- SP8.3 / WEST-5: Long pulse experiments on W coatings using the actively cooled upper divertor

[D]

- SP8.4 / WEST-6: Changeover from D to He operation
- SP8.5 / WEST-7: SOL width in He plasmas
- SP8.6 / WEST-8: W sources in He plasmas
- SP8.7 / WEST-9: He-W PWI studies

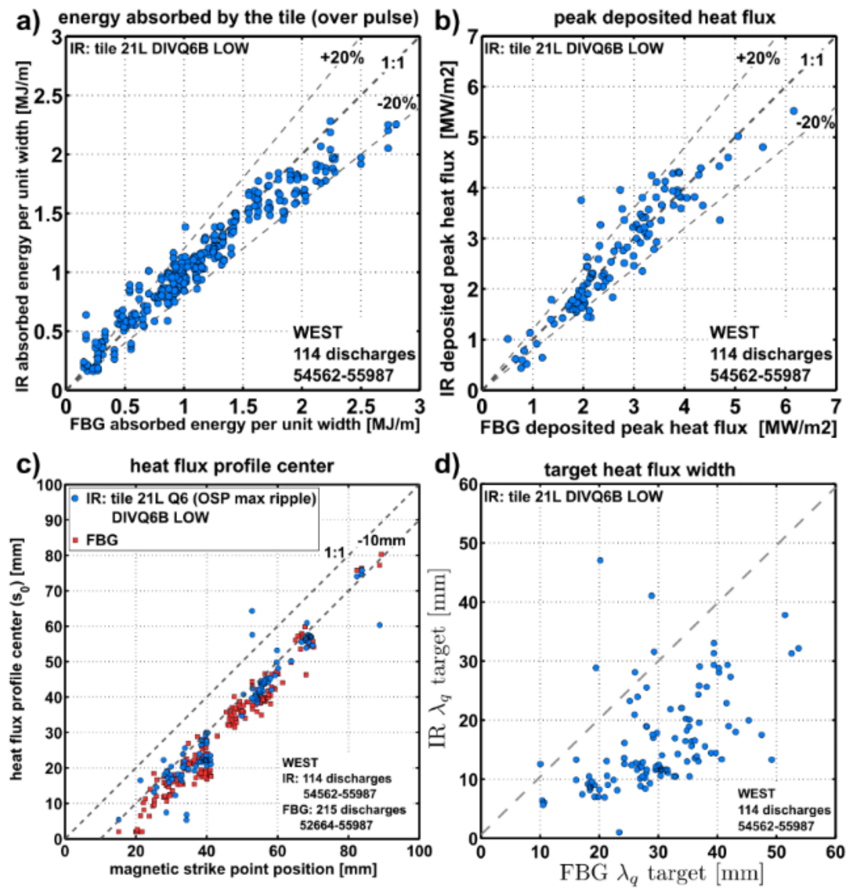
[He]

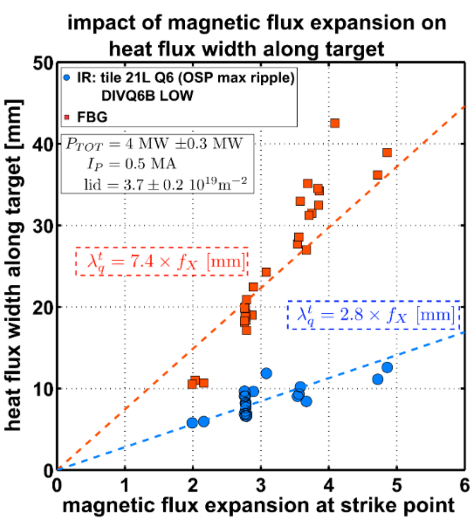
2020 WEST activities

SP8.1 / WEST-1: Qualification of PFC diagnostics and λ_q studies

- Extensive **IR** data analysis + comparison with **FBG**
- Deposited energy and SOL power width measured over a large set of experimental conditions
- Corrections for global reflections and low surface emissivity (W)
- Good agreement between 2 methods for the deposited energy *(over 1 order of magnitude)*, the peak heat flux and SP position.

- Peak heat flux on divertor up to ~6 MW/m^2 w/ P^{add} = 4MW

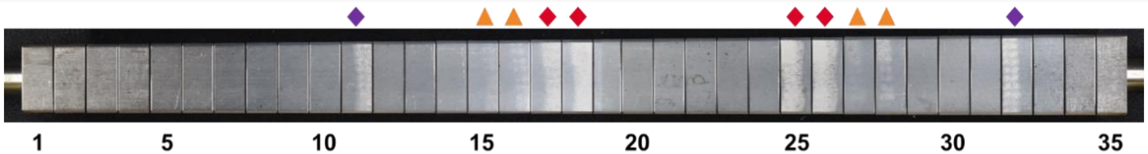


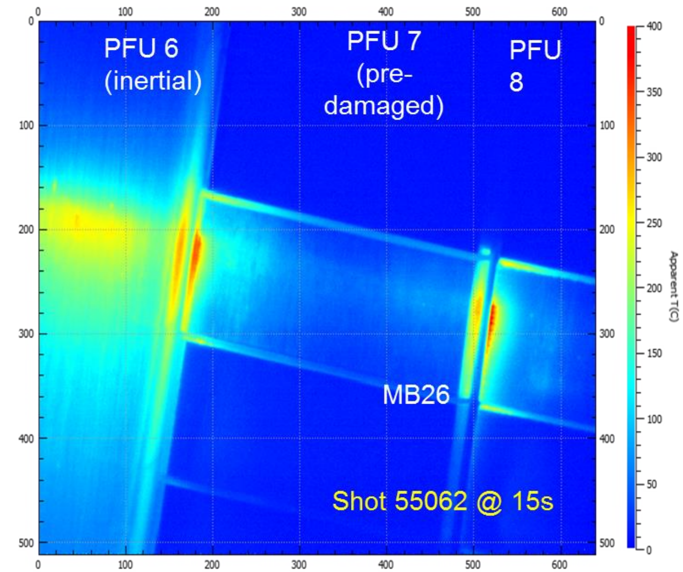


- λ_q^{target} proportional to the magnetic flux expansion
- λ_q^{IR} in good agreement with the L-mode scaling law…
- …but λ_q^{FBG} ~ 3x λ_q^{IR}

2020 WEST activities

SP8.2 / WEST-4: High Power test of ITER PFC, including damaged or below specification components

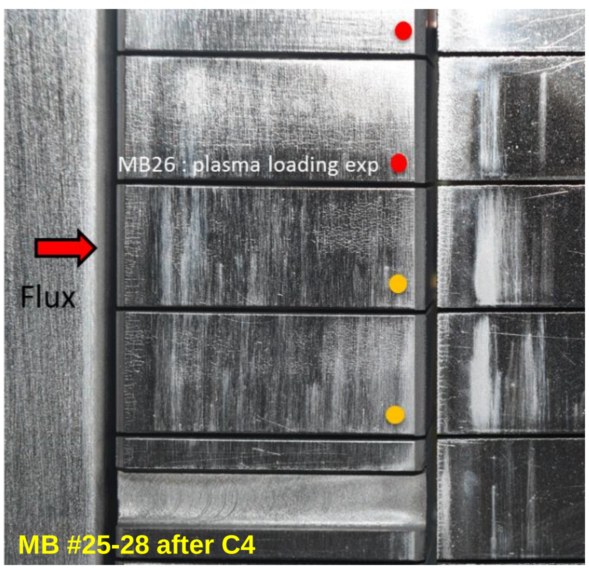


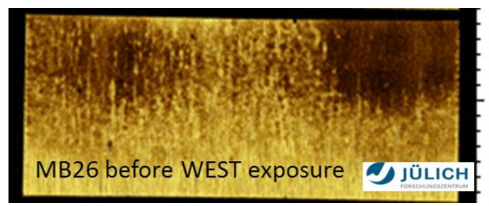


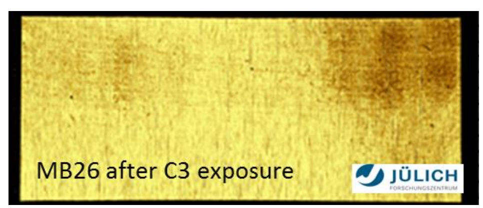
* *3.7 T, 500 kA, P^{LH} = 4.2 MW / 25s*

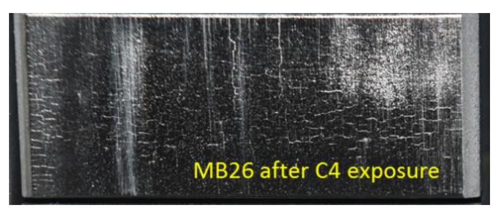
- Pre-damaged PFU in Judith (*small cracks*, *crack network*, *crack network + melting*) exposed to WEST plasmas* (600 s on MB #26) to assess how material damage can form and propagate in ITER divertor.

- MB #26 damage still present : more pronounced crack network ? Further post mortem analysis required before drawing firm conclusions









Other PFU damage observed (not EF):

- Optical Hot Spots confirmed on newly exposed PFU
- Analysis of local cracking/melting on leading edges suggests combination of transients + steady state heat loads is responsible

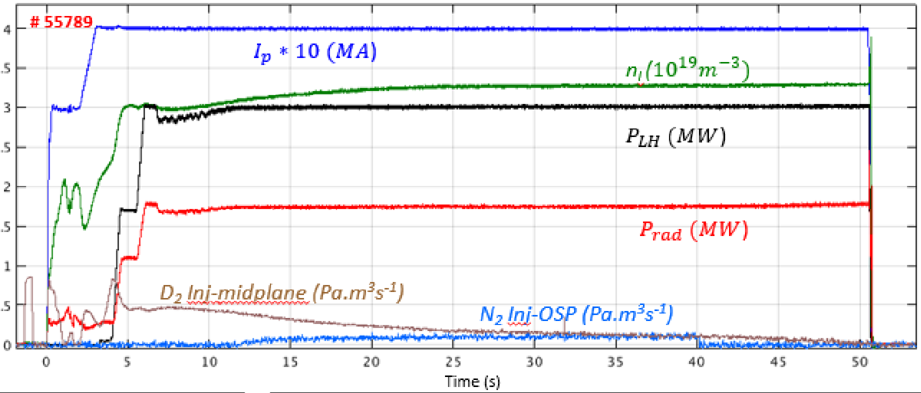
[M. Diez et al., Nuc Fus 2020]
[J. Gunn et al., Nuc Fus 2020]

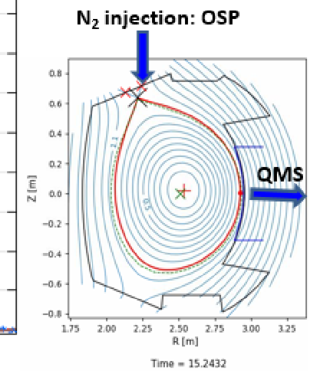
[M. Richou et al., in preparation]

2020 WEST activities

SP8.3 / WEST-5: Long pulse experiments on W coatings using the actively cooled upper divertor

- Robust scenario established for long pulse operation on the actively cooled upper divertor (~50 s discharges) with nitrogen injection.

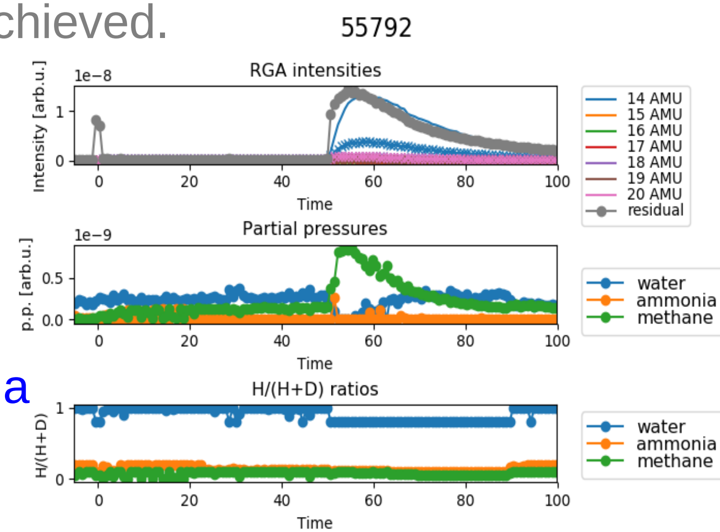




1) to study material migration (W, low and high-Z impurities) in repetitive long pulses

2) to investigate ammonia production with nitrogen seeding

- ~240 s of plasma with ~650 MJ injected has been achieved.
- No N_2 nor W accumulation in the plasma observed *(no active pumping in USN)*
- Weak legacy effect of N_2 injection from shot to shot.
- No ammonia detected by midplane mass spectrometer (QMS) and spectroscopy during plasma operation nor during recovering phase after plasma.

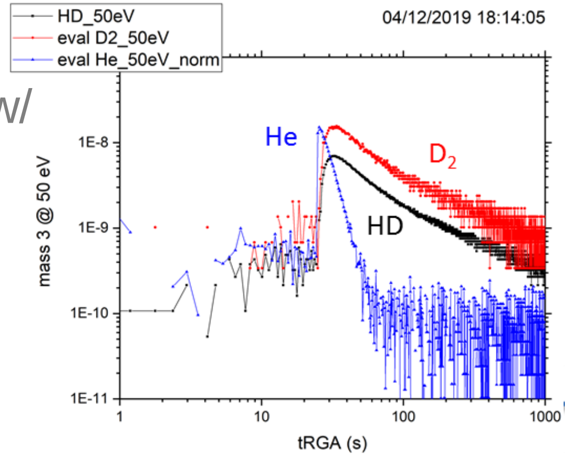


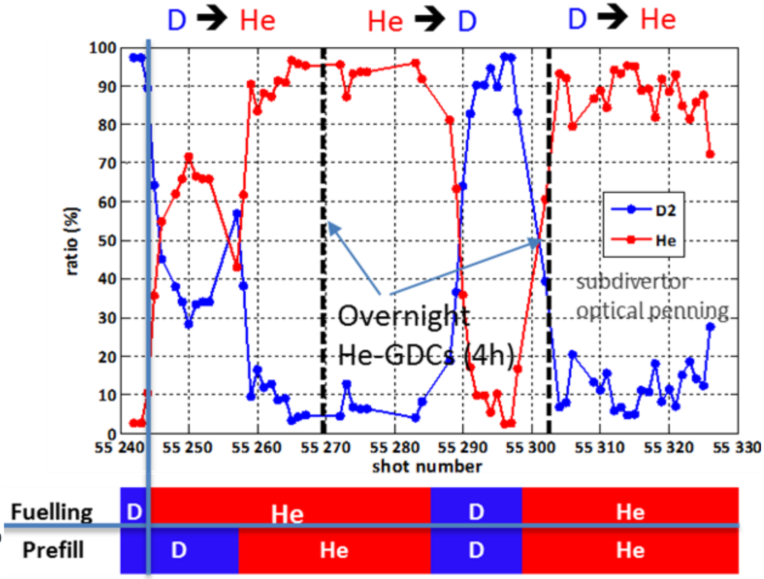
[T. Dittmar et al., Phys. Scr. (2020)]

[T. Loarer et al., Nuc Fus (2020)]

1) **Assess** the **metallic wall response** during **changeover** from D to He operation.
2) **Characterize** He and D **retention in W** by gas balance.

- 3 sessions of [He to D] and [D to He] changeover were performed.
- The remaining D ratio *(respectively He ratio)* measured during discharges quickly falls below 10% during a D to He *(resp. He to D)* changeover.
- **Faster response** observed in **highly plasma loaded areas** compared to remote areas.
- Evidence for **different release mechanisms** w/ a faster release for He.
- 90% of the injected D remains trapped in PFC, compared to 20% for He.





[R. Bisson et al., PSI-24, NME (2020)]

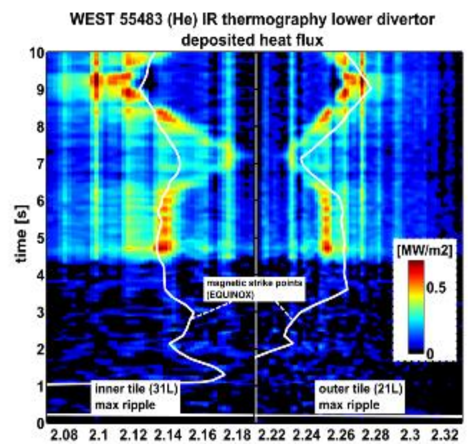
2020 WEST activities

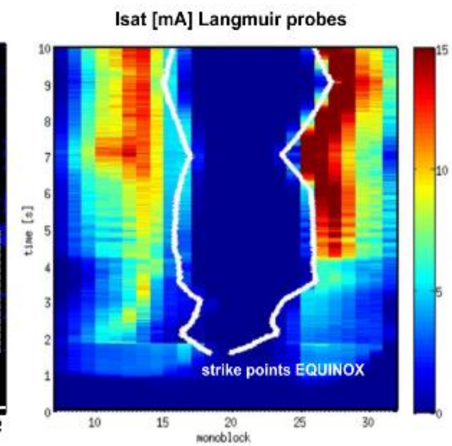
SP8.5 / WEST-7: Qualification of PFC diagnostics and λ_q studies in He

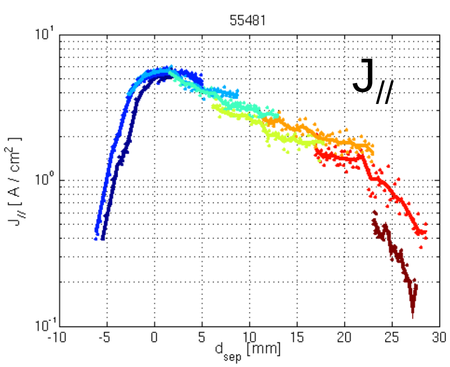
- Ohmic and LHCD heated (3.2 MW) discharges with SP sweeping for better coverage of profiles by flush-mounted LP and with 300 kA < I_P < 700 kA.
- Direct comparison with the D campaign (WEST-1) is complex because of the specific tuning required for He plasmas compared to D operation + change of W emissivity + higher radiated fraction observed for same plasma conditions.
- No large difference in λ_q in He vs D

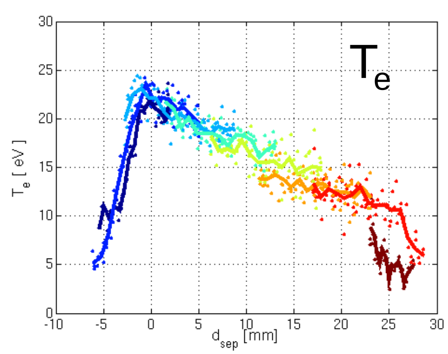
Optimized SP sweeping developed:

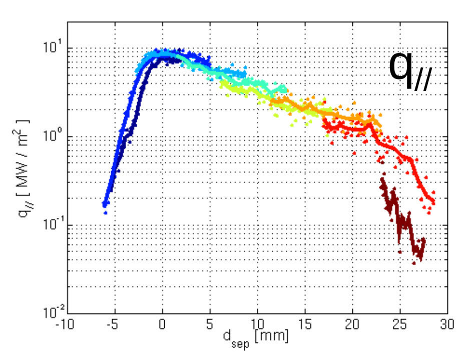
- IR and LP particle/heat flux patterns follow well the magnetic SP position.
- Strong fluctuations in SOL compared to PFR were evidenced from LP data.







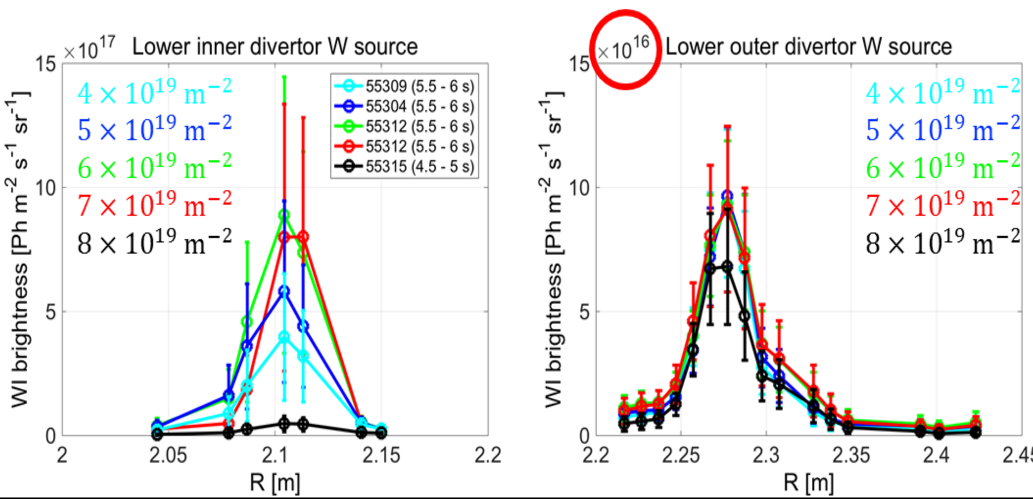




1 color = 1 probe

1) Determine W source as function of plasma temp. and impurity composition.
2) Assessment of the impact of RF heating on W source.
3) Comparison with D discharges.

- Dedicated series of L-mode He discharges with broad parameter space (T_e^{inner} <10eV & T_e^{outer} up to 50 eV) + impurity flux density achieved by upstream plasma fueling and nitrogen seeding.
- Radiated fraction higher in He compared to D
- W sources in He exhibit inner/outer asymmetry in the divertor (as in D plasmas).
- Divertor W sources extinguish at higher density in He compared to D plasmas.



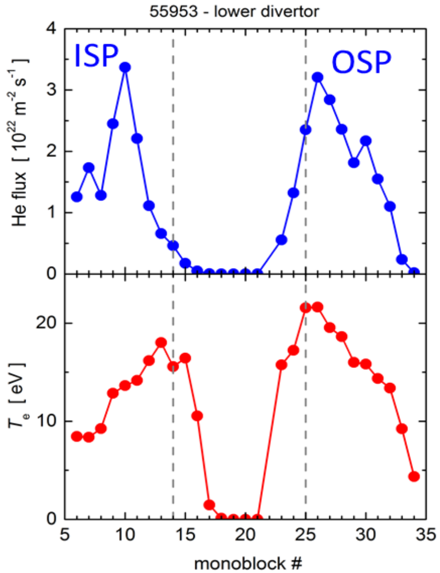
[G. Urbanczyk et al., in preparation]
[A. Gallo et al., NF (2020)]

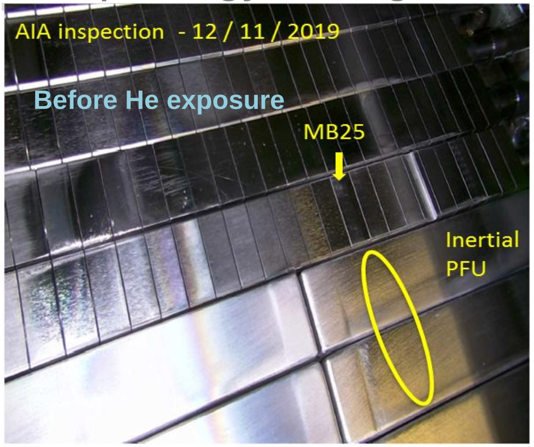
- Assessment of W surface evolution under He fluence as function of PFU surface temperature, plasma conditions, and impurity composition.
- 2000 s of cumulated He plasma discharges *(300 kA, P^{LH} ~4MW, f^{rad}~70%, 20-30 s)* in L-mode was achieved in order to meet the following criteria for W fuzz formation:

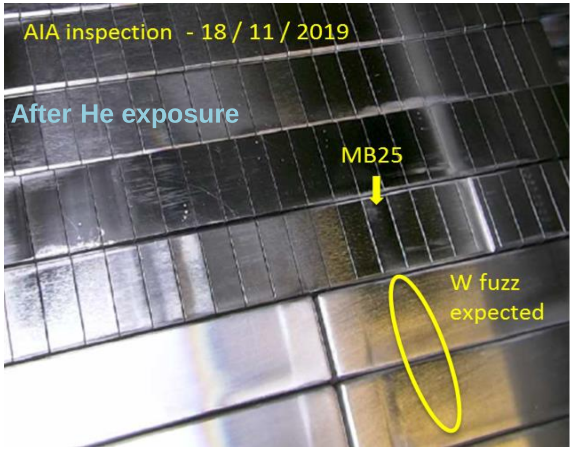
<u>*goal*</u> → E_{inc} > 20 eV, fluence > 10^{24} He.m^{-2}, T_{surf} > 700ºC

<u>*achieved*</u> → E_{inc} ~100 eV, fluence ~4.10^{25} He.m^{-2}, T_{surf} > 700ºC *(over significant amount of time)*

- No macroscopic signs of W fuzz formation
- Post-mortem analysis on-going to assess the W morphology changes.







[M. Diez et al., IAEA-FEC (2020)]
[B. Pegourie et al., IAEA-FEC (2020)]
[E. Tsitrone et al., IAEA-FEC (2020)]
[S. Brezinsek et al., IAEA-FEC (2020)]

The next experimental campaign in WEST (C5)

Timeline

- First plasma expected on November 27th
- C5 = 2 months of experimental campaign (Dec.2020 - Jan.2021)
- EF funded experiments planned in Dec.2020 (weeks #49 & #51)
- Contingency for EF on week #52

2020													2021							
Oct				Nov				Dec					Jan				Feb			
41	42	43	44	45	46	47	48	49	50	51	52	53	1	2	3	4	5	6	7	8
S4 shutdown								C5 campaign									S5 shutdown			

Week #49: commissioning & ohmic EF experiments

Week #50: power ramp up

Week #51: EF experiments with RF heating

Week #52: contingency for EF experiments

Week #1: power ramp up / preparation for H mode

Week #2-#3: H mode

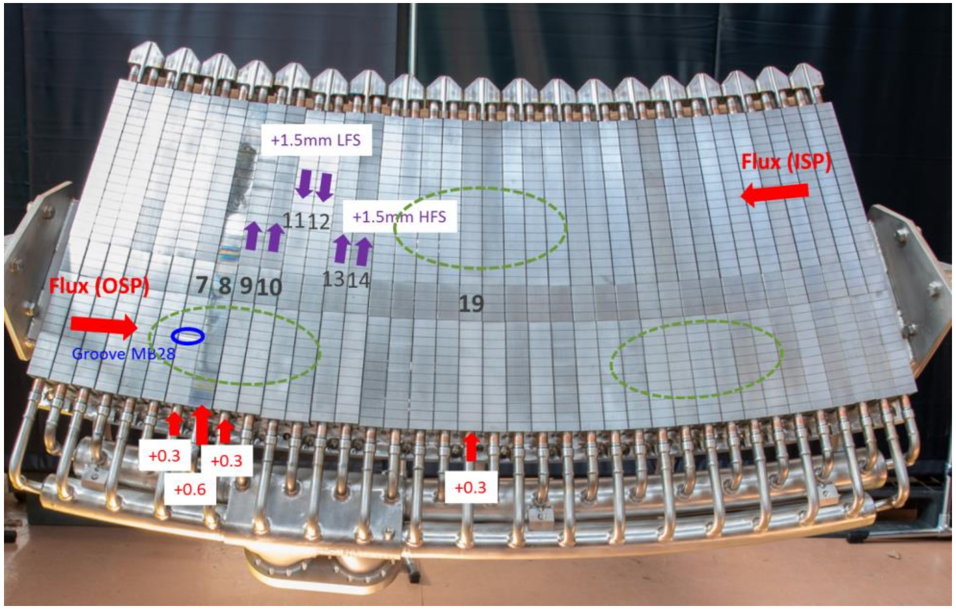
Week #4: contingency

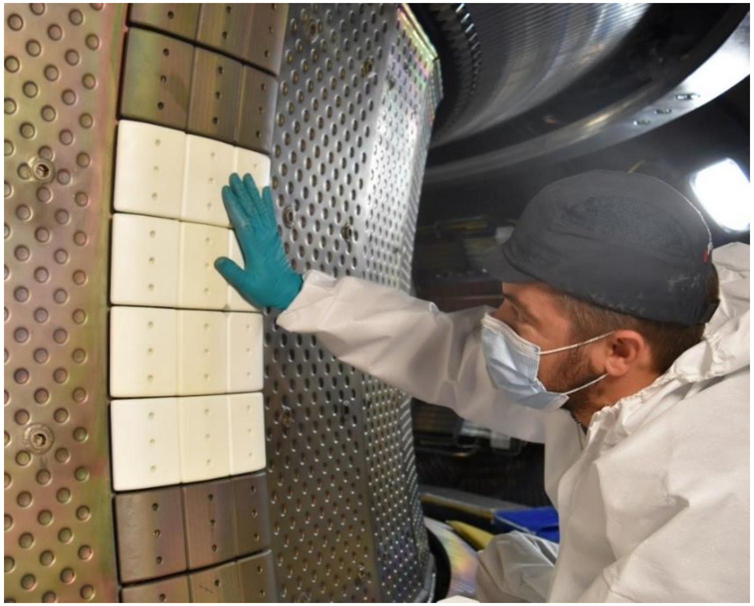
Focus for the C5 campaign

- Investigate the impact of low Z startup limiters on W sources
- H-mode scenario development with full power (10 MW)

Main new features for C5

- two actively cooled ITER-like divertor sectors (MB technology) = 76 ITER-like PFUs *(1 sector for dedicated experiment: PFU melting, poloidal / toroidal gaps misalignment)*
- Central boron nitride tiles for the 6 inner bumpers and the outer limiter





The EF experiments in C5

❑ 6 EUROfusion sessions planned in December 2020

1) W sources with BN limiters (ohmic plasmas) : 2 sessions

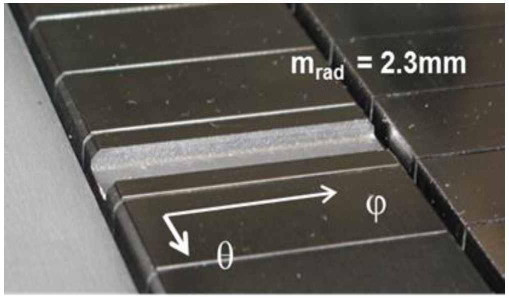
- Main objective: characterize impact of BN tiles on W source during the early phase of the discharge / flat top
- SCs: N. Fedorczak / S. Brezinsek

2) W sources with BN limiters (heated plasmas) : 2 sessions

- Main objective: characterize impact of BN tiles on RF induced W source during the heating phase
- SCs: L. Colas / E. Lerche

3) PFU melting in steady state conditions : 2 sessions

- Main objective: characterize PFU melting under steady state heat flux / modelling
- SCs: Y. Corre / K. Krieger



Future plans (2021)

❑ Full actively cooled ITER-like divertor for 2021

Phase 1									Phase 2					
2020			2021											
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
S4 shutdown		C5 campaign		S5 shutdown (full actively cooled ITER like W divertor)					C6 campaign					S6

WP PFC (FP8) **WP TE (FP9)**

❑ 2 EUROfusion calls for WEST

- WP PFC call for participation in the C5 campaign *(ended on November 5th)*
- WP TE call for proposals for the C6 campaign *(deadline : November 13)*

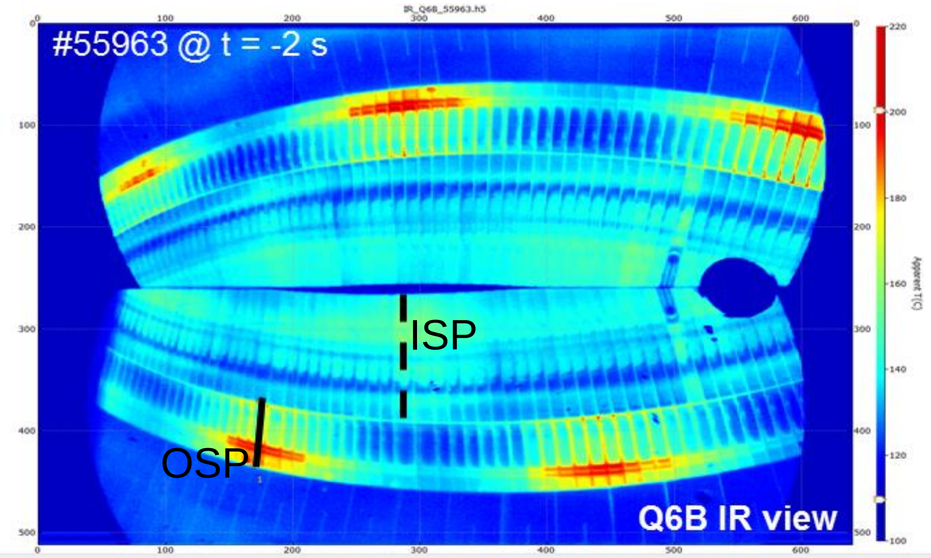
You are very welcome to submit experimental proposals for WEST

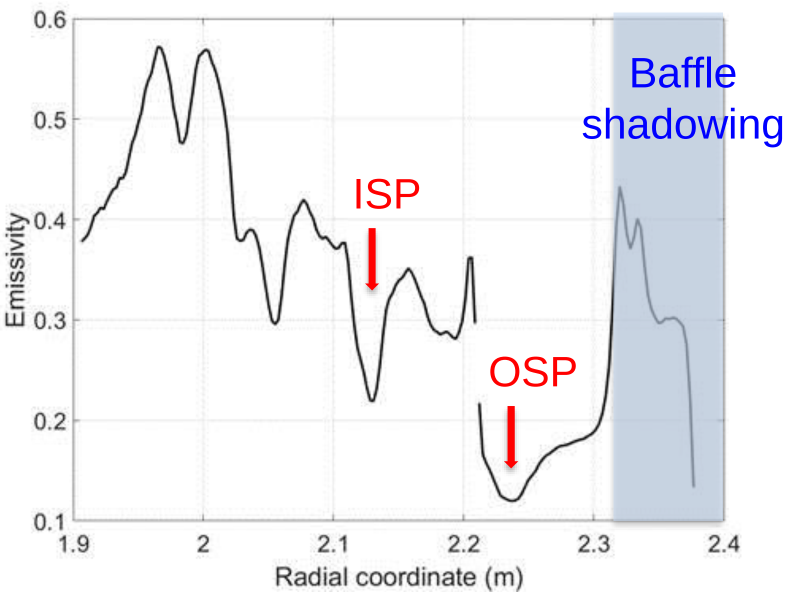
Any question ? Contact WEST TF leaders
(T. Loarer / P. Maget)


WEST ready for the C5 campaign – Oct 2020

Extra slides

Complex spatial distribution of tungsten emissivity on the divertor





- Non uniform IR although uniform TC measurement before plasma ➔ non uniform W emissivity
- In situ method developed to assess W emissivity ➔ complex spatial distribution along the divertor (~0.12 at max OSP, consistent with lab measurements for W coatings)
- Evolves also significantly with time over the campaign, in correlation with strike point position

[J. Gaspar et al., FED 2019, PSI2020] [M. H. Aumeunier et al., PSI2020]