EUROfusion

19th November 2024

RT-06 “Preparation of efficient Plasma Facing Components (PFC) operation for ITER, DEMO and HELIAS”

Discussion on proposals and allocated priorities

E. Tsitrone

On behalf of WPTE TFLs
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Research Topic Coordinators
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Reference TFL
E. Tsitrone, A. Hakola

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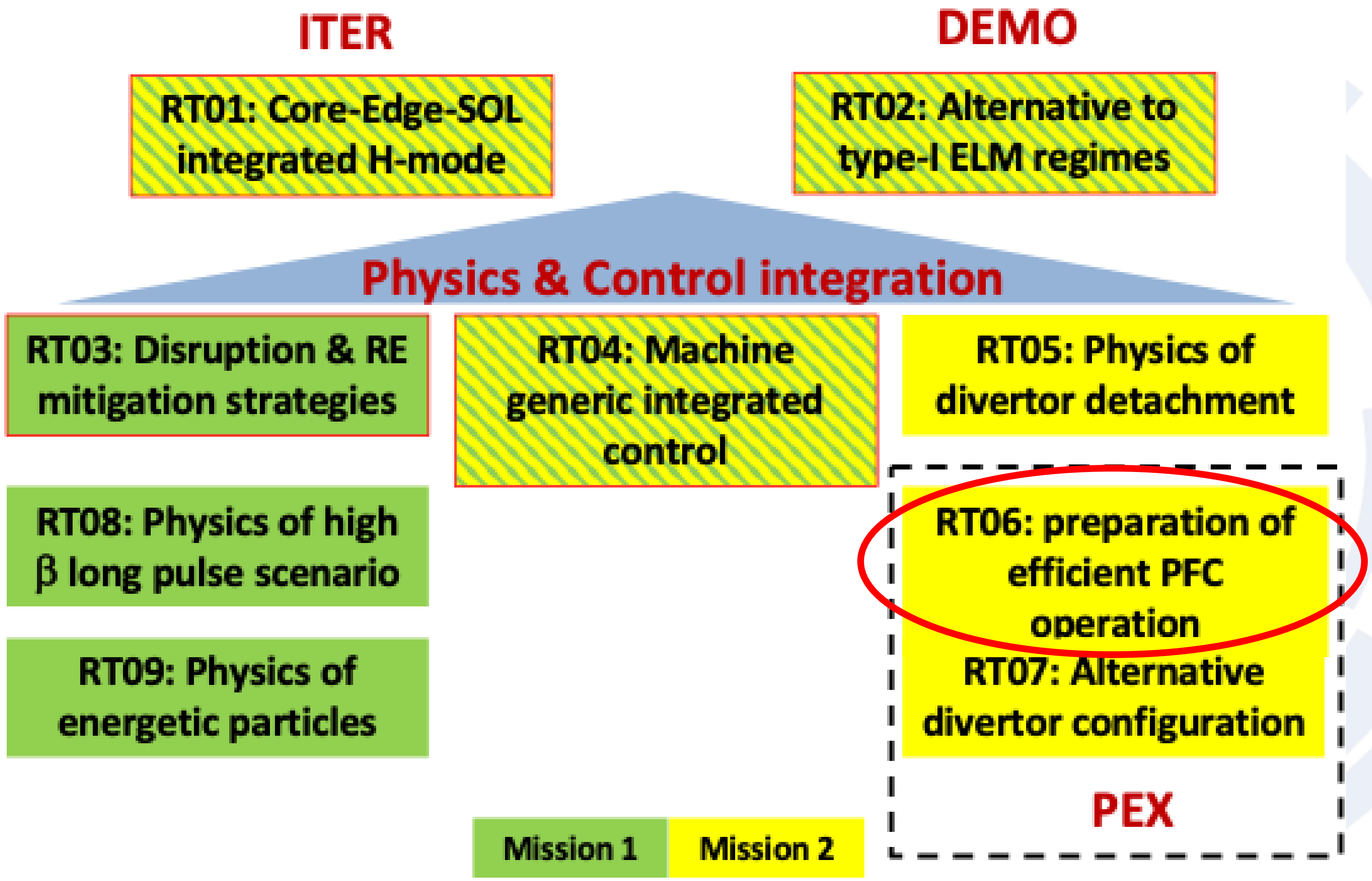
Introduction

- RT-06 is part of mission 2 on plasma exhaust, with a focus on the plasma facing components and PWI
- RT-06 is focussed on metallic devices (AUG, JET and WEST) for preparing next step fusion devices (ITER, DEMO but also DTT, COMPASS-U or the transition of W of JT-60SA)



Scientific Objectives of RT-06 have been updated to account for ITER new baseline

Scientific Objectives	
D1	Quantify local power load distributions on castellated and shaped PFCs for ITER and DEMO, including melting events using experimental data and predictive modelling
D2	Assess the impact of sustained high power / high particle fluence plasma exposure on the thermo-mechanical properties of metallic PFCs as well as on plasma operation
D3	Quantify material erosion sources from metallic walls under ITER relevant plasma conditions (including high power and impurity seeding plasmas) and determine material migration pathways, in particular to assess the net erosion rates.
D4	Quantify fuel retention in devices with metallic walls, with a focus on long pulse operation (using recent fuel retention diagnostic upgrades such as laser-based diagnostics where available) and including impact of **boronisations**
D5	Determine fuel-removal in metallic devices in conditions relevant for ITER (including the impact of **boronisation**) and extrapolate to DEMO
D7	Assess efficiency and lifetime of conditioning methods in metallic devices, with a focus on **boronisation**

- 2024 D3 and D6 on material migation have been merged into D3 (D6 suppressed to avoid confusion)
- A dedicated objective D7 has been added to address boronization related issues

Scientific Objectives of RT-06 : 3 main R&D areas

Scientific Objectives	
D1	Quantify local power load distributions on castellated and shaped PFCs for ITER and DEMO, including melting events using experimental data and predictive
D2	Assess the impact of sustained high power / h … l properties of metallic PFCs as well as on plasma operation
D3	Quantify material erosion sources from metallic walls under ITER relevan … gh power and impurity seeding plasmas) and determine material migration … the net erosion rates.
D4	Quantify fuel retention in devices with metallic walls, with a focus on long pulse operation (using recent fuel retention diagnostic upgrades such as laser-based diagnostics where available) and including impact of boronisations
D5	Determine fuel-removal … e impact of boronisation) and extrap
D7	Assess efficiency and lifetime of conditioning methods in metallic devices, with a focus on boronisation

PFC evolution / damage under plasma exposure

(2025 focus : high fluence, impact of RE on first wall)

Material migration

(2025 focus : W first wall)

Fuel retention / recovery and vessel conditioning

(2025 focus : boronisation)

- Focus for 2025 : urgent R&D for ITER new baseline

Significant overbooking on AUG/WEST for 2025

Allocation of discharges (tentative)

	AUG	TCV	MAST-U	WEST
Allocated for 2025	30			180
Proposed	105			681
Overbooking	3.5			3.8

- RT06 on WEST : largest share of TE experimental time, as priority given to the 2nd High Fluence Campaign
- RT06 on AUG : modest share of TE experimental time as priority on upper divertor upgrade for Mission 2 (NB : more budget could come after fall campaign of AUG is taken into account)

2025 proposals :

- Large requests for divertor / midplane manipulators of AUG : to be coordinated
- Boronisation specific requests : boronisation set ups + regular reference pulses

Overview of proposals : 21 proposals received, 3 R&D areas well covered

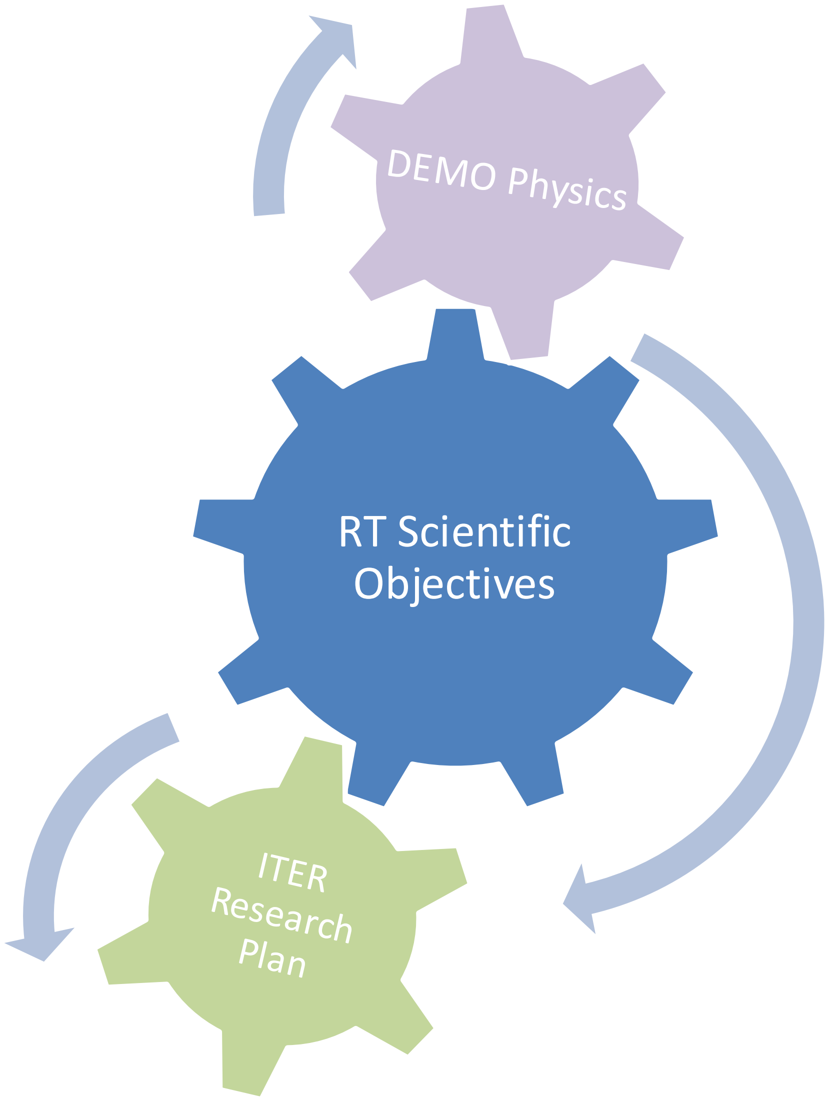
#	Title	Main Proponent
129	W PFC damage induced by runaway electron incidence	S. Ratynskaia
139	Exposure of pre-damaged PFUs (pred#2 &	A. Durif
140	Exposure of pre-damaged INTERFACE PFU	A. Durif
141	High particle fluence campaign in highly ra	Y. Corre
136	Study of non-ambipolar currents on WEST	M. Dimitrova
122	Use of N seeding to study the contribution of ICRH antennas to W core content in WEST	C. Guillemaut
124	Characterize plasma surface interactions in presence of Ne	G. Urbanczyk
127	Mo erosion and migration from ICRF antenna limiter coated tiles	G. Urbanczyk
128	Coupling 1MW ICRF with a propagative Slow Wave	G. Urbanczyk
133	Charge exchange particle flux to 1st wall	K. Krieger
134	W erosion and transport with post-mortem analysis	J. Romazanov
142	W prompt redeposition	J. Romazanov
138	Spectroscopic estimation of Chemically Assisted Physical Sputtering of boron	E. Pawelec
126	Wall isotope changeover with ICWC	E. Lerche
125	Boron removal with ICWC	E. Lerche
130	Validation of the modelling of boron powder injection and boron film deposition	S. Ratynskaia
131	Effect of spatially (non-)uniform boronization on plasma parameters, wall retention and B layer properties	A. Gallo
132	Efficiency of boronisation procedures	K. Krieger
137	Particle balance in AUG as a measure of g	D. Matveev
135	Preparation of reference samples from bo	T. Dittmar
123	Exploring impact of boronizations on mirror reflectivity and contamination of a mirror surface	A. Litnovsky

PFC evolution / damage under plasma exposure (D1, D2)

Material migration (D3)

Fuel retention / recovery and vessel conditioning (D4, D5, D7)

Prioritization scheme and criteria



Proposals evaluated according to the criteria:

Adherence to the Scientific Objectives

Team effort

Size and feasibility

All these aspects were considered by the TFLs when setting the priorities – according to the following scheme

P1: experimental priority for 2025

P2: will be done if time allows after Prio 1 experiments are completed

P3: back-up programme/not possible in 2025

PB: piggy-back experiment/pure analysis proposal

PFC evolution / damage under plasma exposure

#129: W PFC damage induced by runaway electron incidence

- **Proponents and contact person**

S. Ratynskaia srat@kth.se, P. Tolias, K. Krieger, Y. Corre, M. Hoppe, C. Reux, B. Sieglin, R. A. Pitts, G. Papp, E. Nardon, M. Hoelzl, E. Gauthier, J. Gerardin, M. Diez

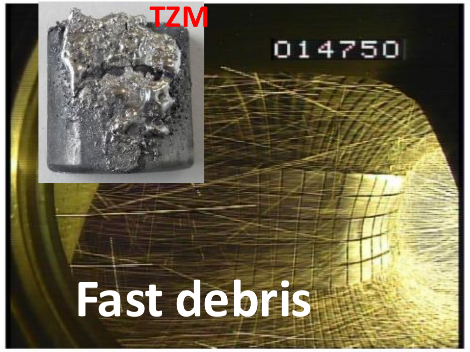
- **Scientific Background & Objectives**
  - RE impact leads to PFC explosion accompanied by the expulsion of fast solid dust that generate PFC craters upon subsequent mechanical impact.
  - RE-induced damage modelling at its infancy.
  - Empirical data from controlled experiments are necessary to understand the underlying physics and validate modelling efforts.
- **Experimental Strategy & Essential diagnostic**
  - Expose instrumented W samples or tiles at midplane (TCs, shunt resistors).
  - Observe evolution of PFC damage and extract size / speed of solid debris by IR/VIS cameras.
  - Utilize witness plates to document impact cratering & compare with existing damage laws.
  - Extensive post-mortem analysis including residual radioactivity & transmutation profiles (➔ PWIE)

***Validate** GEANT4+MEMENTO workflow with **constrained RE input** from DREAM+SOFT codes and later - from JOREK code*

Image coutesy of Y. Corre

Accidental damage of W tiles

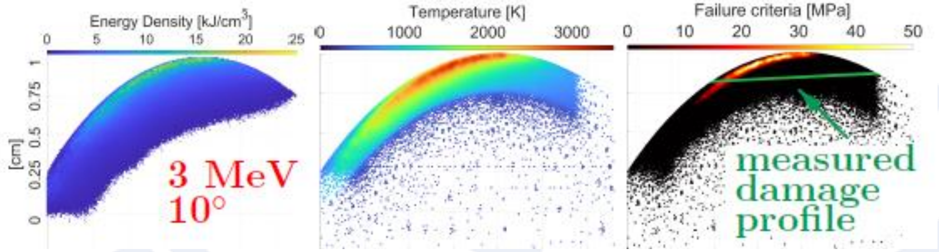
M. De Angeli *et al* *2023 NF* **63**, 014001



GEANT4-MEMENTO modelling at KTH

Example of DIII-D *graphite* sample damage modelling

S. Ratynskaia *et al*, EUROfusion pinboard No 38821



Device	# Pulses	# Development
AUG	10-12	2-4 with reference pulses to be identified from previous studies
WEST	10	Reference pulses to be identified from previous studies

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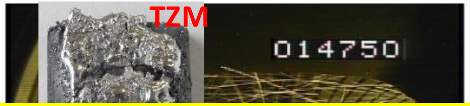
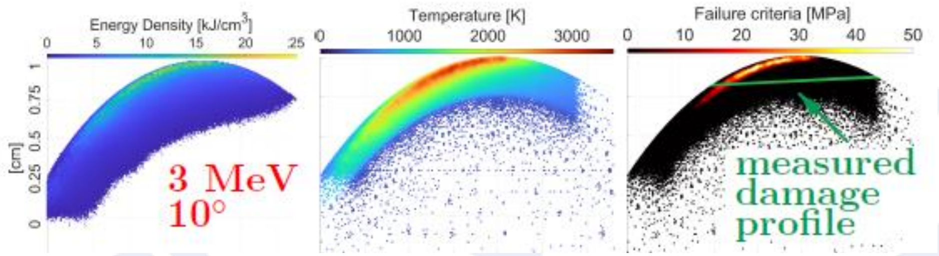


Priority: P1
High priority issue for ITER
Pre requisite : RE beam control (RT03) + check on AUG midplane manipulator resilience to RE impact

Example of DIII-D *graphite* sample damage modelling

S. Ratynskaia *et al*, EUROfusion pinboard No 38821



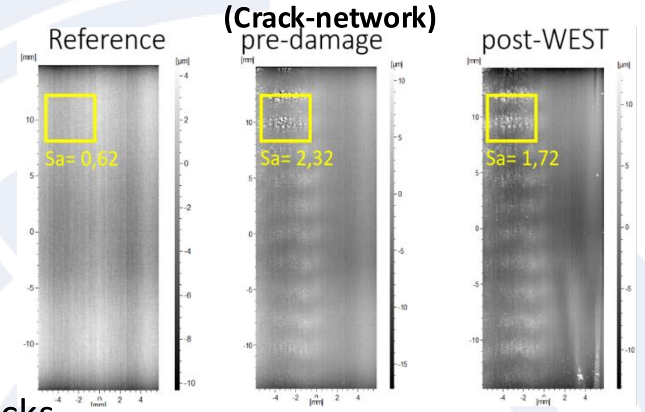
Device	# Pulses	# Development
AUG	10-12	2-4 with reference pulses to be identified from previous studies
WEST	10	Reference pulses to be identified from previous studies

#139: Exposure of pre-damaged ITER-like PFU (pred#2 & #3) – follow-up

- **Scientific Background & Objectives**

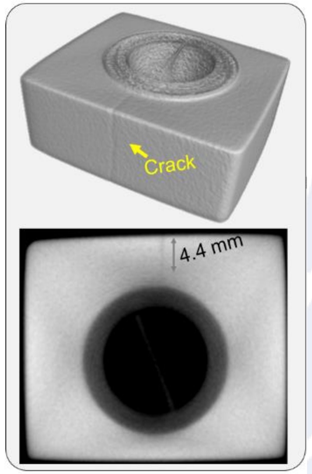
Assumption in IRP : ITER divertor lifetime >10 years - need for PFU testing in tokamak environment, including damaged PFU. Operation with actively cooled ITER-like PFU with crack network and self-castellation

- Determine the impact of different kind of damages (crack network pred#2 MB25 and self-castellation pred#3 MB27) on power exhaust and plasma operation
- Assess the W source and temperature on the leading edge of the self-castellation and assess how the cracks propagates in W monoblock (MB)
- Assess consequences for plasma operation: determine the potential short and long term limitations (reduction of the power exhaust and consequently overheating of the damaged block)
- Characterize the surface texture evolution (confocal, X-ray tomography measurements) of pre-existing damages (comparative study)



- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Pred#2 located on PFU 7 (sector Q3B) for visible spectroscopy measurement and pred#3 MB27 (sector Q3B) give the opportunity to expose continuously the cracks to radiation only and specific session positioning the strike point on MB27 will allow direct plasma/heat loading steady state interactions (plasma scenario baseline #59852).
- Scan of the RF power: comparison W sources with OSP on MB26 (undamaged) and MB25 (pre damage 2).

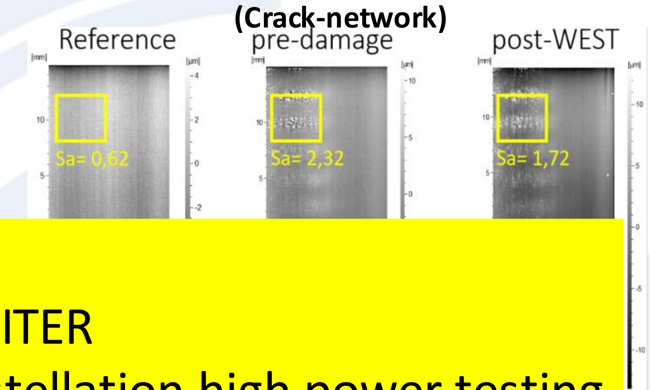
MB 27 **(Self-castellated)**



Proposed pulses

Device	# Pulses/ Session	# Development
WEST	30/2	Existing scenario

#139: Exposure of pre-damaged ITER-like PFU (pred#2 & #3) – follow-up



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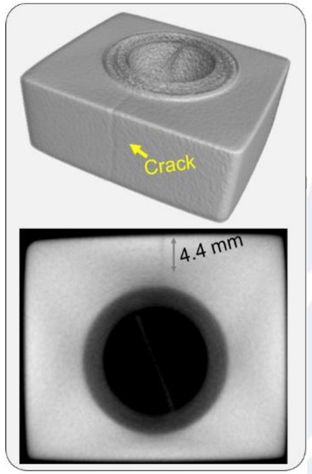
Priority: P1
High priority for ITER
Focus on self castellation high power testing

MB 27 **(Self-castellated)**



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Proposed pulses

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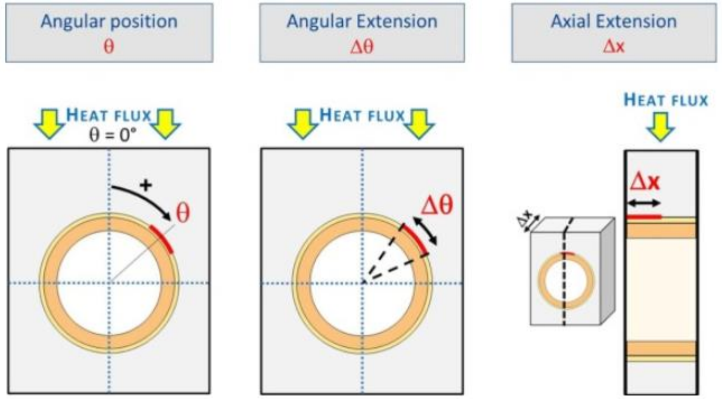
WEST	30/2	Existing scenario

#140: Pre-damaged INTERFACE PFU



- **Proponents and contact person:**

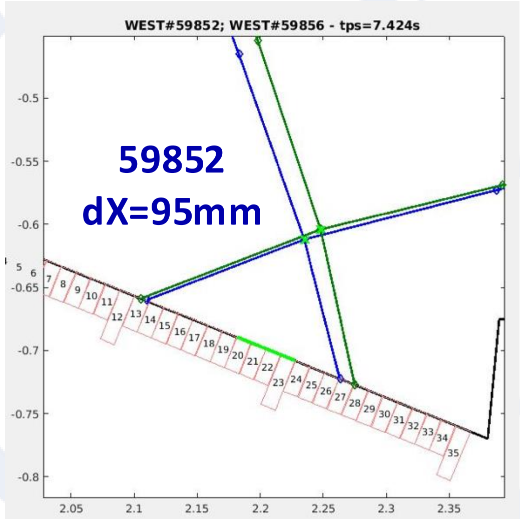
A. Durif (alan.durif@cea,fr), M. Richou, Y. Corre, E. Tsitrone, M. Missirlian, T. Wauters

- **Scientific Background & Objectives**

Provide Structural Health Monitoring (**SHM**) keys for ITER/DEMO to **monitor** and **follow in real time** non expected hot spots related to internal PFU defects via IR diagnostics:

  - Precise the defect acceptance criteria for PFCs (θ, Δθ, ΔX)
  - “in-situ” hotspots monitoring → Reactor maintenance scheme optimization → SHM

  Experiment links with WPTE / WPDIV and ITPA / IO



- **Experimental Strategy/Machine Constraints and essential diagnostic**

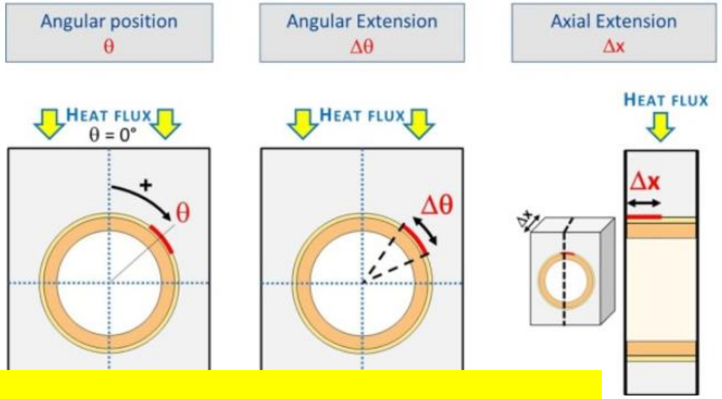
Experiment achieved throughout dedicated sessions / plasma scenario baseline #59852/ Aim: positioned the strike line on MB13

  - Density scan in LSN plasma with LH heating (potentially EC if available to expose the PFU to H-mode plasma)
  - Wide angle IR camera and spectrometer as essential diagnostic (PFU positioned in Q1B)

Proposed pulses

Device	# Pulses/ Session	# Development
WEST	30/2	Existing scenario

#140: Pre-damaged INTERFACE PFU



- **Proponents and contact person:**

A. Durif (alan.durif@cea,fr), M. Richou, Y. Corre, E. Tsitrone, M. Missirlian, T. Wauters

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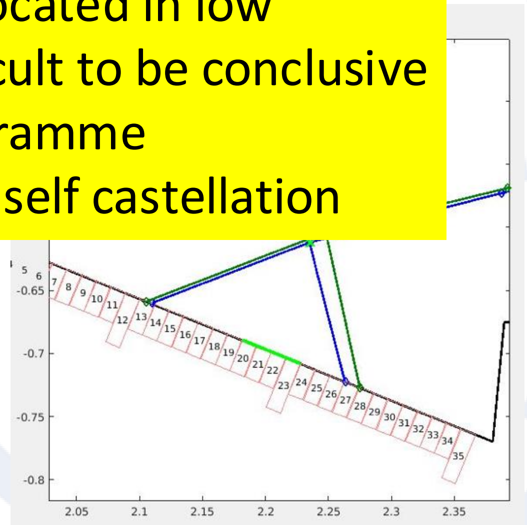
  - Precise the defect acceptance criteria for PFCs (θ, Δθ, ΔX)
  - "in-situ" hotspots monitoring → Reactor maintenance sche

  Experiment links with WPTE / WPDIV and ITPA / IO

Priority: P2
MB with interface defect located in low loaded divertor area : difficult to be conclusive
➔ try first in internal programme
Highest priority = # 139 on self castellation



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Experiment achieved throughout dedicated sessions / plasma scenario baseline #59852/ Aim: positioned the strike line on MB13
  - Density scan in LSN plasma with LH heating (potentially EC if available to expose the PFU to H-mode plasma)
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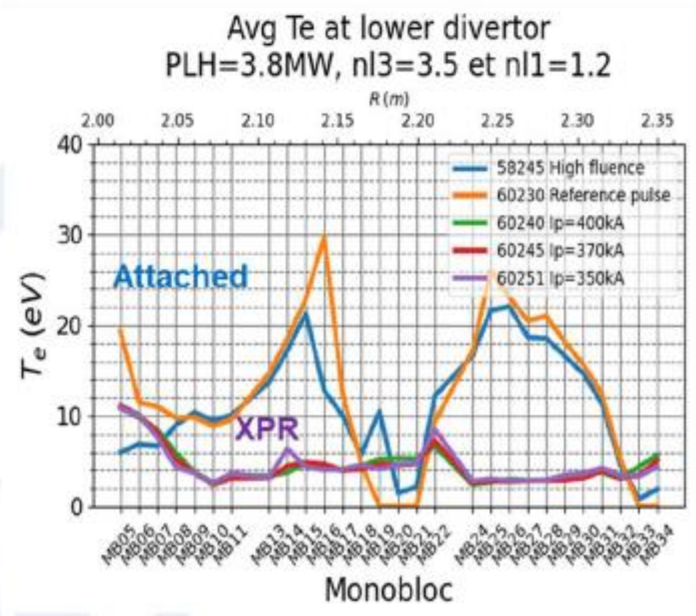
Proposed pulses

Device	# Pulses/ Session	# Development
WEST	30/2	Existing scenario

141 : High particle fluence campaign in highly radiative divertor regime

- **Proponents and contact person:**

Yann.corre@cea.fr, N. Fedorczak, J. Gaspar, E. Tsitrone, K. Krieger, A. Huart, J. Gerardin, J. Gunn, C. Guillemaut, M. Diez, M. Richou, S. Brezinsek, A. Hakola, A. Grosjean, T. Wauters, E. Pawelec, J. Romazanov



- **Scientific Background & Objectives**
- Provide feedback for next step devices on plasma operation and ITER grade PFUs ageing under high particle fluence in radiative divertor regimes :
- Run second high fluence (N_2 seeding) campaign ➔ low temperature plasma (1 month)
- Assess the W source (extinguished?) and transport (surface layer build-up)
- Impact of low Z impurities on PWI with the ITER grade PFU (impurity “legacy”, fuel retention, material migration)
- Link to WP TE RT22-06 (D2), PWIE (post-mortem) and ITPA DivSOL (DSOL44)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Scenario : High fluence XPR (L mode, D & N fuelling, Ip = 350 kA, P_{LH} = 3.8 MW, can go up to ~ 60s, cumulated fluence per pulse $2.5.10^{24}$ D/m^2)
- Test the HF XPR scenario up to 60 s duration + reference HF “fully attached plasma” condition (if not done in 2024)
- High Fluence 2 (HF2) : run repetitive HF XPR pulses for ~1 month to reach a significant fluence (5x 10^{26} D/m^2, about 200 pulses)
- Pre-requisite : Full divertor cleaning before the HF2 campaign
- PFU retrieval after the campaign for post mortem analysis (PWIE)

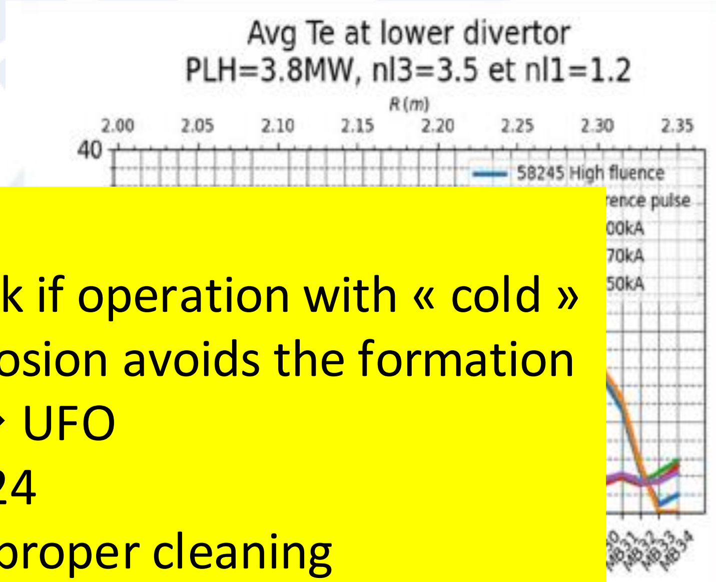
Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	200/16 (C12)	1 (C11)

141 : High particle fluence campaign in highly radiative divertor regime

- **Proponents and contact person:**

Yann.corre@cea.fr, N. Fedorczak, J. Gaspar, E. Tsitrone, K. Krieger, A. Huart, J. Gerardin, J. Gunn, C. Guillemaut, M. Diez, M. Richou, S. Brezinsek, A. Hakola, A. Grosjean, T. Wauters, E. Pawelec, J. Romazanov



Priority: P1
High priority for ITER : check if operation with « cold » divertor less prone to W erosion avoids the formation of thick deposited layers ➔ UFO
Scenario developped in 2024
Pre requisite : full divertor proper cleaning
Shot intensive : to be shared between TE and internal programme

- **Scientific Background & Objectives**
- Provide feedback for next step devices on plasma operation ar
high particle fluence in radiative divertor regimes :
- Run second high fluence (N_2 seeding) campaign ➔ low tempe
- Assess the W source (extinguished?) and transport (surface lay
- Impact of low Z impurities on PWI with the ITER grade PFU (im
material migration)
- Link to WP TE RT22-06 (D2), PWIE (post-mortem) and ITPA Div

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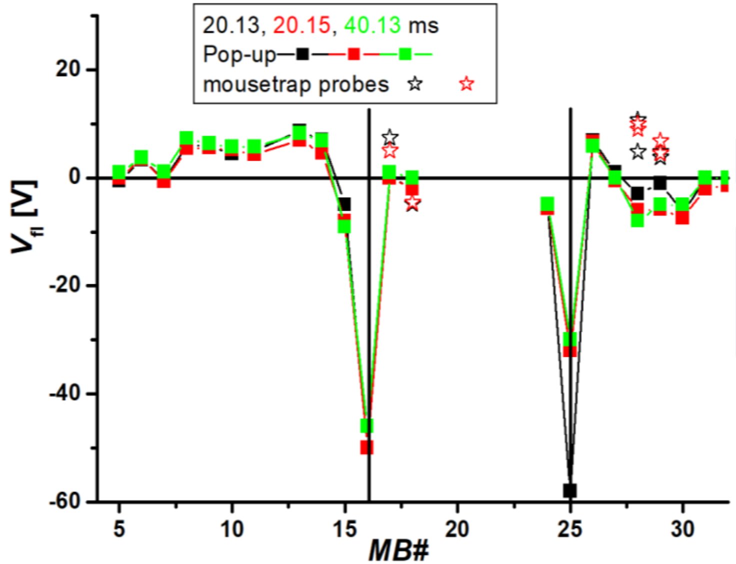
- Test the HF XPR scenario up to 60 s duration + reference HF “fully attached plasma” condition (if not done in 2024)
- High Fluence 2 (HF2) : run repetitive HF XPR pulses for ~1 month to reach a significant fluence (5x 10^{26} D/m^2, about 200 pulses)
- Pre-requisite : Full divertor cleaning before the HF2 campaign
- PFU retrieval after the campaign for post mortem analysis (PWIE)

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	200/16 (C12)	1 (C11)

136 : Study of non-ambipolar currents on WEST tokamak

- **Proponents and contact person:**
  - Miglena Dimitrova (dimitrova@ipp.cas.cz), J. Kovačič , J. Gunn, P. Ivanova, T. Gyergyek
- **Scientific Background & Objectives**
  - Quantify local power load distributions in the divertor (RT-06, D1)
  - Study if there are non-ambipolar current in WEST at different plasma conditions
  - Investigate if the non-ambipolar current play a role in the determination of the heat fluxes at LSN and USN configuration on WEST
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - At LSN to produce a pulse with strike point sweeping on the divertor. Attached plasma. Repeat experiments at USN:
    - Density and plasma current scan at 2 values with IC+LH heating
    - All divertor probes, VRP, pecker probes (Mach), (IR and FBG for comparing heat fluxes)



Divertor profile of V_{fl} using the pop-up probes, #58249.

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	10/1	2

136 : Study of non-ambipolar currents on WEST tokamak

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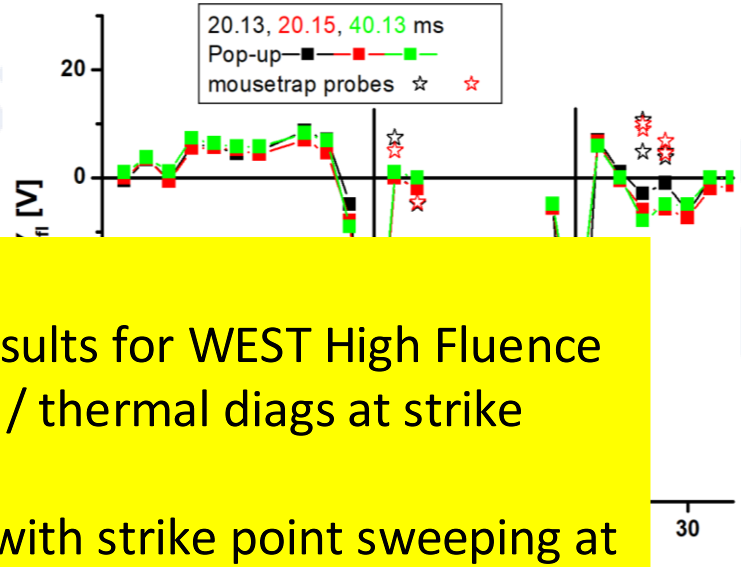


Priority: P2
Key for interpreting LP results for WEST High Fluence (discrepancy between LP / thermal diags at strike point position)
Proposed to be done PB with strike point sweeping at end of pulse
Impact on other TE devices to be discussed

- **Scientific Background & Objectives**
  - Quantify local power load distributions in the divert
  - Study if there are non-ambipolar current in WEST at conditions
  - Investigate if the non-ambipolar current play a role determination of the heat fluxes at LSN and USN co WEST

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - At LSN to produce a pulse with strike point sweeping on the divertor. Attached plasma. Repeat experiments at USN:
    - Density and plasma current scan at 2 values with IC+LH heating
    - All divertor probes, VRP, pecker probes (Mach), (IR and FBG for comparing heat fluxes)

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	10/1	2

Material migration

122 : Use of N seeding to study the contribution of main chamber objects to W core content in ICRH discharges

- **Proponents and contact person:**

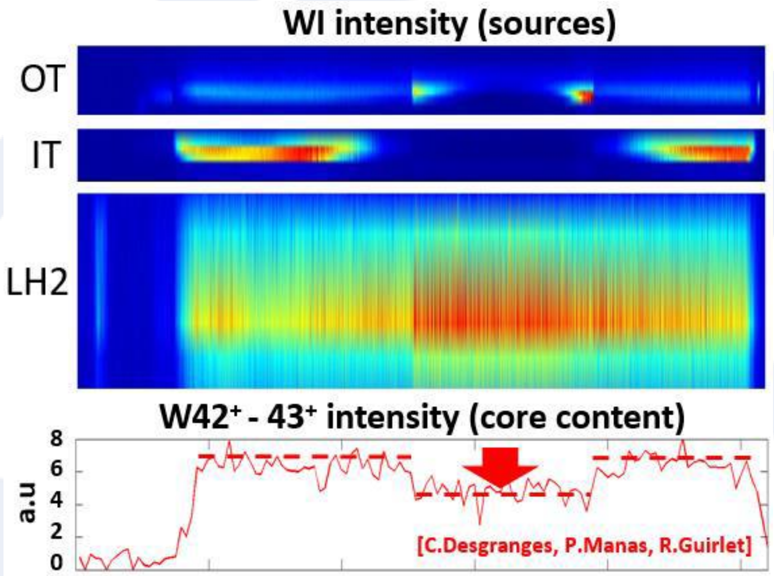
C.Guillemaut, P.Manas, R.Guirlet, C.Desgranges, J.Gunn, L. Colas, J. Hillairet, J. Morales

- **Scientific Background & Objectives**
- The use of N seeding to extinguish the divertor W sources in WEST LH discharges in C7 gave some useful information on the contribution of other objects (antenna limiters & maybe baffles) to the core W content.
- Objectives of the present proposal:

- Repeat a similar experiment in ICRH discharges
- Determine the contribution of main chamber objects to the W core content compared to the divertor contribution
- Optional: the effect of ECRH could be studied too

- **Experimental Strategy/Machine Constraints and essential diagnostic**

- Gradual increase of LH power until ~4 MW
- Introduction of N seeding
- Gradual increase of ICRH power blips until ~2 MW or more on top of the 4 MW LH power with N seeding
- Optional: Blips of ECRH could be attempted
> Essential diagnostics: Visible spectroscopy, UV spectroscopy, LP, ECE, Soft X ray and bolometry



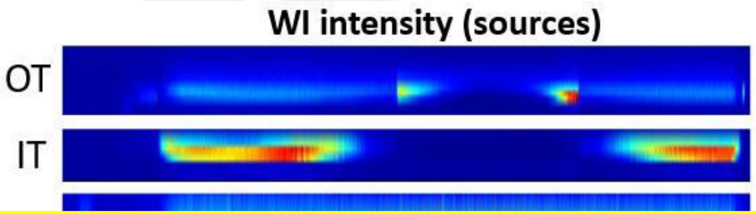
Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	30	

122 : Use of N seeding to study the contribution of main chamber objects to W core content in ICRH discharges

- **Proponents and contact person:**

C.Guillemaut, P.Manas, R.Guirlet, C.Desgranges, J.Gunn, L. Colas, J. Hillairet, J. Morales



- **Scientific Background & Objectives**
- The use of N seeding to extinguish the divertor W sources in WEST
  C7 gave some useful information on the contribution of other obje
  limiters & maybe baffles) to the core W content.
- Objectives of the present proposal:

- Repeat a similar experiment in ICRH discharges
- Determine the contribution of main chamber objects to the W core
to the divertor contribution
- Optional: the effect of ECRH could be studied too

Priority: P2
Good proposal but combined LH/ICRH challenging experimentally : would focus for 2025 on further analysis / modelling of results previously obtained with LH only
Could be attempted in internal programme ?

- **Experimental Strategy/Machine Constraints and essential diagnostic**

- Gradual increase of LH power until ~4 MW
- Introduction of N seeding
- Gradual increase of ICRH power blips until ~2 MW or more on top of the 4 MW LH power with N seeding
- Optional: Blips of ECRH could be attempted

> Essential diagnostics: Visible spectroscopy, UV spectroscopy, LP, ECE, Soft X ray and bolometry

Proposed pulses

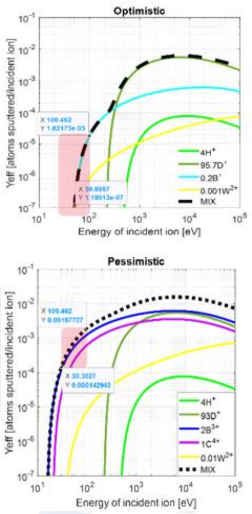
Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	30	

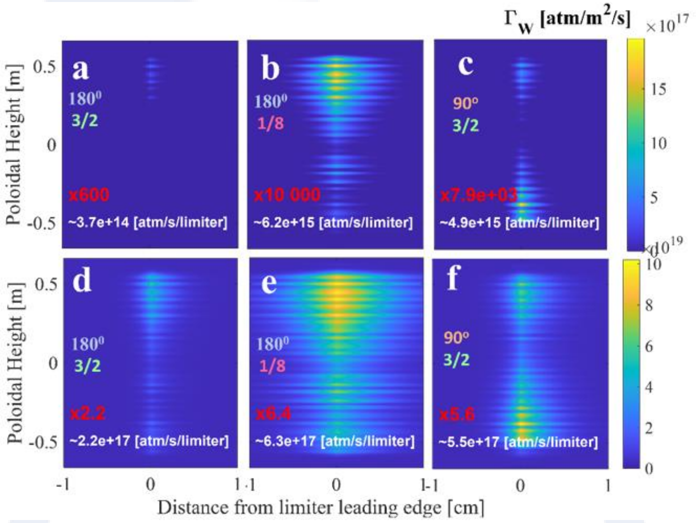
124 : Ne and Ar seeding influence on ICRF-induced W release

- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@univ-lorraine.fr) Matthias BERNERT, Volodymyr BOBKOV, Ralph DUX, Roberto BILATO, Roman OCHOUKOV, Nicolas FEDORCZAK, Julien HILLAIRET, Laurent COLAS, Agata CHOMICZEWSKA, Raymond DIAB
- **Scientific Background & Objectives**
  - How much more tungsten will ICRF produce in ITER when powered, i.e., in presence of seeded Neon?
  - Assess the increase of W production when powering ICRF in seeded discharges with Ne (and Ar). The discharge will be divided in several plateaus with constant P_{TOT} but with different auxiliary heating mix. The question will be answered by assessing the increase of W impurity using visible spectroscopy lines of sight looking at the 3-strap ICRF antenna limiter
- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #41031 but with pure deuterium plasma (without injecting low-Z impurities) with updated waveforms (cf. below) → *non-seeded reference used as a reference point for all measurements*
2) Repeat discharge #1 with moderate injection of Ne
3) Repeat #2 by increasing the amount of Ne injected as much as possible (2 shots suited)
4) Repeat #3 with 90° phasing on the ICRF antenna
5) Repeat #2 with Ar (cf. # 41033)
6) Repeat #3 with Ar

- Visible + UV spectroscopy, RFA probe, antenna reflectometry



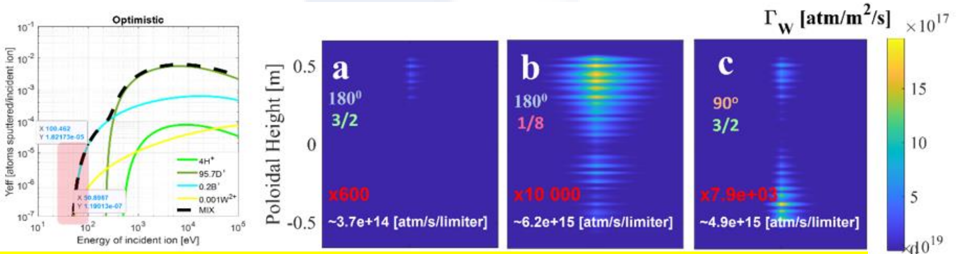


$$\Lambda = \Gamma_{Wtot}^{ICRH \to ON} / \Gamma_{Wtot}^{ICRH \to OFF} \quad \text{with } \Gamma_{Wtot} = \iint_{Limiter} \Gamma_W$$

Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	6
MAST-U	-	-
TCV	-	-
WEST	6	14

124 : Ne and Ar seeding influence on ICRF-induced W release



- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@univ-lorraine.fr) Matthias BERNERT, Volodymyr BOBKOV, Ralph DUX, Roberto BILATO, Roman OCHOUKOV, Nicolas FEDORCZAK, Julien HILLAIRET, Laurent COLAS, Agata CHOMICZEWSKA, Raymond DIAB
- **Scientific Background & Objectives**
  - How much more tungsten will ICRF produce in ITER when powe[...] presence of seeded Neon?
  - Assess the increase of W production when powering ICRF in see[...] with Ne (and Ar). The discharge will be divided in several platea[...] P_{TOT} but with different auxiliary heating mix. The question will be answered by assessing the increase of W impurity using visible spectroscopy lines of sight looking at the 3-strap ICRF antenna limiter

Priority: P2
Good proposal but pre requisite = good Ne/Ar seeded scenario in both devices
Reduced scan ?

$$\Lambda = \Gamma_{Wtot}^{ICRH\rightarrow ON} / \Gamma_{Wtot}^{ICRH\rightarrow OFF} \quad \text{with } \Gamma_{Wtot} = \iint_{Limiter} \Gamma_W$$

- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #41031 but with pure deuterium plasma (without injecting low-Z impurities) with updated waveforms (cf. below) → *non-seeded reference used as a reference point for all measurements*
2) Repeat discharge #1 with moderate injection of Ne
3) Repeat #2 by increasing the amount of Ne injected as much as possible (2 shots suited)
4) Repeat #3 with 90° phasing on the ICRF antenna
5) Repeat #2 with Ar (cf. # 41033)
6) Repeat #3 with Ar

- Visible + UV spectroscopy, RFA probe, antenna reflectometry

Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	6
MAST-U	-	-
TCV	-	-
WEST	6	14

127 : PSI characterization on Mo-coated antenna limiter tiles

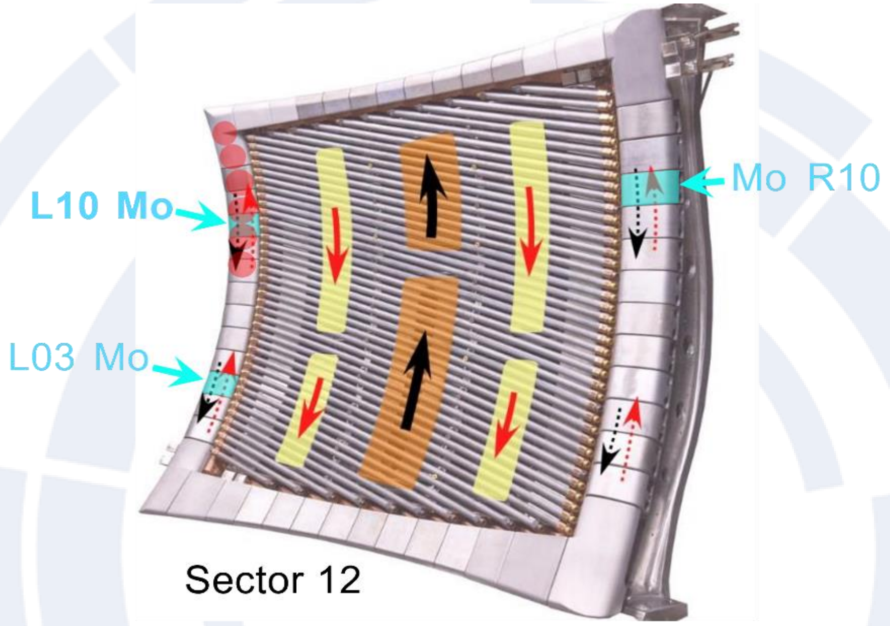
- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@univ-lorraine.fr), Volodymyr BOBKOV, Martin BALDEN, Ralph DUX, Roman OCHOUKOV, Rudi NEU, Pierre Manas, Jérôme MORITZ, Stéphane HEURAUX, Léonel TSOWEMOO

- **Scientific Background & Objectives**
  - **How is the balance between gross and net erosion of W sputtered from antenna limiters ?**
- Through parametric scans (ICRF ant. Phasing & power ratio, Raus), the main goals are
  - to assess the influence of ICRF excitation on the erosion of Mo and W
  - to compare Mo-I vs W-I lines to deduce local fields and plasma composition
  - to use Mo as impurity trace of interactions on the ICRF antenna limiter to assess penetration factors by comparing gross erosion with core contamination
  - to complement pre and post mortem analysis on the limiter tiles to evaluate the migration/redeposition of Mo impurity in the edge.

- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #33105 (cf, [V. Bobkov et al., NME 18 (2019) 131–140])
2) Repeat #33105 by ramping up the ICRF power from 0 to 2MW
3) For maximum power (>2MW) balanced on the straps and dipole phasing, scan the position of the separatrix until bringing the LH resonance 2cm in front of the antenna limiter.
4) Repeat #33105 in DN configuration
5) 1Hz ICRF power modulations between 0 & 1MW, track Mo with both visible and UV spectro to derive transport coefficients (cf. [C Bruhn et al 2018 Plasma Phys. Control. Fusion 60 085011 & R.M. McDermott et al 2022 Nucl. Fusion 62 026006]

- Visible + UV spectroscopy monitoring W



Proposed pulses

Device	# Pulses/Session	# Development
AUG	5	-
MAST-U	-	-
TCV	-	-
WEST	-	-

127 : PSI characterization on Mo-coated antenna limiter tiles

- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@univ-lorraine.fr), Volodymyr BOBKOV, Martin BALDEN, Ralph DUX, Roman OCHOUKOV, Rudi NEU, Pierre Manas, Jérôme MORITZ, Stéphane HEURAUX, Léonel TSOWEMOO

- **Scientific Background & Objectives**
  - **How is the balance between gross and net erosion of W sp[…] antenna limiters ?**
- Through parametric scans (ICRF ant. Phasing & power ratio, Raus), the […]
  - to assess the influence of ICRF excitation on the erosion of Mo and W
  - to compare Mo-I vs W-I lines to deduce local fields and plasma composition
  - to use Mo as impurity trace of interactions on the ICRF antenna limiter to assess penetration factors by comparing gross erosion with core contamination
  - to complement pre and post mortem analysis on the limiter tiles to evaluate the migration/redeposition of Mo impurity in the edge.

Priority: P1 to exploit the new Mo vs W settings of the AUG ICRH antenna
PB will also yield interesting data

- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #33105 (cf, [V. Bobkov et al., NME 18 (2019) 131–140])
2) Repeat #33105 by ramping up the ICRF power from 0 to 2MW
3) For maximum power (>2MW) balanced on the straps and dipole phasing, scan the position of the separatrix until bringing the LH resonance 2cm in front of the antenna limiter.
4) Repeat #33105 in DN configuration
5) 1Hz ICRF power modulations between 0 & 1MW, track Mo with both visible and UV spectro to derive transport coefficients (cf. [C Bruhn et al 2018 Plasma Phys. Control. Fusion 60 085011 & R.M. McDermott et al 2022 Nucl. Fusion 62 026006]

- Visible + UV spectroscopy monitoring W

Proposed pulses

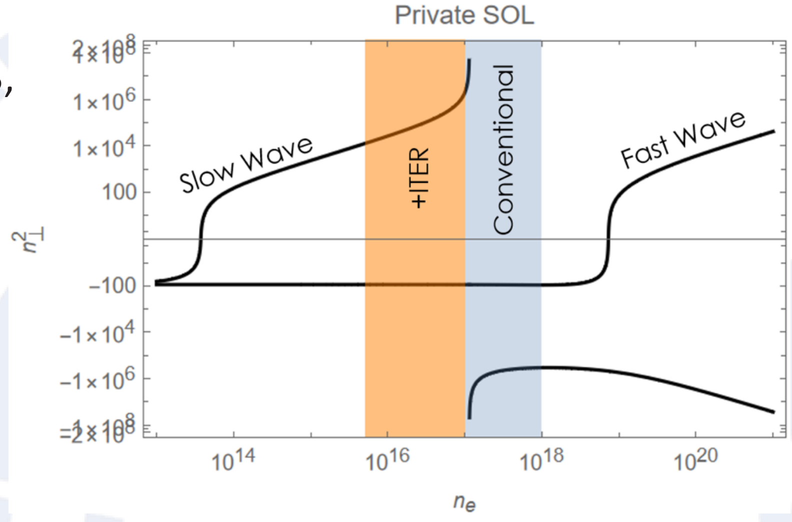
Device	# Pulses/Session	# Development
AUG	5	-
MAST-U	-	-
TCV	-	-
WEST	-	-

128 : Coupling 1MW ICRF with a propagative Slow Wave (low density)

- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@ipp.mpg.de), Wouter TIERENS, Raymond DIAB, Ralph DUX, Roberto BILATO, Roman OCHOUKOV
- **Scientific Background & Objectives**
  - ITER will have to operate its ICRF system with a propagative slow wave, which is unusual
  - Can we couple 1MW ICRF on a low density plasma where the slow wave is propagative ?
  - If yes, what is the impact of the slow wave on impurity production and heating efficiency ?
  - Can we move the LH resonance behind the antenna using local gas injection ?
- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #**37963** (~100kW ICRF power coupled for ~160kW injected à ~40% reflected)
2) Repeat #**1** by achieving 1MW power coupled per antenna. To do so, we wish to feedback control the coupled power, but if this controller is too difficult to implement, we will otherwise assume for ~40% power reflected, and require ~1.6MW ICRF to each generator to get 1MW coupled in per antenna pure deuterium plasma (without injecting low-Z impurities) with updated waveforms (cf. below)
3) Repeat discharge #2 by moving the plasma closer to the antenna (Raus scan), to start with the LH resonance in front of the antenna and push it slowly behind
4) Repeat discharge #2 by feedback controlling the core density with main valves, and feedforward injecting gas locally at the surrounding of the active antenna (to assess local gas injection in moving the LH resonance behind the antenna and improve its coupling)
5) Repeat #3 by adding 2 Hz ICRF power modulation to track with Break In Slope analysis how the heating efficiency evolves (this will help checking rather if the different waves generated from mode conversion occuring at different densities are still well absorbed in the core, in particular IBWs)
6) Repeat #5 at Ip = 700kA to change the magnetic connections and increase the changes to register meaningful signal

- Visible + UV spectroscopy, RFA probe, antenna reflectometry, B-dot probes



Proposed pulses

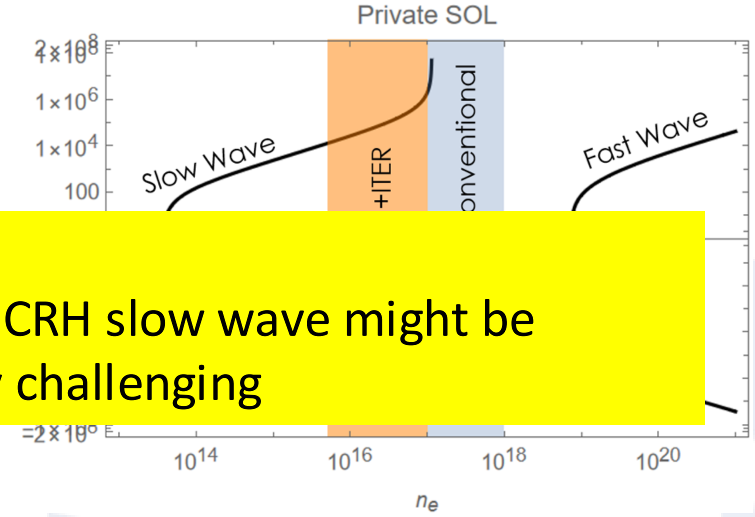
Device	# Pulses/Session	# Development
AUG	6	12
MAST-U	-	-
TCV	-	-
WEST	-	-

128 : Coupling 1MW ICRF with a propagative Slow Wave (low density)

- **Proponents and contact person:**
  - Guillaume URBANCZYK (guillaume.urbanczyk@ipp.mpg.de), Wouter TIERENS, Raymond DIAB, Ralph DUX, Roberto BILATO, Roman OCHOUKOV
- **Scientific Background & Objectives**
  - ITER will have to operate its ICRF system with a propagative
  - Can we couple 1MW ICRF on a low density plasma where th
  - If yes, what is the impact of the slow wave on impurity produ
  - Can we move the LH resonance behind the antenna using lo
- **Experimental Strategy/Machine Constraints and essential diagnostic**

1) Repeat #**37963** (~100kW ICRF power coupled for ~160kW injected à ~40% reflected)
2) Repeat #**1** by achieving 1MW power coupled per antenna. To do so, we wish to feedback control the coupled power, but if this controller is too difficult to implement, we will otherwise assume for ~40% power reflected, and require ~1.6MW ICRF to each generator to get 1MW coupled in per antenna pure deuterium plasma (without injecting low-Z impurities) with updated waveforms (cf. below)
3) Repeat discharge #2 by moving the plasma closer to the antenna (Raus scan), to start with the LH resonance in front of the antenna and push it slowly behind
4) Repeat discharge #2 by feedback controlling the core density with main valves, and feedforward injecting gas locally at the surrounding of the active antenna (to assess local gas injection in moving the LH resonance behind the antenna and improve its coupling)
5) Repeat #3 by adding 2 Hz ICRF power modulation to track with Break In Slope analysis how the heating efficiency evolves (this will help checking rather if the different waves generated from mode conversion occuring at different densities are still well absorbed in the core, in particular IBWs)
6) Repeat #5 at Ip = 700kA to change the magnetic connections and increase the changes to register meaningful signal

- Visible + UV spectroscopy, RFA probe, antenna reflectometry, B-dot probes



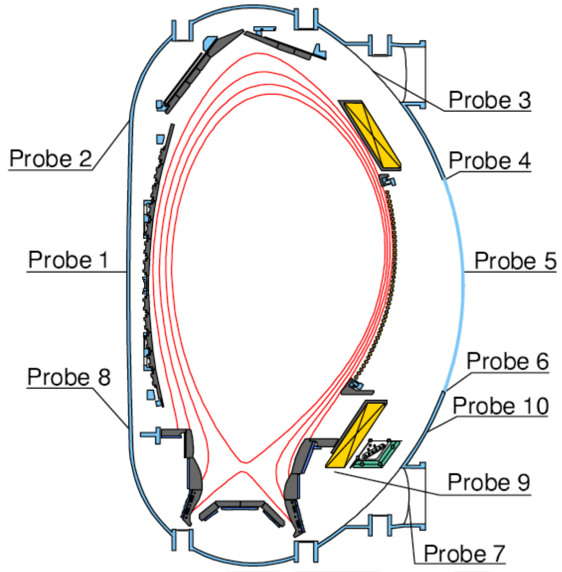
Priority: P2
Of interest for ITER where ICRH slow wave might be propagative but technically challenging

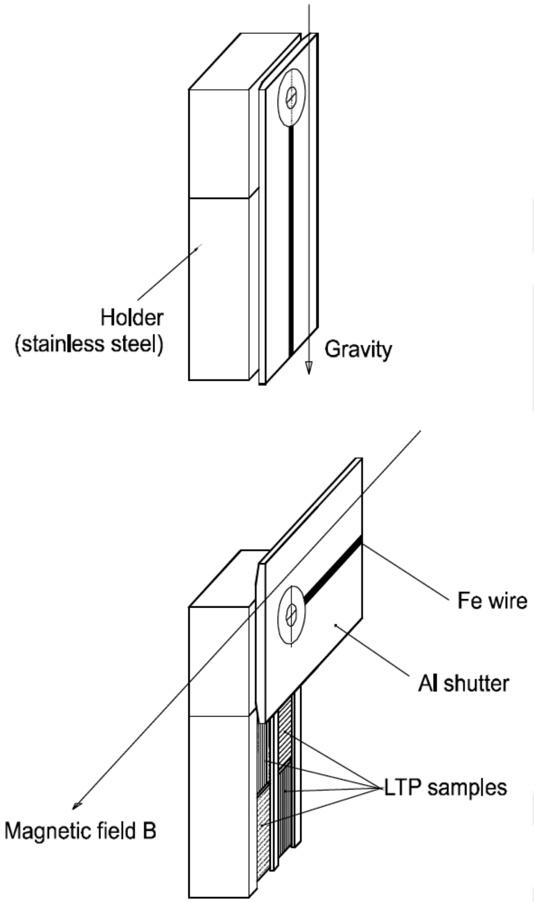
Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	12
MAST-U	-	-
TCV	-	-
WEST	-	-

133 : Charge Exchange neutral flux to 1st wall

- **Proponents and contact person**
  Y. Corre, K. Krieger, T. Wauters
- **Scientific Background & Objectives**
  - Rekindled strong R&D effort to characterise energy spectra and spatial distribution of CX neutral fuel atom flux
  - Optimise experimental data base by combining discharge resolved and campaign integrated data for validating predictive models
- **Experimental Strategy & Essential Diagnostic**
  - Exposure of dedicated samples followed by ex-situ surface analysis using IBA and TDS
  - Derive information of averaged energy spectra
  - Deterrmine poloidal and toroidal variation of campaign integrated CX flux
  - Combine with available discharge resolved data
  - Compare simulations for representative discharge scenarios against experimental data base
  - Sample analysis in collaboration with WP PWIE



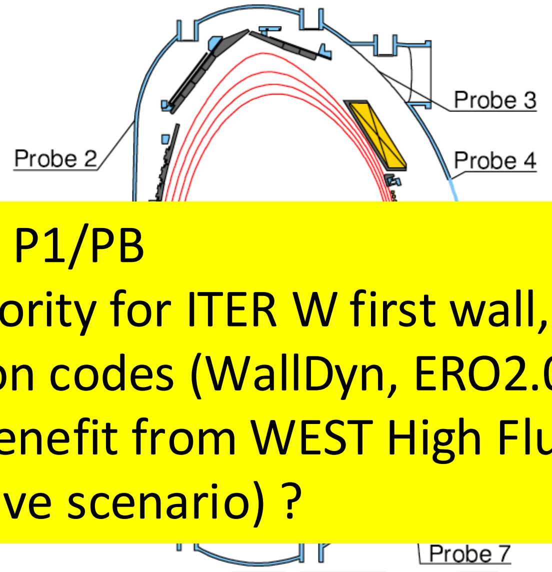


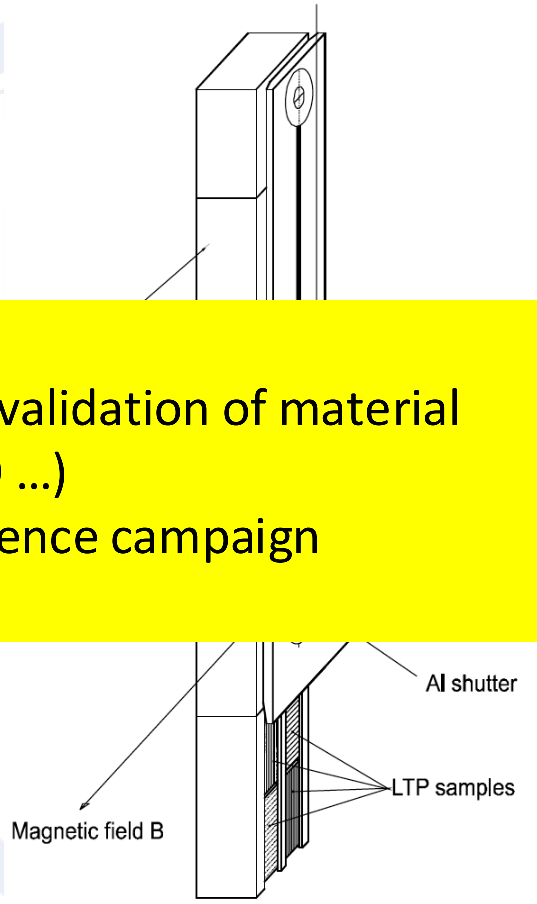
Device	# Pulses/Session	# Development
AUG	piggy back	-
MAST-U	piggy back	-
TCV	piggy back	-
WEST	piggy back	-

133 : Charge Exchange neutral flux to 1st wall

- **Proponents and contact person**
  Y. Corre, K. Krieger, T. Wauters
- **Scientific Background & Objectives**
  - Rekindled strong R&D effort to characterise energy spec spatial distribution of CX neutral fuel atom flux
  - Optimise experimental data base by combining discharge and campaign integrated data for validating predictive m
- **Experimental Strategy & Essential Diagnostic**
  - Exposure of dedicated samples followed by ex-situ surface analysis using IBA and TDS
  - Derive information of averaged energy spectra
  - Deterrmine poloidal and toroidal variation of campaign integrated CX flux
  - Combine with available discharge resolved data
  - Compare simulations for representative discharge scenarios against experimental data base
  - Sample analysis in collaboration with WP PWIE

Priority: P1/PB
High priority for ITER W first wall, validation of material migration codes (WallDyn, ERO2.0 …)
Could benefit from WEST High Fluence campaign (repetitive scenario) ?

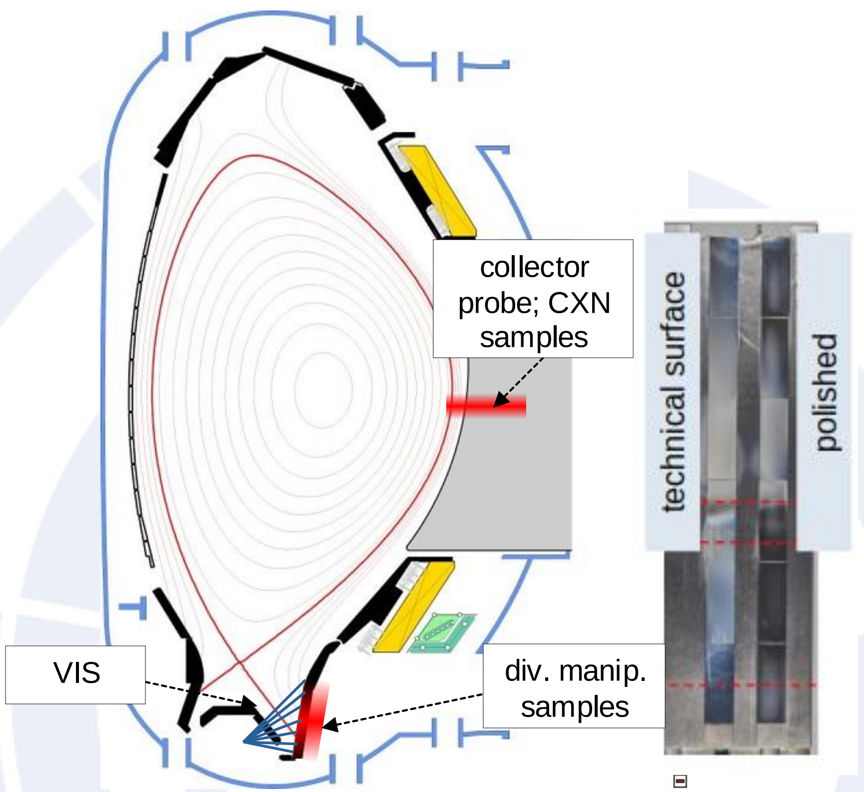




Device	# Pulses/Session	# Development
AUG	piggy back	-
MAST-U	piggy back	-
TCV	piggy back	-
WEST	piggy back	-

134 : W erosion sources and global transport in Ne-seeded D2 plasma

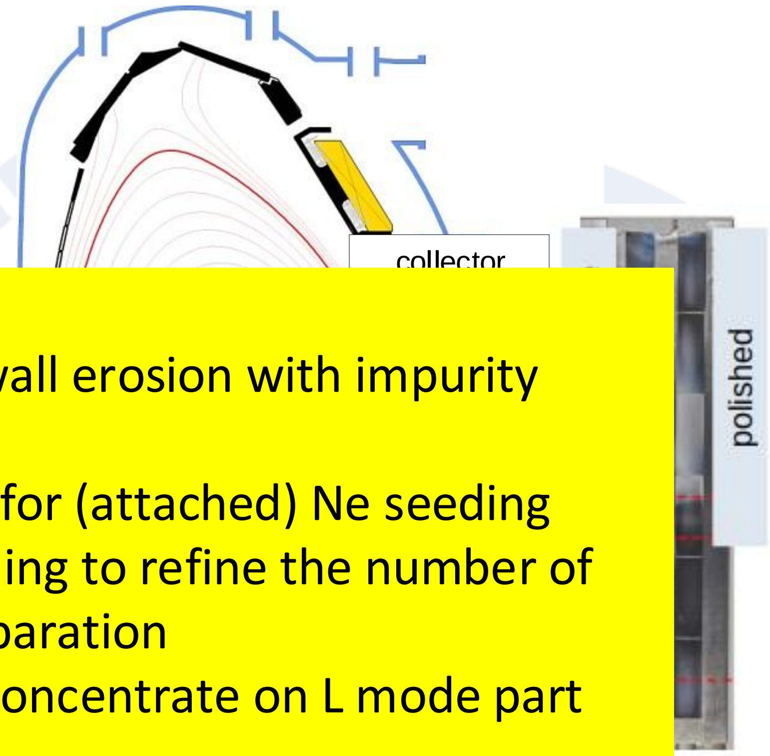
- **Proponents and contact person:**
  - j.romazanov@fz-juelich.de
- **Scientific Background & Objectives**
  - Characterize wall erosion and global impurity transport in full-W environment, validate PWI/impurity transport codes
  - Use post-mortem analysis of W marker samples (divertor manip.) / collector probes (OMP manip.) and W spectroscopy
  - Characterize CXN angular distribution relevant for main chamber sources by additional samples with varying exposed angle
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Ne-seeded attached plasma
  - 12 identical pulses (6 L- and 6 H-mode)
  - Maximise W divertor sample net erosion
  - preferred to use existing pulses with SOLPS or EMC3-EIRENE solutions available
  - WI, WII spectroscopy in divertor + main chamber LOS, core impurity VUV and bolometry, plasma charact. (spectr., LP, Thomson sc., Li beam, reflectom.), desirable: flow and ion temperature charact. of Ne impurity by CXRS and CIS



Proposed pulses

Device	# Pulses/Session	# Development
AUG	12	2
MAST-U	0	0
TCV	0	0
WEST	0	0

134 : W erosion sources and global transport in Ne-seeded D2 plasma



- **Proponents and contact person:**
  - j.romazanov@fz-juelich.de
- **Scientific Background & Objectives**
  - Characterize wall erosion and global impurity tra environment, validate PWI/impurity transport co
  - Use post-mortem analysis of W marker samples collector probes (OMP manip.) and W spectrosco
  - Characterize CXN angular distribution relevant fo sources by additional samples with varying expo
- **Experimental Strategy/Machine Cons essential diagnostic**
  - Ne-seeded attached plasma
  - 12 identical pulses (6 L- and 6 H-mode)
  - Maximise W divertor sample net erosion
  - preferred to use existing pulses with SOLPS or EMC3-EIRENE solutions available
  - WI, WII spectroscopy in divertor + main chamber LOS, core impurity VUV and bolometry, plasma charact. (spectr., LP, Thomson sc., Li beam, reflectom.), desirable: flow and ion temperature charact. of Ne impurity by CXRS and CIS

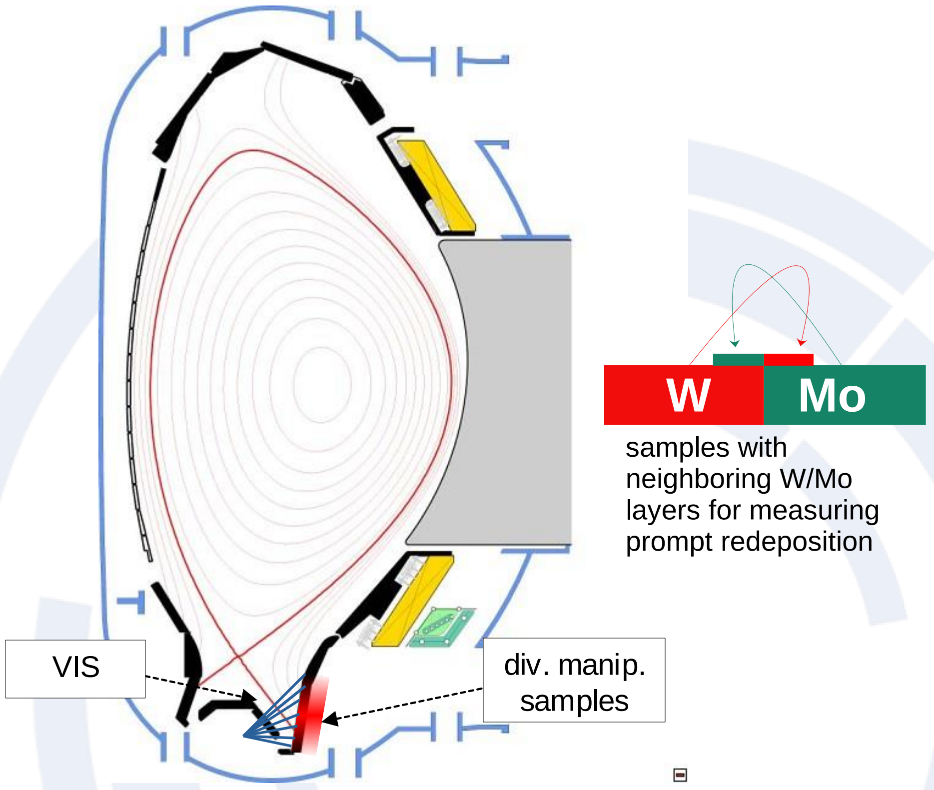
Priority: P1
High priority for ITER : first wall erosion with impurity seeding.
Requires adequate scenario for (attached) Ne seeding plasmas, preparation modelling to refine the number of shots required / sample preparation
Reduced number of shots : concentrate on L mode part first for code validation.

Proposed pulses

Device	# Pulses/Session	# Development
AUG	12	2
MAST-U	0	0
TCV	0	0
WEST	0	0

142 : W prompt redeposition characterization

- **Proponents and contact person:**
  - j.romazanov@fz-juelich.de
- **Scientific Background & Objectives**
  - Characterize W prompt redeposition by WI, WII line ratio and neighboring W/Mo samples
  - Variation of B-field, density, temperature and measurement in divertor + main chamber, validation of PWI/impurity transport codes
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Maximise W divertor sample net erosion, avoid type-I ELMs for simpler modelling and interpretation -> Ne-seeded attached plasma, L-mode or QCE (t.b.d.), preferred to use existing pulses with SOLPS or EMC3-EIRENE solutions available
  - AUG: 2 sessions: 1 at low, 1 at high B-field (avoid overlap for samples); repeat for changing spectroscopy settings
  - WEST: piggyback, as for AUG but w/o B-field scan, investigate WIII, WIV
  - local analysis + modelling, no global transport -> focus on W spectroscopy and LP arrays



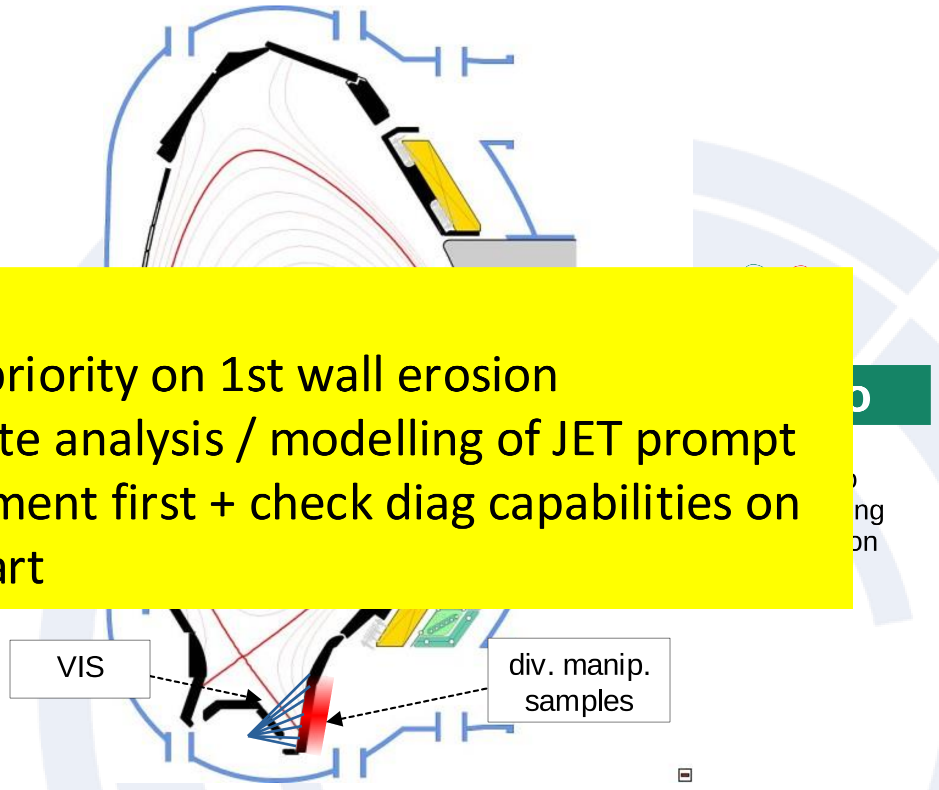
Proposed pulses

Device	# Pulses/Session	# Development
AUG	2 + 2	1-2
MAST-U	0	0
TCV	0	0
WEST	0	0

142 : W prompt redeposition characterization

- **Proponents and contact person:**
  - j.romazanov@fz-juelich.de
- **Scientific Background & Objectives**
  - Characterize W prompt redeposition by WI, WII neighboring W/Mo samples
  - Variation of B-field, density, temperature and m + main chamber, validation of PWI/impurity transport codes

Priority: P2
Good proposal but priority on 1st wall erosion
Proposed to complete analysis / modelling of JET prompt redeposition experiment first + check diag capabilities on AUG/WEST PB to start



- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Maximise W divertor sample net erosion, avoid type-I ELMs for simpler modelling and interpretation -> Ne-seeded attached plasma, L-mode or QCE (t.b.d.), preferred to use existing pulses with SOLPS or EMC3-EIRENE solutions available
  - AUG: 2 sessions: 1 at low, 1 at high B-field (avoid overlap for samples); repeat for changing spectroscopy settings
  - WEST: piggyback, as for AUG but w/o B-field scan, investigate WIII, WIV
  - local analysis + modelling, no global transport -> focus on W spectroscopy and LP arrays

Proposed pulses

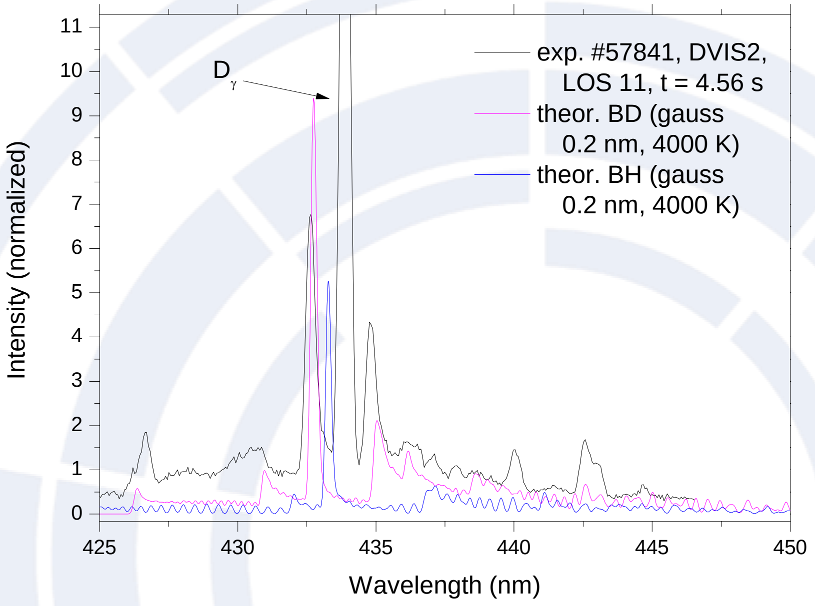
Device	# Pulses/Session	# Development
AUG	2 + 2	1-2
MAST-U	0	0
TCV	0	0
WEST	0	0

138 : Spectroscopic estimation of Chemically Assisted Physical Sputtering of boron

- **Proponents and contact person:**
- Ewa Pawelec ewap@uni.opole.pl , Dawid Mazur, Timo Dittmar

- **Scientific Background & Objectives**
  - In JET, important part of beryllium erosion is due to CAPS, and the resulting erosion depends on plasma and wall parameters
  - Molecular part of boron erosion (and deposition?) was not yet studied, though the BD bands are visible e.g. in WEST midplane
  - Objectives:
    - Quantify the BD production and dissociation with respect to plasma and wall parameters
    - Obtain the BD internal energy distributions (rotational and vibrational temperatures) as a source for molecular modeling of boron erosion

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Piggyback during other B concentrated experiments (pre-, during and post-boronization stages), also in hydrogen
  - Crucial diagnostics:
    - visible spectrometer covering the vicinity of 433 nm band (midplane/limiter for preference),
    - IR camera for wall temperature,
    - Langmuir probes for electron density and temperature estimations, interferometry to obtain the edge plasma density



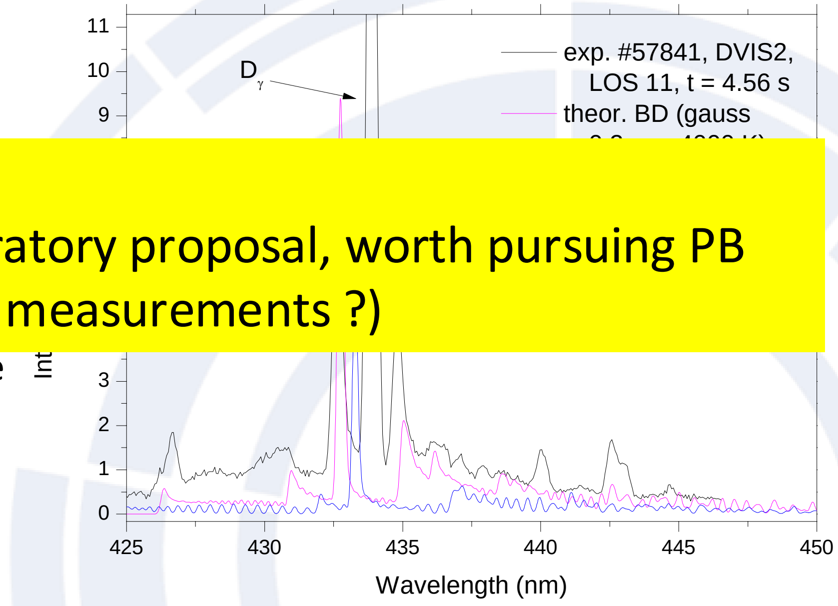
Proposed pulses

Device	# Pulses/Session
AUG	Piggyback experiment
MAST-U	Not yet (CD band overlap)
TCV	Not yet (CD band overlap)
WEST	Piggyback experiment

138 : Spectroscopic estimation of Chemically Assisted Physical Sputtering of boron

- **Proponents and contact person:**
- Ewa Pawelec ewap@uni.opole.pl , Dawid Mazur, Timo Dittmar

- **Scientific Background & Objectives**
  - In JET, important part of beryllium erosion is due to CA[...] depends on plasma and wall parameters
  - Molecular part of boron erosion (and deposition?) was not yet studied, though the BD bands are visible e.g. in WEST midplane
  - Objectives:
    - Quantify the BD production and dissociation with respect to plasma and wall parameters
    - Obtain the BD internal energy distributions (rotational and vibrational temperatures) as a source for molecular modeling of boron erosion



Priority: P1/PB
Interesting but exploratory proposal, worth pursuing PB (requirements for BD measurements ?)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Piggyback during other B concentrated experiments (pre-, during and post-boronization stages), also in hydrogen
  - Crucial diagnostics:
    - visible spectrometer covering the vicinity of 433 nm band (midplane/limiter for preference),
    - IR camera for wall temperature,
    - Langmuir probes for electron density and temperature estimations, interferometry to obtain the edge plasma density

Proposed pulses

Device	# Pulses/Session
AUG	Piggyback experiment
MAST-U	Not yet (CD band overlap)
TCV	Not yet (CD band overlap)
WEST	Piggyback experiment

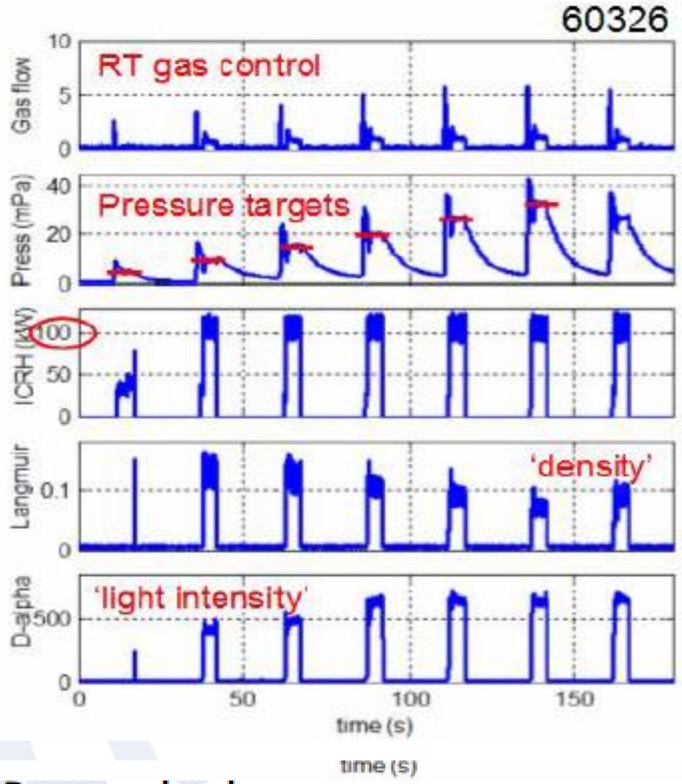
Fuel retention / recovery and vessel conditioning

126 : Isotope wall changeover with ICWC

- **Proponents and contact person:**

Ernesto Lerche, Tom Wauters, Julien Hillairet, Eléonore Geulin, Laurent Colas, Pierre Dumortier, Johan Buermans

- **Scientific Background & Objectives**
- ICWC has been successfully demonstrated in WEST (final in Dec 2024); WEST has ITER-relevant PFC's and ICWC capability for long pulses
- Wall changeover with ICWC is critical in ITER (for Tritium clean-up) and several machines have characterized its efficiency (JET, AUG, EAST, …)
- The objective is to perform an isotope changeover with ICWC in WEST from D ➔ H➔ D and assess the ICWC 'wall cleaning' efficiency; compare with the results from other devices.



- **Experimental Strategy/Machine Constraints and essential diagnostic**
- After a normal D2 experiment day, start with the best ICWC plasma obtained in 2024
- Execute a series of H2 ICWC plasmas until the H2 composition exceeds 90%
- Execute a series of D2 ICWC plasmas until the D2 composition exceeds 90%
- Ohmic monitoring pulses to be performed before and after each ICWC session
- Essential Diagnostics: Visible spectroscopy, interferometer, mass spectrometry, bolometer, Langmuir probes, Fast cameras, What else?

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	20-25 pulses / 2 sessions (in H2 and D2)	

126 : Isotope wall changeover with ICWC

- **Proponents and contact person:**

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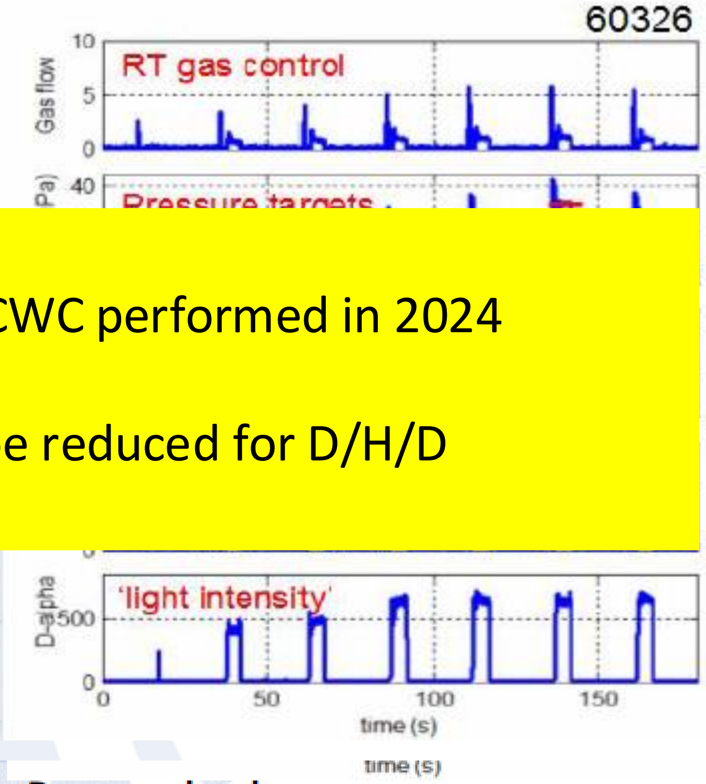

Priority: P1
Technical optimization of ICWC performed in 2024
Relevant for ITER.
Shot intensive but cannot be reduced for D/H/D changeover

- **Scientific Background & Objectives**
- ICWC has been successfully demonstrated in WEST (final i relevant PFC's and ICWC capability for long pulses
- Wall changeover with ICWC is critical in ITER (for Tritium c machines have characterized its efficiency (JET, AUG, EAST
- The objective is to perform an isotope changeover with ICWC in WEST from D ➔ H➔ D and assess the ICWC 'wall cleaning' efficiency; compare with the results from other devices.

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- Essential Diagnostics: Visible spectroscopy, interferometer, mass spectrometry, bolometer, Langmuir probes, Fast cameras, What else?

Proposed pulses

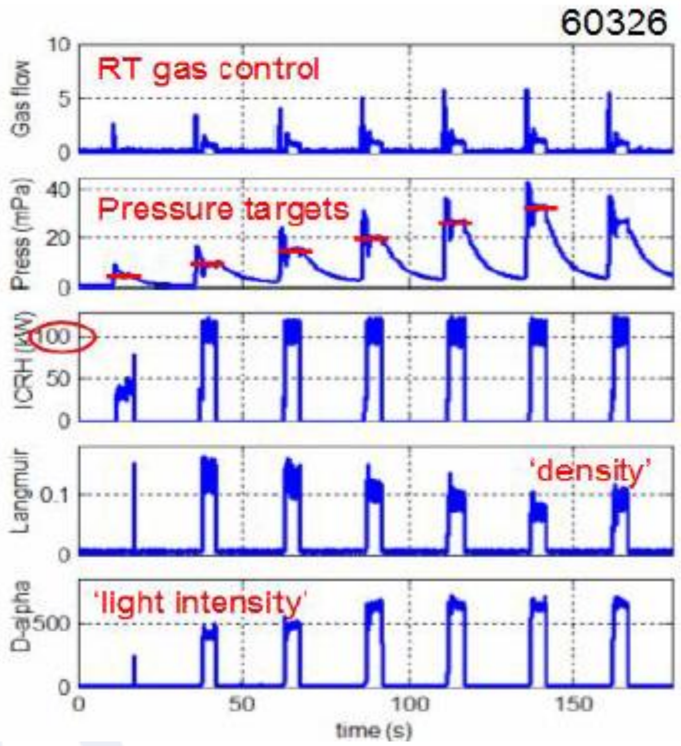
Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	20-25 pulses / 2 sessions (in H2 and D2)	

125 : Boron removal with ICWC

- **Proponents and contact person:**

Ernesto Lerche, Tom Wauters, Julien Hillairet, Eléonore Geulin, Laurent Colas, Pierre Dumortier, Johan Buermans

- **Scientific Background & Objectives**
- ICWC has been successfully demonstrated in WEST (final in Dec 2024); WEST has ITER-relevant PFC's and ICWC capability for long pulses
- Removal of Boron with ICWC is ITER-relevant since boronization is considered
- in ITER
- The objective is to assess the ICWC 'Boron removal' efficiency; compare with the results from other devices if available.



- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Right after a boronization session, start with the best ICWC plasma obtained in 2024
- Execute a series of ICWC plasmas until the Boron content is strongly decreased
- Ohmic monitoring pulses to be performed before and after the ICWC session
- Essential Diagnostics: Visible spectroscopy, interferometer, mass spectrometry, bolometer, Langmuir probes, Fast cameras, What else?

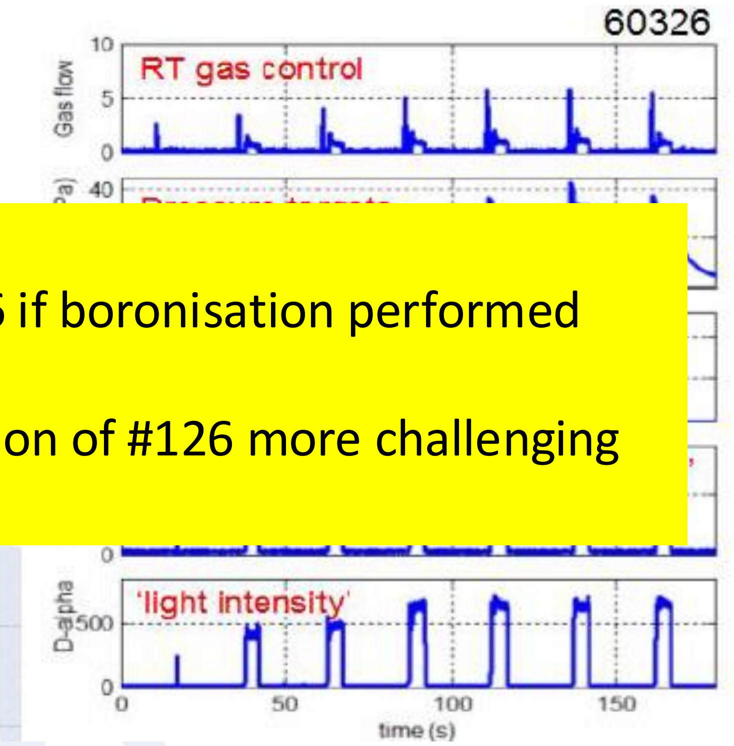
Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	1 session (after a fresh boronization)	

125 : Boron removal with ICWC

- **Proponents and contact person:**

Ernesto Lerche, Tom Wauters, Julien Hillairet, Eléonore Geulin, Laurent Colas, Pierre Dumortier, Johan Buermans



Priority: P2
Could be done PB with #126 if boronisation performed before change over to H ?
But might make interpretation of #126 more challenging
➔ to be performed later

- **Scientific Background & Objectives**
- ICWC has been successfully demonstrated in WEST (final i
relevant PFC's and ICWC capability for long pulses
- Removal of Boron with ICWC is ITER-relevant since boroni
- in ITER
- The objective is to assess the ICWC 'Boron removal' efficiency; compare with the results from other devices if available.

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Right after a boronization session, start with the best ICWC plasma obtained in 2024
- Execute a series of ICWC plasmas until the Boron content is strongly decreased
- Ohmic monitoring pulses to be performed before and after the ICWC session
- Essential Diagnostics: Visible spectroscopy, interferometer, mass spectrometry, bolometer, Langmuir probes, Fast cameras, What else?

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	1 session (after a fresh boronization)	

130 : Validation of the modelling of boron powder injection and boron film deposition

➢ Proponents and contact person

S. Ratynskaia srat@kth.se, P. Tolias, S. Brezinsek, K. Krieger, V. Rohde, T. Lunt, D. Matveev, J. Romazanov, M. De Angeli, T. Wauters, R. A. Pitts

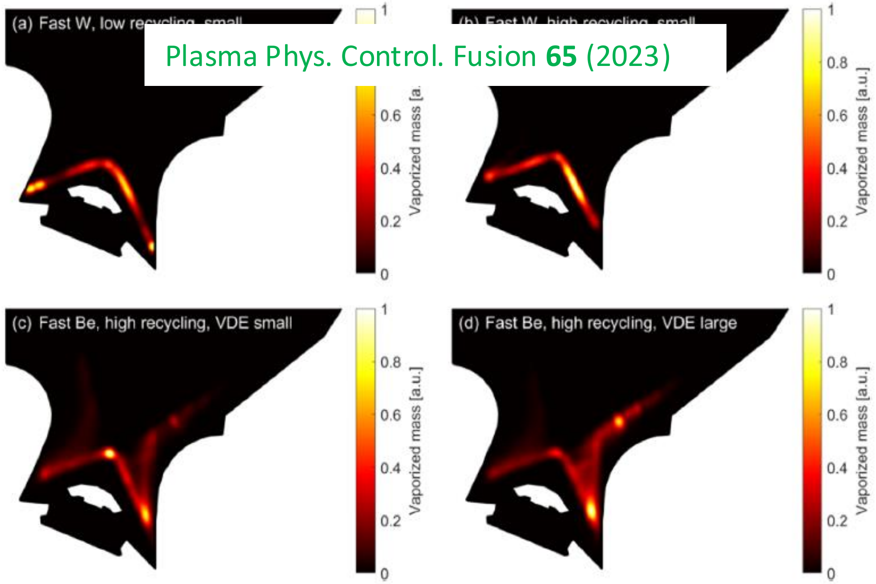
➢ Scientific Background & Objectives

- **Validate** the modelling of B dust transport and ablation in fusion plasmas with a focus on the impurity source term due to B dust vaporization
- Provide experimental data for intense B dust-plasma interaction resulting in dust ablation
- Model B dust transport and vaporization with MIGRAINe → provide impurities as input to ERO 2.0

➢ Experimental Strategy & Essential diagnostic

- Impurity powder dropper or piezoelectric injector
- Small and large size monodisperse B populations to probe different dust plasma collection regimes
- Record the injected dust trajectories
- Observe the ablated material and transported impurities with spectroscopic means
- Install witness plates on the divertor and mid-plane manipulators to measure the B film deposition

Validate** MIGRAINe and MIGRAINe + ERO 2.0 workflow for **B – a material with poorly known surface properties



Plasma Phys. Control. Fusion **65** (2023)

MIGRAINe calculations for selected ITER scenarios: Atomic mass source from dust vaporization

Looks can be deceiving: 'dust transport codes' are less about transport and more about **heating**

The MIGRAINe dust transport code boasts the most complete description of microphysical processes and features a reactor-relevant plasma collection model → both are critical for accurate **heat balance description**

Device	# Pulses	# Development
AUG	8	1-2 (reference L-mode scenario tbd)

130 : Validation of the modelling of boron powder injection and boron film deposition

➢ Proponents and contact person

S. Ratynskaia srat@kth.se, P. Tolias, S. Brezinsek, K. Krieger, V. Rohde, T. Lunt, D. Matveev, J. Romazanov, M. De Angeli, T. Wauters, R. A. Pitts

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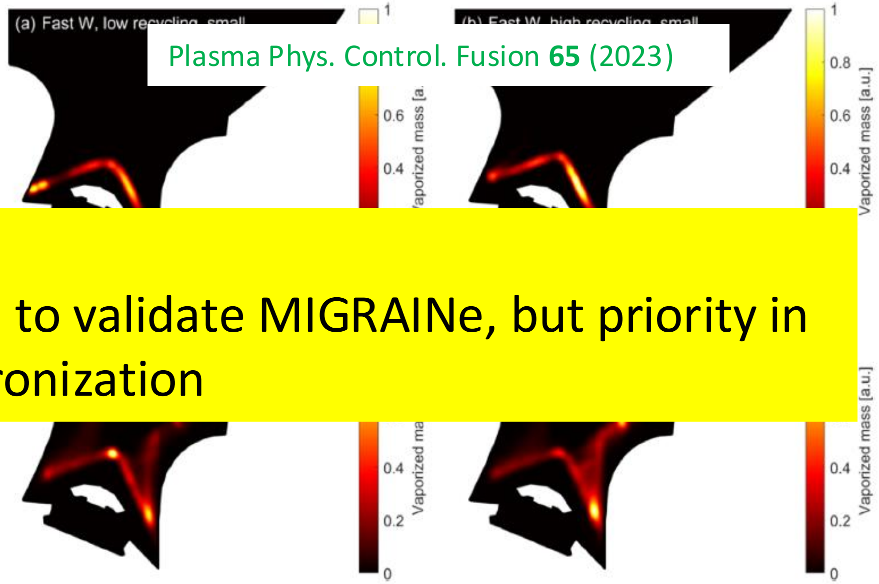
- Small and large size monodisperse B populations to probe different dust plasma collection regimes
- Record the injected dust trajectories
- Observe the ablated material and transported impurities with spectroscopic means
- Install witness plates on the divertor and mid-plane manipulators to measure the B film deposition

Validate** MIGRAINe and MIGRAINe + ERO 2.0 workflow for **B – a material with poorly known surface properties

Priority: P2
Interesting proposal to validate MIGRAINe, but priority in 2025 = standard boronization



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The MIGRAINe dust transport code boasts the most complete description of microphysical processes and features a reactor-relevant plasma collection model → both are critical for accurate **heat balance description**

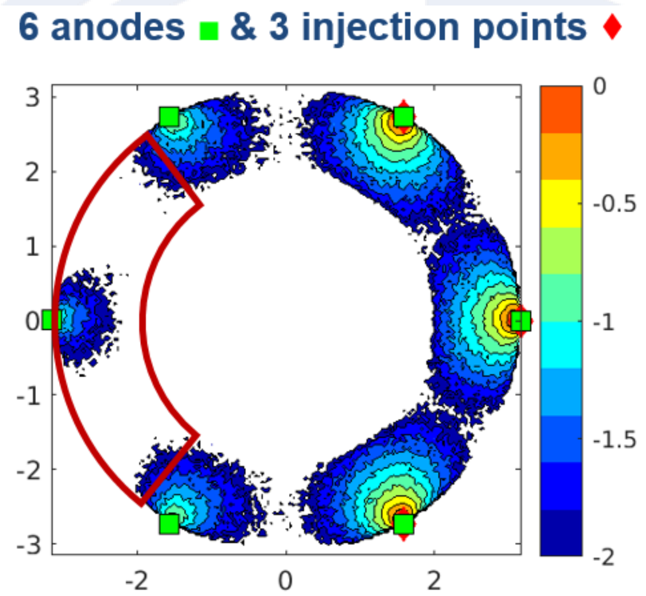
Device	# Pulses	# Development
AUG	8	1-2 (reference L-mode scenario tbd)

131 : Effect of spatially (non-)uniform boronization on plasma parameters, wall retention and B-rich layer properties

- **Proponents and contact person:**
- A. Gallo, M. Diez, T. Dittmar, E. Hodille, J. Gaspar. E. Geulin, L. Laguardia, P. Manas, P. Puglia, N. Rivals, T. Wauters

- **Scientific Background & Objectives**
  - Full-W wall in ITER calls for quantitative studies on boronization
  - Minimum B mass needed to operate while respecting T budget?
  - Minimum number / optimal position of glow electrodes?
  - Minimum number / optimal position of B_2D_6 injections?

- **Experimental Strategy / Constraints / Diagnostics**
  - Non-uniform boronization in WEST (3/6 glow electrodes)
  - Non-uniform boronization in WEST (any of 6 B_2D_6 injections)
  - 2 new probes to collect B layer profiles during boronization
  - Dedicated pulses to compare plasma before/after boronization
  - Compare effects with modeling of glow discharge by ITER



Proposed pulses

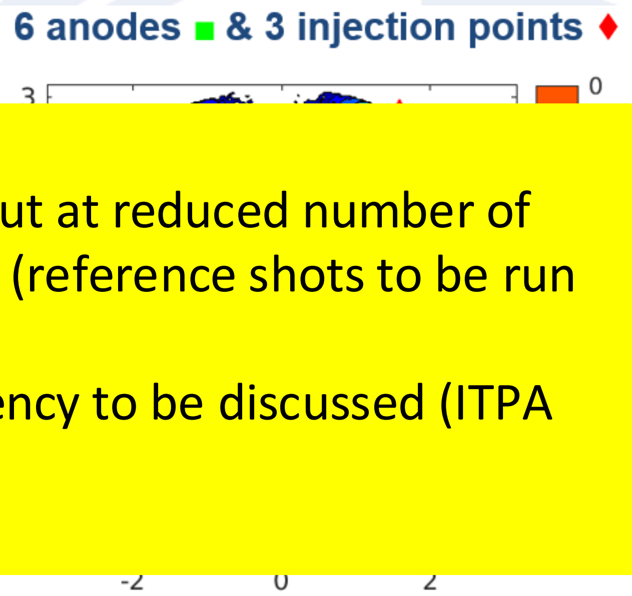
Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	180 + 4 boronization days	

131 : Effect of spatially (non-)uniform boronization on plasma parameters, wall retention and B-rich layer properties

- **Proponents and contact person:**
  - A. Gallo, M. Diez, T. Dittmar, E. Hodille, J. Gaspar. E. Geulin, L. Laguardia, P. Manas, P. Puglia, N. Rivals, T.

- **Scientific Background & Objectives**
  - Full-W wall in ITER calls for quantitative st
  - Minimum B mass needed to operate while
  - Minimum number / optimal position of glo
  - Minimum number / optimal position of B_2

Priority: P1
High priority R&D for ITER, but at reduced number of boronisation set ups / shots (reference shots to be run regularly)
Metrics to assess GDB efficiency to be discussed (ITPA DivSOL)
To be combined with #132



- **Experimental Strategy / Constraints / Diagnostics**
  - Non-uniform boronization in WEST (3/6 glow electrodes)
  - Non-uniform boronization in WEST (any of 6 B_2D_6 injections)
  - 2 new probes to collect B layer profiles during boronization
  - Dedicated pulses to compare plasma before/after boronization
  - Compare effects with modeling of glow discharge by ITER

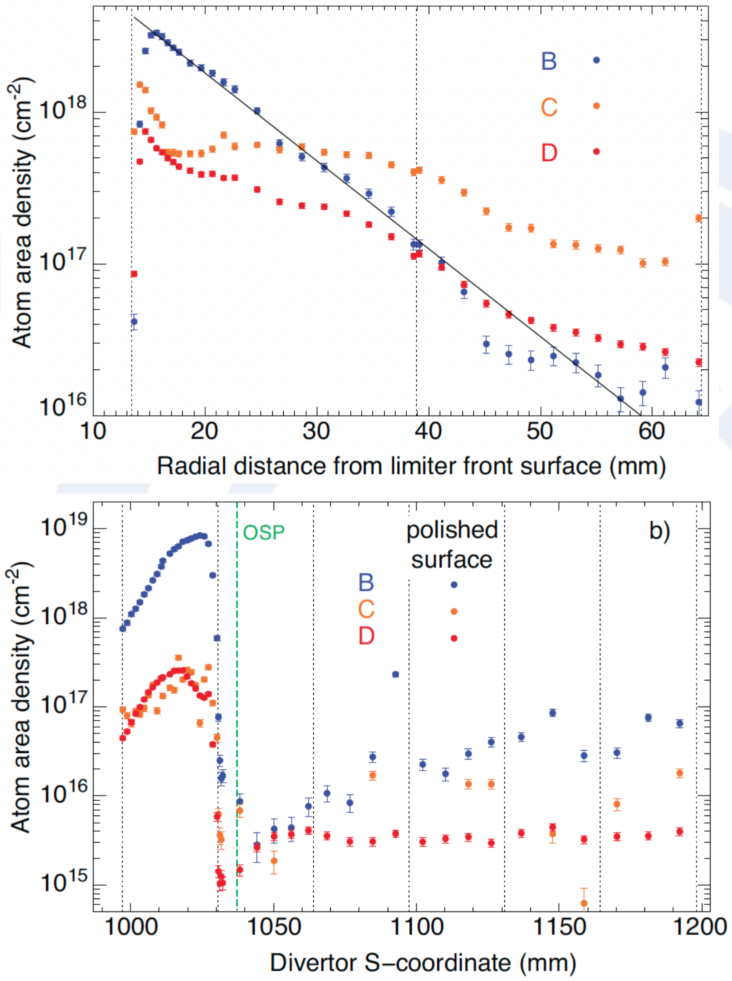
Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	180 + 4 boronization days	

132 : Efficiency and lifetime of boronisation

- **Proponents and contact person**
  M. Balden, S. Brezinsek, A. Gallo, A. Hakola,
  K. Krieger, J. Likonen, V. Rohde, T. Wauters
- **Scientific Background & Objectives**
  - Build on previous experiments in AUG&WEST where boron redistribution was studied during boron powder injection in running plasma discharges and apply a similar methodology to the study of B redistribution following GDB
- **Experimental Strategy & Essential Diagnostic**
  - Apply GD boronisation in devices AUG and/or WEST and document efficacy and lifetime of the boronisation effects
  - a) in-situ measured parameters (neutr. pressure, imp. flux, imp. conc., recycl. flux)
  - b) ex-situ analysis of exposed witness samples
  - If available use isotopically enriched $^{10}B_2D_6$ or $^{11}B_2D_6$
  - If available compare GDB in D2 with GDB in He and with B-powder dropper operation

[1] B deposition in main chamber and divertor, after B powder injection, K. Krieger et al. (2023)



Device	# Pulses	# Development
AUG	10+7	Reference pulses to be identified from previous studies
WEST	12+7	Reference pulses to be identified from previous studies

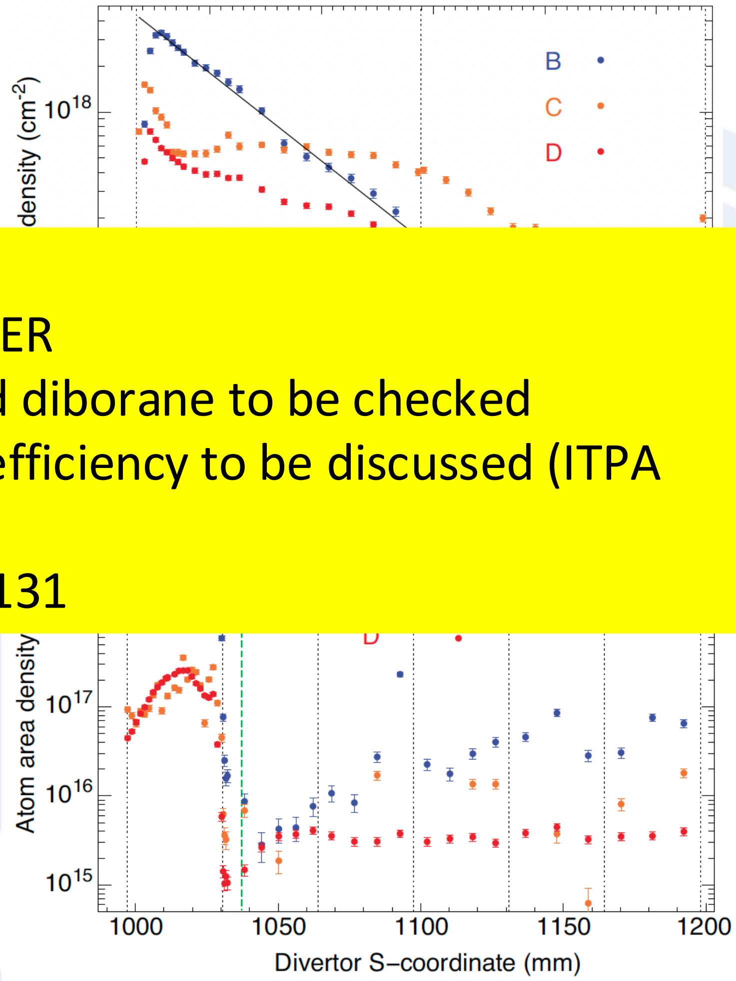
132 : Efficiency and lifetime of boronisation

- **Proponents and contact person**

  M. Balden, S. Brezinsek, A. Gallo, A. Hakola,
  <u>K. Krieger</u>, J. Likonen, V. Rohde, T. Wauters

- **Scientific Background & Objectives**
  - Build on previous experiments in AUG&WEST where b was studied during boron powder injection in running and apply a similar methodology to the study of B red GDB

- **Experimental Strategy & Essential Diagnostic**
  - Apply GD boronisation in devices AUG and/or WEST and document efficacy and lifetime of the boronisation effects
  - a) in-situ measured parameters (neutr. pressure, imp. flux, imp. conc., recycl. flux)
  - b) ex-situ analysis of exposed witness samples
  - If available use isotopically enriched $^{10}B_2D_6$ or $^{11}B_2D_6$
  - If available compare GDB in D2 with GDB in He and with B-powder dropper operation



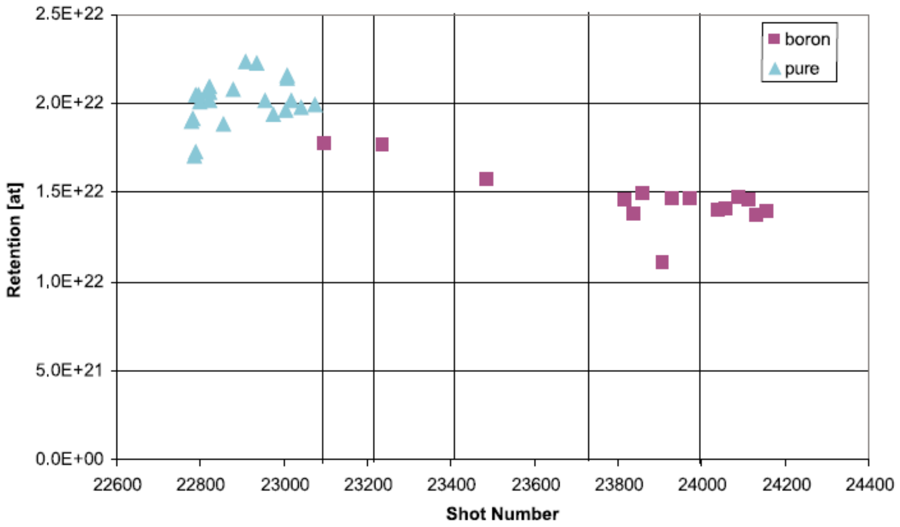
Priority: P1
High priority R&D for ITER
Feasibility of B enriched diborane to be checked
Metrics to assess GDB efficiency to be discussed (ITPA DivSOL)
To be combined with #131

Device	# Pulses	# Development
AUG	10+7	Reference pulses to be identified from previous studies
WEST	12+7	Reference pulses to be identified from previous studies

[1] B deposition in main chamber and divertor, after B powder injection, K. Krieger et al. (2023)

137 : Particle balance in AUG as a measure of global D retention in pulses following fresh boronisation

- **Proponents and contact person**
  D. Matveev, S. Brezinsek, V. Rohde, T. Wauters, …
- **Scientific Background & Objectives**
  - Fuel retention in as-deposited and re-deposited boron layers is a potential safety issue in full W ITER. Predictive estimates require validation in existing full W devices. Earlier analysis [1] mostly focused on pulses without boronisation.
  - Apply global particle balance analysis method to follow the evolution of in-vessel fuel retention in-pulse and in short-term as a function of plasma time after boronization.
- **Experimental Strategy & Essential Diagnostic**
  - Re-calibrate all relevant neutral gas diagnostics (pressure gauges, pumping speeds, RGAs, …)
  - Execute reference pulses prior and repetitively after boronization to follow the evolution of in-vessel retention
  - Essential diagnostics:
    - Pressure gauges
    - Optical Penning
    - RGAs
    - Plasma spectroscopy
    - Core plasma density (LIDAR/HRTS/…)

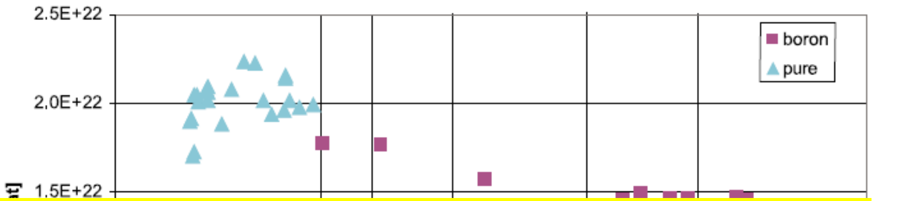


Wall retention needed to reach steady-state conditions
Cyan triangles - data for non-boronized wall
Magenta squares - after boronizations (vertical lines)

[2] V. Rohde et al., PPPCF 51 (2009) 124033
doi:10.1088/0741-3335/51/12/124033

Device	# Pulses	# Development
AUG	>10+7	Reference pulse to be identified from previous studies and in connection to relevant proposals, such as “Boronization efficiency”

137 : Particle balance in AUG as a measure of global D retention in pulses following fresh boronisation



- **Proponents and contact person**
  D. Matveev, S. Brezinsek, V. Rohde, T. Wauters, …
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  - Re-calibrate all relevant neutral gas diagnostics (pressure gauges, pumping speeds, RGAs, …)
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  - Essential diagnostics:
    - Pressure gauges
    - Optical Penning
    - RGAs
    - Plasma spectroscopy
    - Core plasma density (LIDAR/HRTS/…)

Priority: P1
High priority R&D for ITER
To be combined with #131/132 defining reference shot suitable for gas balance / boronisation monitoring
Results to be compared with similar gas balance experiments carried out in WEST

Cyan triangles - data for non-boronized wall
Magenta squares - after boronizations (vertical lines)

[2] V. Rohde et al., PPPCF 51 (2009) 124033
doi:10.1088/0741-3335/51/12/124033

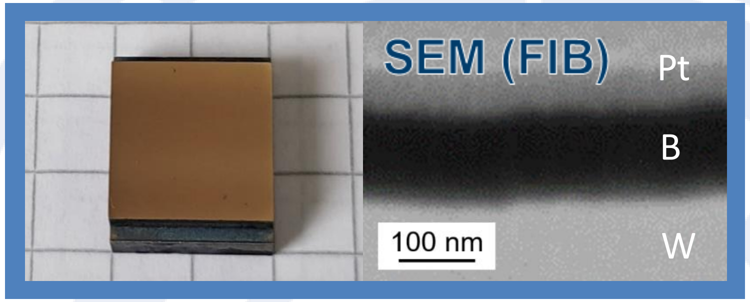
Device	# Pulses	# Development
AUG	>10+7	Reference pulse to be identified from previous studies and in connection to relevant proposals, such as “Boronization efficiency”

135 : Preparation of B reference samples

- **Proponents and contact person:**
  T.dittmar@fz-juelich.de, An.houben@fz-juelich.de

- **Scientific Background & Objectives**
  Investigation of B coatings fabricated in different fusion devices:
  - Comparison of composition of B layer
  - Study of the mechanism of the impurity gettering of the boron layer during boronization
  - Comparison with laboratory samples
  - Identical tungsten substrate samples

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Pre-characterized samples exposed on manipulator systems during boronization
  - samples must be retrieved before normal plasma Operation and should be carried in air/humidity tight containers.



Proposed pulses

Device	# Pulses/Session	# Development
AUG	During boronization	
MAST-U		
TCV		
WEST	During boronization	

135 : Preparation of B reference samples

- **Proponents and contact person:**
  T.dittmar@fz-juelich.de, An.houben@fz-juelich.de

Priority: Boro-P1
Will allow cross comparison of B layers from lab vs tokamaks (PWIE)
Sample handling challenging (no air exposure)

- **Scientific Background & Objectives**
  Investigation of B coatings fabricated in different fusion de
  - Comparison of composition of B layer
  - Study of the mechanism of the impurity gettering of the boron layer during boronization
  - Comparison with laboratory samples
  - Identical tungsten substrate samples

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Pre-characterized samples exposed on manipulator systems during boronization
  - samples must be retrieved before normal plasma Operation and should be carried in air/humidity tight containers.

Proposed pulses

Device	# Pulses/Session	# Development
AUG	During boronization	
MAST-U		
TCV		
WEST	During boronization	

123 : Mirror exposure during boronizations : Exploring impact of boronizations on mirror reflectivity and contamination of a mirror surface

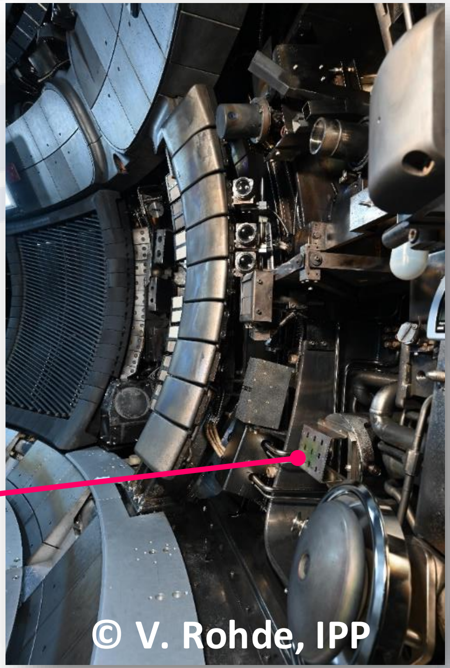
- **Proponents and contact person:**
- A. Litnovsky a.litnovsky@fz-juelich.de , S.Brezinsek, K. Krieger, V. Rohde, E. Tsitrone

- **Scientific Background & Objectives**

With a change of plasma-facing material to tungsten in ITER the use of boronization seems to be inevitable. An impact of boronization on the contamination of diagnostic mirrors is an acute research topic. Further, the capability of *in-sit*u ITER mirror cleaning systems to efficiently remove boron-containing deposits from the mirror surface must be validated. The study will address the following objectives:

- Expose pre-characterized diagnostic mirrors made of single crystal molybdenum to the series of routine boronization campaigns in ASDEX Upgrade
- Study the deposition efficiency and elemental composition of deposits
- Reveal the effect of deposition of boron-containing deposits on mirror reflectivity
- Study the homogeneity of boronization
- Study combined effect of boronization and plasma operation on deposition on mirror surface
- Provide samples for dedicated mirror cleaning studies
- Provide input for a dedicated ITER modeling

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Plan : accompany three routine boronization campaigns. The latest campaign followed by plasma restart and regular plasma operation. No specific plasma discharges needed.
- Availability of LBO manipulator in AUG along with routine boronization monitoring system are essential



LBO manipulator with samples in AUG

Proposed pulses

Device	# Pulses/Session	# Development
AUG	Accompanying activity for routine boronization and plasma operation campaign	
WEST	tbd	tbd

123 : Mirror exposure during boronizations : Exploring impact of boronizations on mirror reflectivity and contamination of a mirror surface

- **Proponents and contact person:**
- A. Litnovsky a.litnovsky@fz-juelich.de , S.Brezinsek, K. Krieger, V. Rohde, E. Tsitrone

Priority: Boro-P1
Impact of GDB on mirror : ITPA Diags
LBO manipulator availability to be checked

- **Scientific Background & Objectives**

With a change of plasma-facing material to tungsten in ITER the inevitable. An impact of boronization on the contamination of c research topic. Further, the capability of *in-situ* ITER mirror clea boron-containing deposits from the mirror surface must be validated. The study will address the following objectives:

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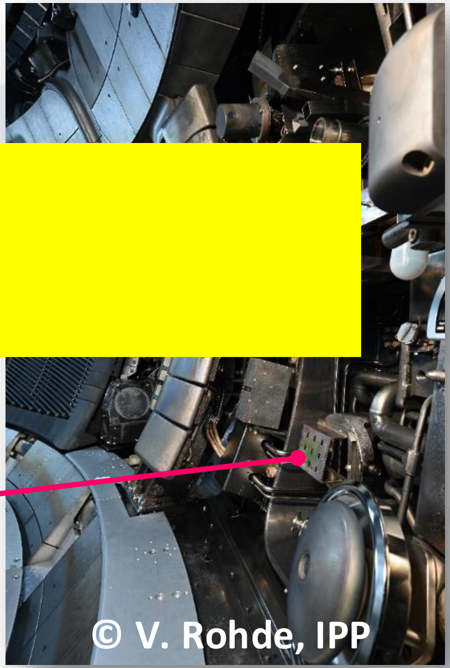
- Provide input for a dedicated ITER modeling



LBO manipulator with samples in AUG

Proposed pulses

Device	# Pulses/Session	# Development
AUG	Accompanying activity for routine boronization and plasma operation campaign	
WEST	tbd	tbd

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Plan : accompany three routine boronization campaigns. The latest campaign followed by plasma restart and regular plasma operation. No specific plasma discharges needed.
- Availability of LBO manipulator in AUG along with routine boronization monitoring system are essential

Activities to be continued on JET data analysis in 2025

High priority items to be continued from JET

Fuel retention / recovery

- Further analysis of overall gas balance in DTE3 (+DTE2) (in particular once T accountancy completed)
- Modelling of fuel retention during DTE3 / fuel recovery post DTE3
- Further analysis of LID QMS data, in particular evolution during DTE3 clean up
- Comparison of LIBS s LID QMS data for consistency (with PWIE)

(Much) longer term : consistency of gas balance / laser diags measurements with sample post mortem analysis

Material migration

- Further analysis and modelling of W prompt redeposition experiment
- Completion of Be erosion studies + publication

He campaign

- Further analysis / modelling of the (no) W fuzz formation (more insight from visual inspection once tiles removed ?)

NB : data analysis from previous campaigns under RT11

In summary ...

Summary of the proposals and their priorities

#	Title	Main Proponent	Priority
129	W PFC damage induced by runaway electron incidence	S. Ratynskaia	P1
139	Exposure of pre-damaged PFUs (pred#2 & pred#3) - follow up	A. Durif	P1 (self castellation)
140	Exposure of pre-damaged INTERFACE PFU	A. Durif	P2
141	High particle fluence campaign in highly radiative divertor regime on WEST	Y. Corre	P1 (shared TE/internal)
136	Study of non-ambipolar currents on WEST	M. Dimitrova	P2-PB
122	Use of N seeding to study the contribution of ICRH antennas to W core content in WEST	C. Guillemaut	P2
124	Characterize plasma surface interactions in presence of Ne	G. Urbanczyk	P2
127	Mo erosion and migration from ICRF antenna limiter coated tiles	G. Urbanczyk	P1
128	Coupling 1MW ICRF with a propagative Slow Wave	G. Urbanczyk	P2
133	Charge exchange particle flux to 1st wall	K. Krieger	P1 (PB)
134	W erosion and transport with post-mortem analysis	J. Romazanov	P1 (L mode part)
142	W prompt redeposition	J. Romazanov	P2
138	Spectroscopic estimation of Chemically Assisted Physical Sputtering of boron	E. Pawelec	P2-PB
126	Wall isotope changeover with ICWC	E. Lerche	P1
125	Boron removal with ICWC	E. Lerche	P2 (PB ?)
130	Validation of the modelling of boron powder injection and boron film deposition	S. Ratynskaia	P2
131	Effect of spatially (non-)uniform boronization on plasma parameters, wall retention and B layer properties	A. Gallo	P1 (reduced nb of shots), combine #132
132	Efficiency of boronisation procedures	K. Krieger	P1, combine #131
137	Particle balance in AUG as a measure of global D retention in pulses following fresh boronisation	D. Matveev	P1, combine #131-132
135	Preparation of reference samples from boronisation	T. Dittmar	**P1-boro**
123	Exploring impact of boronizations on mirror reflectivity and contamination of a mirror surface	A. Litnovsky	**P1-boro**

Concluding remarks

- Proposals covering **high priority issues for ITER new baseline** with AUG/WEST cross machines comparison : runaway impact on first wall, first wall W erosion, boronisation
- Strong overbooking of both machines, so that only P1 proposals could be accomodated as main programme
  - If/when possible, some P2 proposals could be partially run PB on P1 shots (using end of shots ...)

RT06 R&D area	AUG	WEST
PFC evolution / damage (D1-D2)	**Runaway impact on first wall #129**	
		Self castellation exposure # 139
		High Fluence (~100 shots) #141
Material migration (D3)	ICRH W source (Mo vs W) #127	
	First wall erosion (WEST PB tbc) #133 and 134	
Fuel retention/recovery/ wall conditioning (D4-D5-D7)	**Boronisation lifetime + gas balance + sample/mirrors exposure #131, 132, 137 + 135, 123 (PWIE)**	
		ICWC changeover #126
Shot allocation	30*	180

* AUG might have additional budget from the fall campaign

Now open for discussion !