WPTE GPM 05th November 2025

RT-05: Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation

N. Vianello

On behalf of WPTE TFLs
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Research Topic Coordinators
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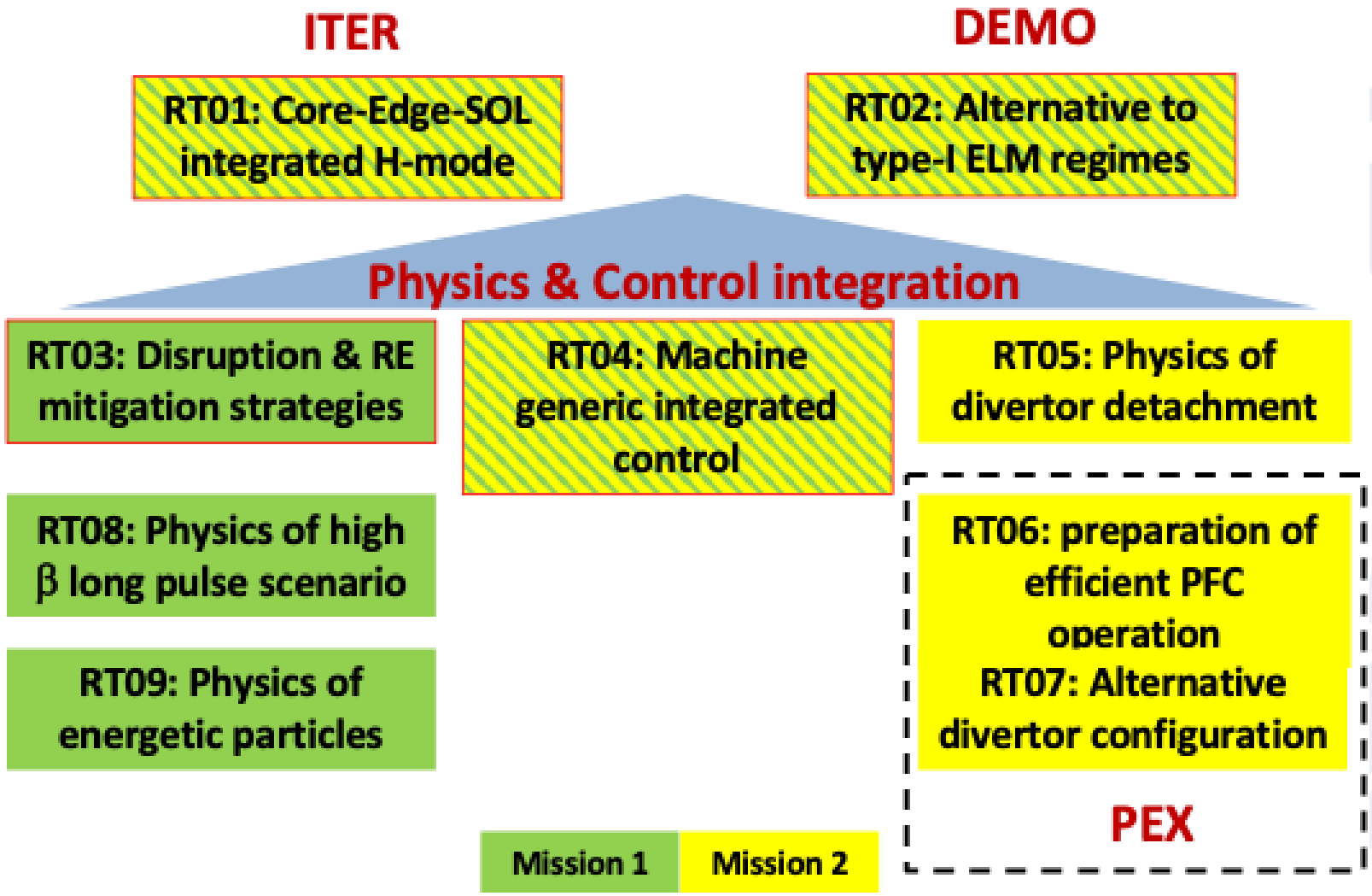
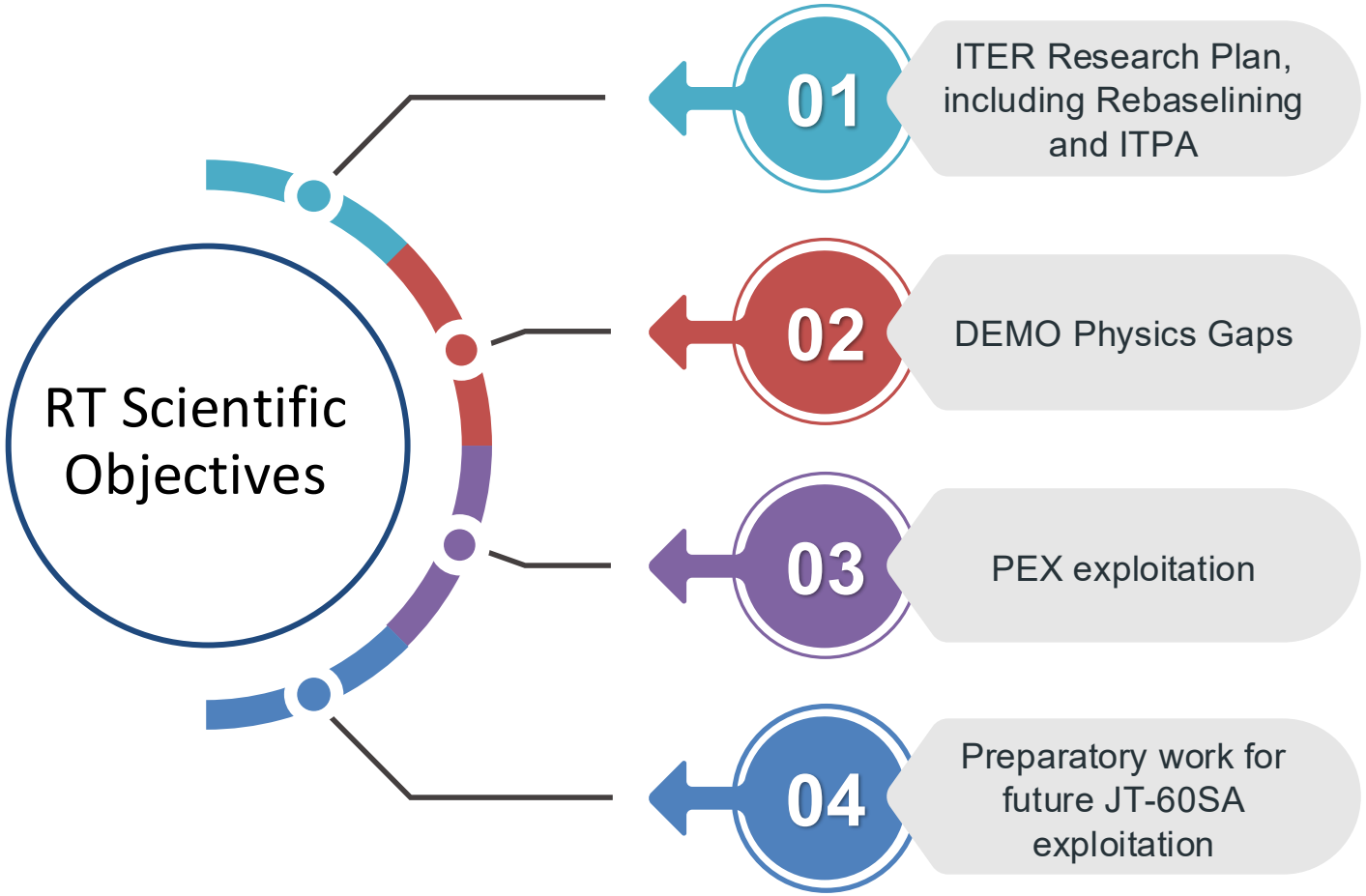
Introduction

RT05 is investigating the detachment physics and possible scenarios at high-radiation fraction which are of potential interest for ITER and next step



Prioritization scheme and criteria



Proposal Evaluated according to the criteria:

Adherence to the Scientific Objectives

Team effort

Size and feasibility

P1-2026-DEV: experimental priority for 2026: machine time granted but pulse budget might need reduction

P1-2027-DEV: experimental priority for 2027: machine time granted but pulse budget might need reduction

P2-DEV: will be done if time allows after *all* P1 proposals are completed

P3: low priority programme/out of scope

PB: piggy-back experiment/pure analysis proposal

Scientific Objectives and Machine Time

#	Scientific Objectives for 2026-2027	SSRL (to be re-evaluated at the end of 2025)
D1	Characterize detachment access and core plasma performance in scenarios using different fuelling schemes, different impurity mixtures	Mature (needs underpinning)
D2	Develop reduced physics model which can be included in radiative detachment control schemes or extrapolations to DEMO/ITER	Mature (needs underpinning)
D3	Quantify edge-SOL particle, impurity, and heat transport, above and below the X-point under detached conditions	Judgemental
D4	Assess the compatibility and stability in terms of overall confinement of X-point radiator regimes	Judgemental
D5	Quantify the degree of ELM heat load mitigation achievable by impurity seeding, investigating the dependences on relevant machine parameters	Judgmental
D6	Assess the evolution of detachment under slow transients (L-H transitions, sawtooth, loss of impurity seeding)	Mature (needs underpinning)

Proposals received (Scientific/Scenario Dev.)				
	AUG	MAST-U	TCV	WEST
RT05	100 / 33	57 / 12	150 / 58	174 / 15

Summary of proposals (24)

No	Proposal name	Proposer
88	Impulsive detachment experiments for SOLPS-ITER and JOREK time-dependent validation	F. Cursi
89	Helium transport, source localization and wall recycling in single-null divertor plasmas	A. Perek
90	Characterization of the ion temperature turbulence at x-point and midplane locations for different regimes	J. Adamek
91	Exploration of the XPR regime in open and closed geometry	S. Henderson
92	How far inwards can the XPR be pushed while staying in QCE?	M. Faitsch
94	Interplay between core and edge radiation for detachment	P. David
95	ELM buffering in conventional divertor configuration including real-time control	M Komm
96	Relation between n_sep and impurity throughput, p0div and impurity concentration for reduced SOL models	D. Silvagni
97	Nitrogen distribution, compression and core contamination: investigation of seeding location, L/H-mode, dynamic behavior	R. Morgan
98	XPR: Extension of operational space and increase of performance	M. Bernert
99	Flow characterization in the Scrape-Off Layer	R. Ducker
100	Characterization of the X-point radiator with horizontal and vertical equilibrium sweeps in H-mode	M. Szucs
101	Edge turbulence characterization with the MEM and the XPM for the XPR regime at low heating at AUG	Yu-Chih Liang
102	X-machine exploration of pellet fueling compatibility with X-Point Radiation (XPR) regimes	E. Geulin
103	Integral XPR scenario from X-Point formation to ramp-down at WEST	N. Rivals
104	H-mode Density Limit (HDL) with impurity seeding	C. Perez von Thun
105	Cross-machine-scaling for far-SOL density decay with metallic walls (unseeded)	C. Perez von Thun
106	Seeding effect on scrape-off layer profiles and fluctuations	A. Stagni
107	Physics of plasma-neutral interactions for ITER and beyond	K. Verhaegh
108	Detachment control in EDA H-mode	L. gil
110	Evaluation and Comparative Study of Fluctuation-Induced Transport in the SOL and First-Wall Interaction in Different Plasma Conditions in TCV	K. Singh
111	First-principles investigations of WEST L-mode detached plasmas at reduced Btor by validation of turbulence simulations	D Sales de Oliveira
112	First-principles investigation of boundary turbulence in seeded detached plasmas in the TCV-X21 scenario	D Sales de Oliveira
113	Divertor Ti profile in XPR	M. Dimitrova

#88 Impulsive detachment experiments for SOLPS-ITER and JOREK time-dependent validation

Proponents and contact person(s)

Federico.Cursi@kuleuven.be, D.Maris@differ.nl, Timo.Ravensbergen@iter.org, Javier.Artol
Xavier.Bonnin@iter.org, Richard.Pitts@iter.org, Gustavo.Grenfell@ipp.mpg.de, Matthias.Be
S.Wiesen@differ.nl, Wouter.Dekeyser@kuleuven.be, Martine.Baelmans@kuleuven.be

Scientific Background

- Shared effort to simulate time-dependent detachment with SOLPS-
  Leuven) and JOREK (D. Maris, DIFFER/TUe) to inform ITER detachm
- Successfully carried out impulsive detachment L-mode shots in AU
  puff (#42611/2,#42650/1), but upstream profiles were largely affec
  diagnostics missing (few LPs, divertor spectroscopy, XPM probe pos

Scientific Objectives

- Detachment transient in H-mode with step in N_2 seeding, with upst
  unaffected and full diagnostic coverage
- Validate and compare SOLPS-ITER and JOREK in time-dependent mode

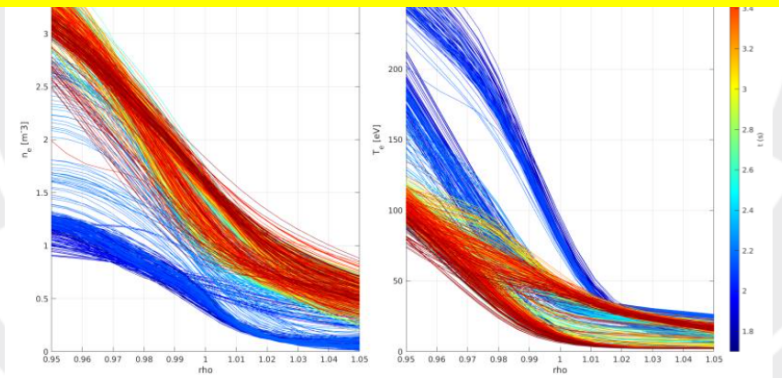
Experimental Strategy/Machine Constraints

- Repeat Ohmic L-mode shots (2 shots) with full diagnostic coverage (possibly USN?)
- H-mode shots at low power (5-7 MW) with step in N_2 seeding:
  - Attempt detachment with different N_2 puffs (3 shots scenario development)
  - Repeat with optimized N_2 puff to maintain steady conditions before and after transient, optimize for diagnostic measurements (3 shots)

Essential diagnostics: Langmuir probes, Divertor spectroscopy, Midplane & X-point Manipulator Probes, Thomson scattering (div & main chamber), Li-beams, ECE, He-beam, Ionization gauges, AXUV-diode & foil bolometry, CXRS, IR cameras, …

Continuation of an effort initiated in 2025 to validate detachment dynamic models (SOLPS-ITER time dependent/JOREK with kinetic neutral)
Address D1 and D2.
Suggested to:
1. Complete L-mode first
2. Discuss if transient can be properly embedded into discharges for general detachment studies/XPR exploitation

P1-AUG-2026



Device	# Pulses/Session	# Development
AUG	2 L-mode + 3 H-mode	3 H-mode

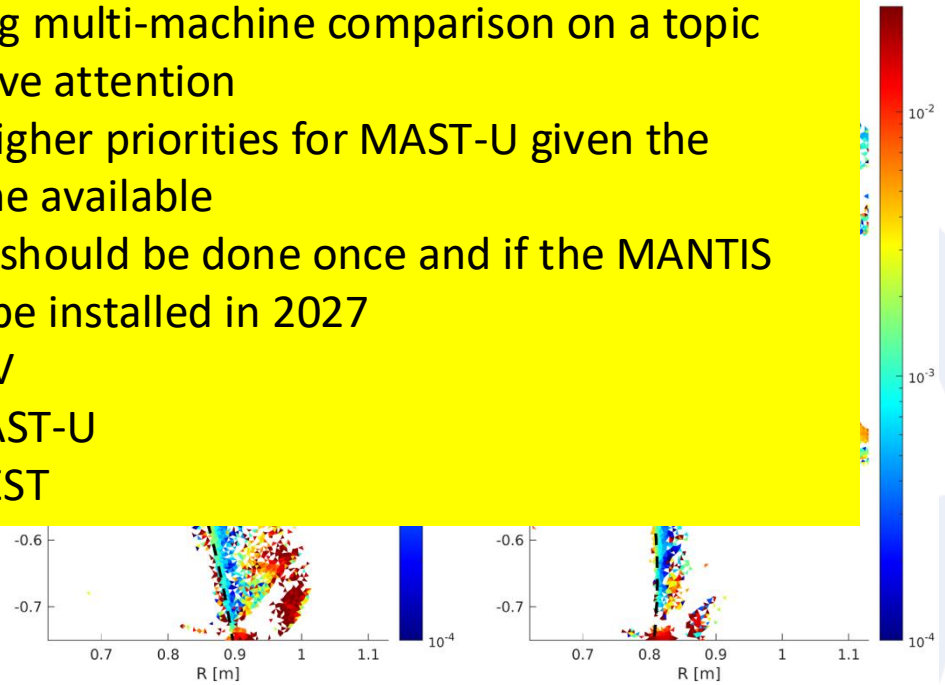
#89 - Helium transport, source localization and wall recycling in single-null divertor plasmas

- **Proponents and contact person:**
  - artur.perek@epfl.ch , ryoko.osawa@ukaea.uk , david.MOIRAF
- **Scientific Background & Objectives**
  - Helium exhaust at the edge and divertor remains inefficient co
    core.
  - 2D spectral imaging can provide poloidally resolved maps of ne
    ionised helium to measure source localisation.
  - By varying helium puff rate and location, the study will identify
    helium transport, validate SOLPS-ITER modelling, and quantify helium
    transport and poloidal gradients approaching detachment.
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Unseeded L-mode discharges with varying helium gas puff location and rate | requires absolutely calibrated gas valves.
  - H-mode controlled XPR discharges with additional heating.
  - 2D spectral imaging, spectroscopy, and residual gas analysers are essential. Coherence imaging spectroscopy is highly desirable.

1. Interesting multi-machine comparison on a topic which deserve attention
2. Not the higher priorities for MAST-U given the machine time available
3. On WEST should be done once and if the MANTIS system will be installed in 2027

P1-2026-TCV
P2-2026-MAST-U
P2-2027-WEST

2D neutral helium concentration inferences



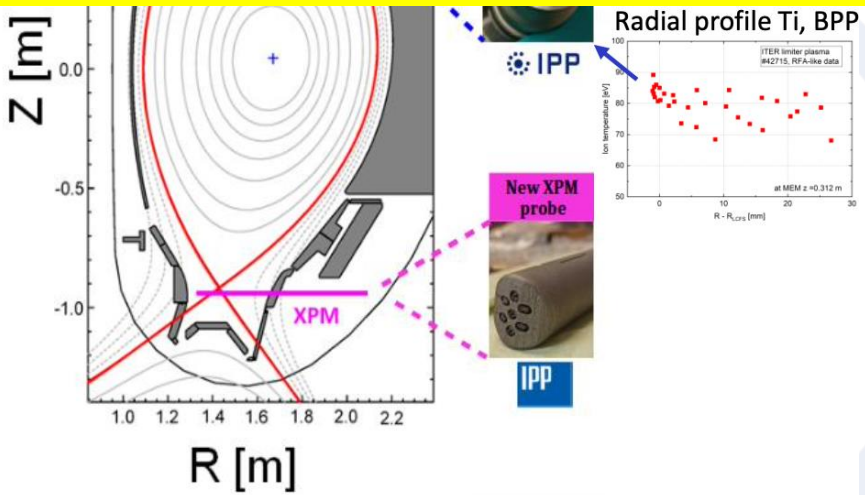
Proposed pulses

Device	# Pulses	# Hopr
AUG	-	-
MAST-U	20	2
TCV	32	3
WEST	24	3

#90 Characterization of the ion temperature turbulence at x-point and midplane locations for different regimes.

- **Proponents and contact person:**
  J. Adamek , J. Cavalier, G. Grenfell, D. Brida, Yu-Chih Liang, W. Fuller, S. Hörmann
- **Scientific Background:**
  Understanding the ion temperature and, in particular, its fluctuations in the scrape-off layer (SOL) of tokamaks. It is crucial for predicting the gross material erosion and heat flux to the plasma-facing components.
- **Objectives:**
  a) provide the ion temperature during filamentary transport during different regimes (QCE, X-point radiator) at (far)SOL downstream and upstream locations with high temporal resolution
  b) provide profiles of the ratio of Ti and Te
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  a) achieve QCE/XPR regime with both probe heads located only in the (far)SOL
  b) perform fast Ti (5 – 10 µs) measurements with dedicated probe heads (see figure) at X-point and midplane locations

To be checked how much perturbative would be the XP probe plunges for the scenarios proposed (XPR and QCE). In case prioritize the acquisition of far SOL from the MEM
P1-2026-AUG-PB



Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	3
MAST-U	0	0
TCV	0	0
WEST	0	0

#91 - Exploration of XPR access and stability in baffled and unbaffled geometry

Complete the exploration of XPR on MAST-U, providing path for a more stable scenario
P1-MAST-U-2026

Proponents and contact person:

S. Henderson, H. Sun, P. Ryan, D. Morbey, Q. Xia

Scientific Background

- Analytical XPR model shows dependency on neutral gas density at X-PT
- HL transitions frequently disrupt XPR scenarios on MAST-U, putting emphasis on finding an operational window avoiding back-transitions

Objectives

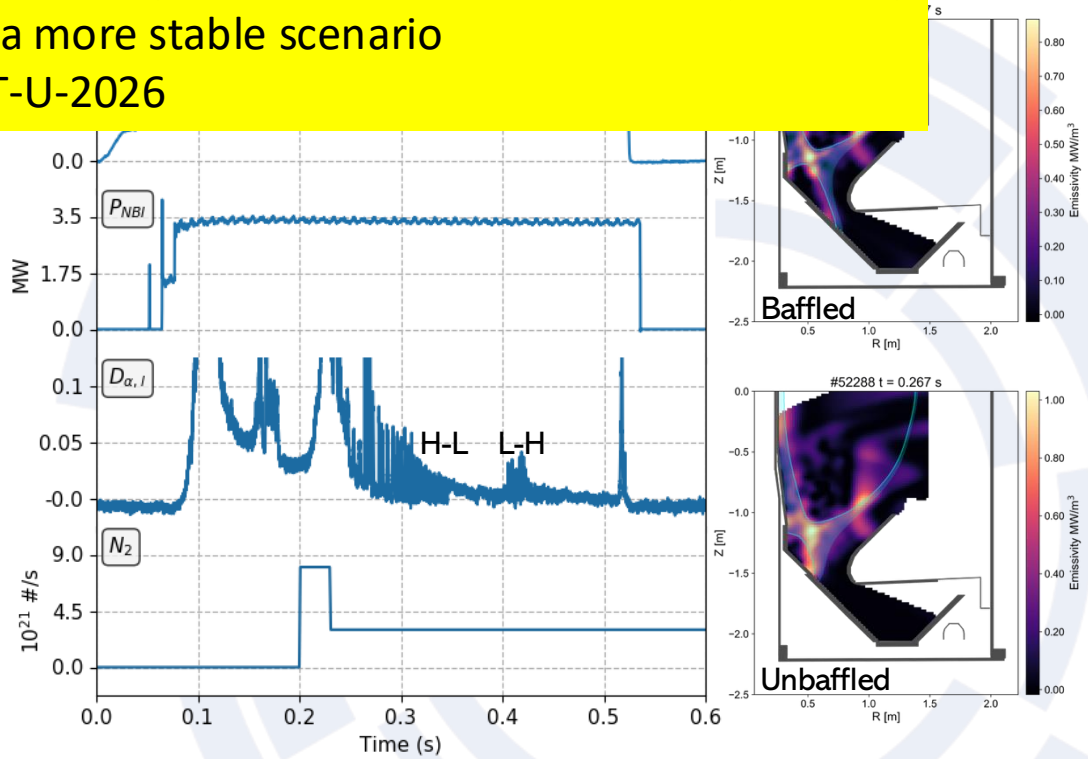
- Compare XPR access in scenarios with different neutral densities X-PT
- Assess SOL broadening in strongly seeded scenarios
- Determine XPR operational window in which HL transitions are avoided

Deliverables

- **D1** (Characterize detachment access); **D3** (Edge/SOL particle transport); **D6** (Evolution under slow transients)

Experimental Strategy

- N-seeded H-mode at max. power (3.5 MW)
- Stabilize two baffled and unbaffled divertor scenarios with an XPR
- Vary the elongation to change the distance between the X-point and target
- Compare two sets of seeding/fuelling rates for XPR access in each geometry
- Apply gas cuts to understand reattachment time in strongly detached conditions



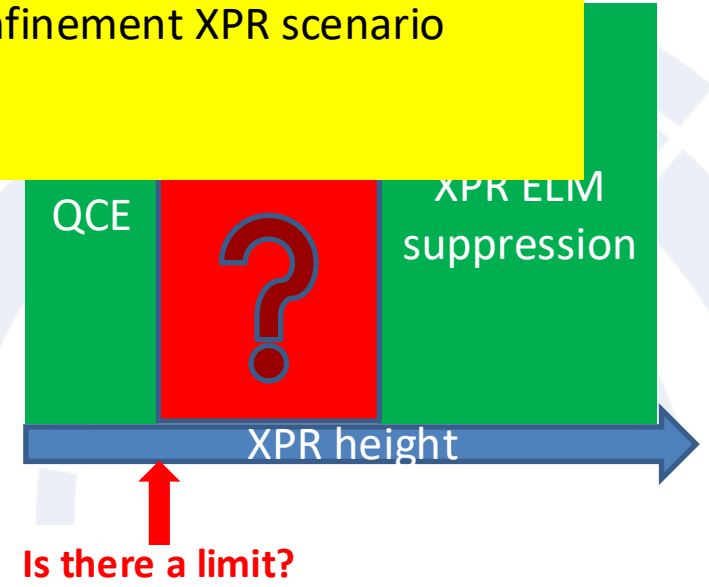
Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U	8	
TCV		
WEST		

#92 - How far inwards can the XPR be pushed while staying in QCE?

QCE operational space/shape might be explored on the path towards high-confinement XPR scenario explored in proposal #96
P1-AUG-2027

- **Proponents and contact person:**
  - Michael.Faitsch@ipp.mpg.de, Matthias.Bernert@ipp
    Mike.Dunne@ipp.mpg.de
- **Scientific Background & Objectives**
  - Demonstrate the relation between QCE and XPR
  - Quantify if there is a threshold at which QCE is lost once the radiator is moving further inside
  - Study if there is a smooth transition from QCE to XPR ELM suppression or what happens in between the two states.
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - execute feed-forward and feed-back seeding ramps/steps from a QCE reference and adjust the deuterium fuelling in order to stay in QCE as fas inside with the XPR as possible.



Proposed pulses

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

#94 - Interplay between core and edge radiation for detachment

Proposal trying to disentangle core/SOL radiation by means of heavy impurities radiating in the pedestal region (Kr). Due to budget constraints priorities given to qualification of XPR in view of potential ITER interest (rather than next step)
P2-AUG

- **Proponents and contact person:**
  - Pierre.David@ipp.mpg.de, Matthias.Bernert@ipp.m
    Michael.Faitsch@ipp.mpg.de, Dominik.Brida@ipp.m
- **Scientific Background & Objectives**
  - Optimize impurity mixes for detachment, in Feedfor
    and/or feedback
  - Assess interplay between core and edge radiation for detachment
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Reproduce existing detachment scan (light impurity seeding), but with various Paux yet constant Psep (heavy impurity seeding)
  - Add impurity seeding to existing partially detached scenarios without an XPR (typ. QCE) to try to achieve full detachment

Proposed pulses

Device	# Pulses/Session	# Development
AUG	10+8	8
MAST-U	-	-
TCV	-	-
WEST	-	-

#95 ELM buffering in conventional divertor configuration including real-time control

Nice multi-machine proposal, also aiming to exploit one of the TE-Enhancement program. Well defined strategy for all devices
P1-AUG-2026
P1-TCV-2026
P2-MAST-U

- **Proponents and contact persons:**

M. Komm (komm@ipp.cas.cz), R. Scannell (rory.scannell@ukaea.uk), M. Zurita (martim.zurita@epfl.ch), Jack Flanagan, S. Henderson, M. Faitsch, D. Silvagni, M. Be O. Kudlacek, M. Astrain, H. Reimerdes

- **Scientific Background & Objectives**

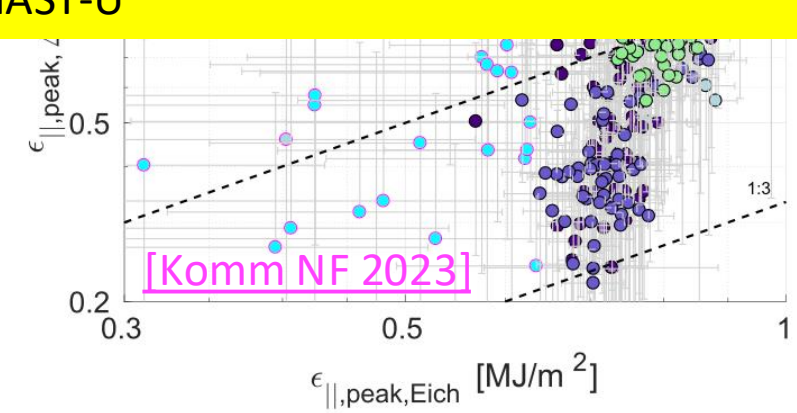
Directly linked to RT05-22: D5

- **Objectives at AUG**

1. Simultaneous observation ELM impact on both divertor targets by IR camera (at the top divertor)
2. Measurements of Te in ELM filaments by recipr. manipulators
3. Effect of divertor closure - comparison between ELM buffering in the bottom closed divertor and open upper divertor
4. Optimisation of the impurity mixture for simultaneous high ELM buffering and good confinement
5. **Development of a real-time controller for the ELM impacting energy/fluence using shunt current measurements**
6. Effect of seeding termination on the duration of ELM buffering **Objectives at MAST-U**
7. Develop an ELM buffering scenario both for the conventional and long divertor leg **Objectives at TCV**
8. Assess the effect of seeding location & baffling on ELM buffering

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

- Type I ELMy plasma with the AUG lower and upper divertor
- Divertor IR thermography
- Stable H-mode scenario with impurity seeding at MAST-U



Proposed pulses

Device	# Pulses/Session	# Development
AUG	13 pulses	9 pulses
MAST-U	5 pulses	10 pulses
TCV	11 pulses	21 pulses
WEST		

#96 Relation between n_{sep} and impurity throughput, p_{0div} and impurity concentration for reduced SOL models

- **Proponents and contact person:**
- D. Silvagni, S. Henderson, D. Brida, B. Lomanowski (full l
in wiki)

- **Scientific Background & Objectives**
  - Nsep prediction key for confinement, detachment, ELM avoidance, disruption
  - Impact of combination of Γ_D and Γ_Z on n_{sep} (and on c_Z and p_{0div}) nontriv
from simulations: if Γ_D and Γ_Z increase accordingly to keep c_Z constant,
does not change, despite increase in p_{0div} [Pitts NME 2019, Lore NF 202
  - Goals:

1) Determine the relationship between n_{sep} and Γ_D and Γ_Z
2) Determine how c_Z and p_{0div} depend on Γ_D and Γ_Z
3) Develop reduced models able to recover experimental findings (D2)

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

Similar for AUG and MAST-U:
- 1 unseeded reference with 5 Γ_D levels
- 5 discharges with same Γ_Z staircase and different background Γ_D levels (N seeding)
- 5 discharges with same Γ_Z staircase and different background Γ_D levels (Ar seeding)
- 1 discharge where Γ_D and Γ_Z increase linearly at different rates to keep c_Z constant --> experimental proof that n_{sep} does not change
- Good edge profile data, spectroscopy, Langmuir probes
- For MAST-U, focus only on two levels of N and D

Proposal aiming to disentangle role of fuelling of main gas and seeding of impurities on ne,sep, p0,div, and cZ to further expand reduced model prediction capabilities of ne,sep. Overall matrix of Gas/seeding to be reduced to cope with lower shot budget. Synergies should be found with proposals #104 and #106 on the overall effort on impurities effects on separatrix (including transport)
P1-AUG-2026
P1-MAST-U-2026

Proposed pulses

Device	# Pulses/Session	# Development
AUG	11	1
MAST-U	4	
TCV		
WEST		

#97 Nitrogen distribution, compression and core contamination: investigation of seeding location, L/H-mode, dynamic behavior

- **Proponents and contact person:**
  Riccardo.morgan@epfl.ch , ryoko.osawa@ukaea.uk et al.

- **Scientific Background & Objectives**
  - SOLPS simulations predicting very different behavior in impurity distribution for differe seeding locations
  - Experimental indications of toroidal asymmetries caused by non axisymmetric (localize seeding
  - Uncertainty on impurity transport timescales and recycling coefficient

  - Investigate the role of seeding location on impurity distribution/compression, access to detachment and core contamination in H-mode
  - Compare experimental measurements, including the 2D emission distribution, to SOLPS predictions
  - Obtain estimates of impurity transport timescales and recycling coefficient
  - Assess different behaviour of heavier impurities
- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Repeat same LSN, H-mode shot while changing poloidal location of seeding valve: PFR (v8), TOP(v2), LFS(v6), HFS(v4).

  - Compare nitrogen emission with MANTIS, bolometry, DSS

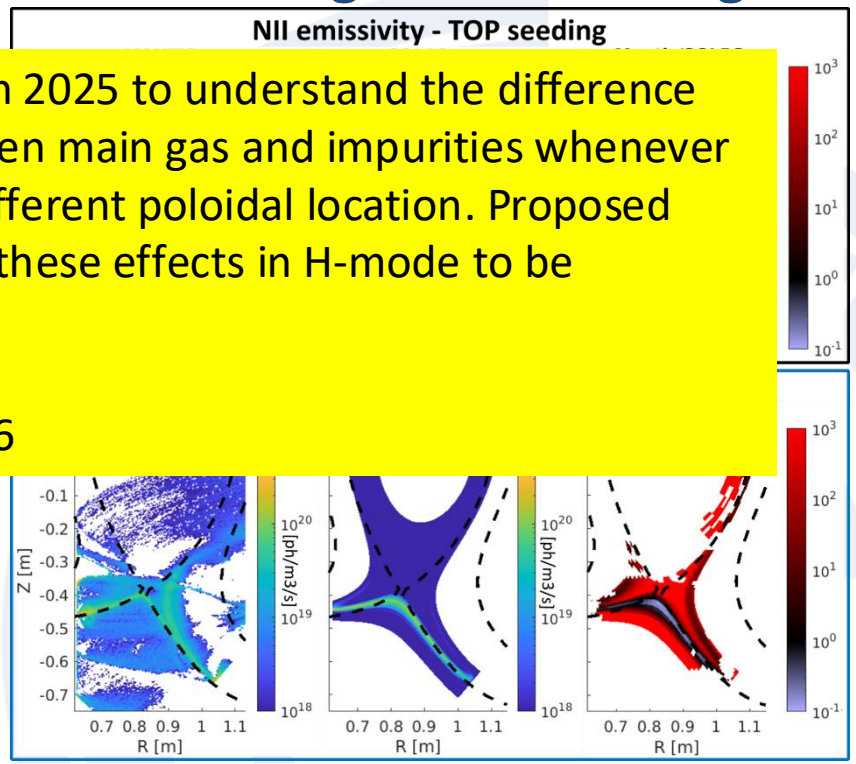
  - Compare effects on heat fluxes with LPs, IR camera

- Repeat same LSN, L-mode shot while changing toroidal location of seeding valve: toroidal angles 48, 111, 214, 310 (4 shots + 1 for reproducibility)

  - Compare fixed diagnostics signal with changing seeding location

- Compare the shots with new and/or existing SOLPS-ITER simulations
- Repeat 3-4 selected discharges while changing the seeding time trace
- Repeat poloidal fuelling location scan with Ar seeding

Effort initiated in 2025 to understand the difference observed between main gas and impurities whenever injected from different poloidal location. Proposed investigation of these effects in H-mode to be prioritized.
P1-TCV-2026
P2-MAST-U-2026



Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U	4	
TCV	30	30 (including wall cleaning)
WEST		

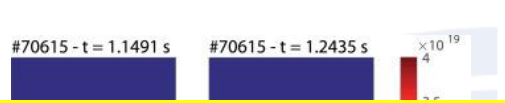
#98 - XPR: Extension of operational space and increase of performance

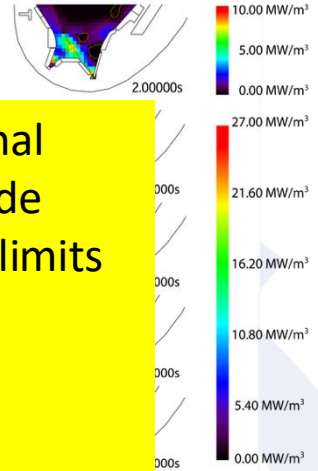
- **Proponents and contact person:**

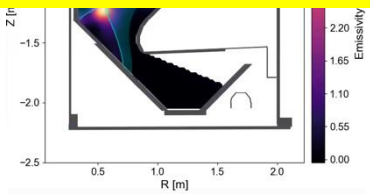
Matthias Bernert, Stuart Henderson, Holger Reimerdes, Nicolas Rivals, Pier
Fedorczak, Eléonore Geulin, M. Czarski, R. Mishra, K. Shingh, C. Theiler, Y. V

- **Scientific Background & Objectives**
  - XPRs exist at AUG, TCV, WEST & MAST-U, with different access con
    devices
  - The operational range in all machines should be extended, and sce
    optimized for performance (AUG/TCV/MAST-U: minimize confinem
    in H-mode, WEST: maximize confinement increase in L-mode)
  - This will be tried to overcome by avoiding internal modes (AUG) an
    tools to increase confinement (shaping, reduced gas puff, wall clearance) across machines
  - **Operational space extension**:
    - TCV: new control with MANTIS, higher power, Ne development
    - WEST: high plasma current scan, high density (+ECRH) scenarios, Argon development
  - **Performance optimization**:
    - Triangularity variations : AUG, TCV, MAST-U (incl. squareness), WEST
    - Upper divertor clearance scan (unscreened W source): WEST
    - Lower fueling: AUG
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Cross machine experiment, specific parameters for each device listed on wiki page

Workhorse proposal aiming to expand operational space in all the 4 devices, targeting better H-mode confinement or at least document confinement limits
Clear path identified in all the 4 devices.
Suggested synergies with proposal #92
P1-AUG-2026
P1-MAST-U-2026
P1-TCV-2026
P1-WEST-2026







Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	6
MAST-U	6	
TCV	20	
WEST	5 sessions	

#99 - Flow characterization in the Scrape-Off Layer

Address important gap in present SOL understanding, particularly relevant for impurity transport/screening in the SOL. Potentially feasible in piggy-back for both devices. Important to ensure the indicated block-2 in strongly heated L-mode or H-mode.
P2-TCV-2026/PB
P2-MAST-U-2026/PB

- **Proponents and contact person:**

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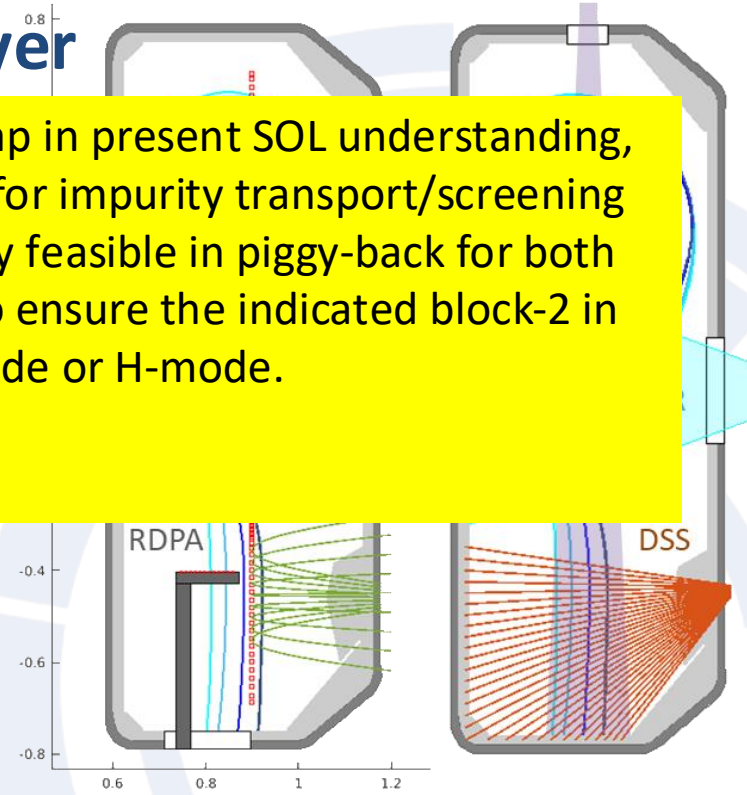
massimo.carpita@epfl.ch
m.j.h.cornelissen@tue.nl
alysee.khan@epfl.ch

- **Scientific Background & Objectives**
  - Perform multi-device (TCV, MAST-U) characterization of the parallel plasma flows along the SOL in L-mode and H-mode.
  - Evaluate the influence on parallel flows in the SOL for
    - ❖ divertor regime (attached / detached), closure & pumping
    - ❖ detachment strategy: seeded impurity and fuelling location

- **Experimental Strategy and essential diagnostics**
  - L-mode for best-diagnosed scenario to develop an in-depth understanding of the physics and testbed for diagnostics:
    - ❖ TDSS – including new LoS arrangement
    - ❖ CIS – benchmark new diagnostic for 2D flows
    - ❖ RDPA – 2D Langmuir and Mach probe measurements
    - ❖ MANTIS & TS – 2D plasma quantities
    - ❖ FReDi – electron, ion temperature and Mach number upstream radial profiles
  - ECH heating to characterize divertor flows for reactor-relevant divertor conditions.



Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U	10	
TCV	20	
WEST		

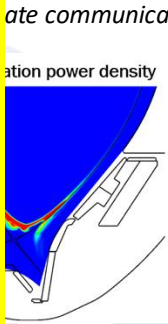
#100 Characterization of the X-point radiator with horizontal and vertical equilibrium sweeps in H-mode

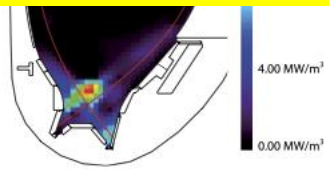
Proposal aimed to increase diagnostic coverage using DTS by performing horizontal and vertical sweeps of the XPR position to further constrain the modelling.
P2-AUG/PB
To be explored if they can accommodated at the end of XPR main proposals

- **Proponents and contact person:**
- Mate Szucs mate.szuecs@ipp.mp.de
- Yu-Chih Liang, Sven Korving, Matthias Bernert, Ou Pan, Matthias Höl
  Andres Cathey

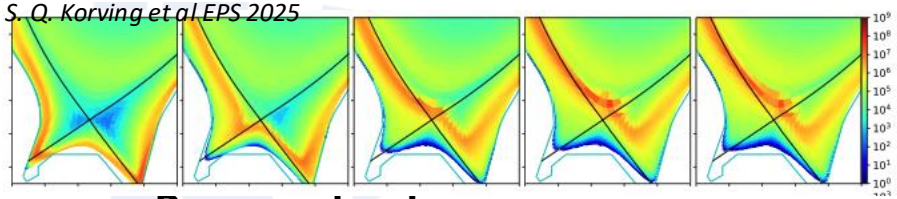
- **Scientific Background & Objectives**
- XPR simulations show different XPR core radiation shapes then bolometry
- Deeper knowledge of the XPR core is beneficial for reduced models and predictive simulations
  Figs 1.-3.
- Vertical sweeps help to get more accurate IDA profile reconstructions
- Compare XPR core and pedestal profiles across different XPR heights and Bt strengths

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- Using reference #38773, keep XPR at low height with control, develop and preform equilibrium sweeps
- Repeat for higher XPR height and Bt
- Compare to JOREK, SOLPS-ITER, JINTRAC results
- Diagnostics: Vertical Thomson, Divertor Thomson, Helium beam, ECEI, ECE, Li-beam, CXRS





S. Q. Korving et al EPS 2025



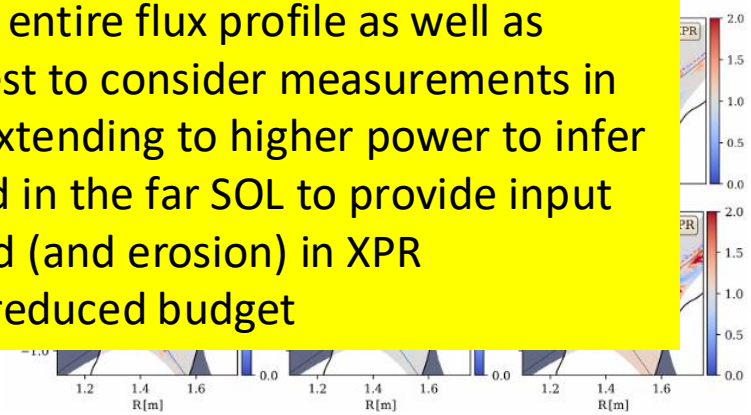
Proposed pulses

Device	# Pulses/Session	# Development
AUG	3	2
MAST-U		
TCV		
WEST		

#101 Edge turbulence characterization for the XPR regime at low heating at AUG

- **Proponents and contact person:**
  - Y-C. Liang (Yu-Chih.Liang@ipp.mpg.de), A. Mancini, G. Eder, M. Bernert, M. Szucs, O. Pan, S. Hörmann, T. Hap W. Zholobenko
- **Scientific Background & Objectives**
  - Use the **high heat flux ball-pen probe heads** in the mi manipulator to characterize the edge turbulence in the XPR scenario
  - Use the diode bolometry to measure the fluctuations around the XPR volume
  - Use the X-point manipulator and the divertor thermal He beam to measure fluctuations at the (far)SOL downstream
  - Execute the turbulence measurements at different XPR heights (including the ELMy phase and the ELM suppressed phase)
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - **H-mode XPR, NBI + ECRH** at low power
  - **MEM, LFS THB, DBS, CECE**: edge fluctuations measurements
  - **AXUV**: fluctuations measurements near the XPR volume
  - **CXRS**: Er measurements for comparison between low & high XPR heights
  - **XPM, divertor THB**: fluctuation measurements at (far)SOL downstream

While the low-power XPR operation might be interesting to get the entire flux profile as well as fluctuation, we suggest to consider measurements in front of the limiter, extending to higher power to infer particle and heat load in the far SOL to provide input towards first wall load (and erosion) in XPR P1-AUG-2026 but at reduced budget



[K. Eder et al 2025 Nucl. Fusion 65 096029]

Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	1
MAST-U		
TCV		
WEST		

#102 - X-machine exploration of pellet fueling compatibility with X-Point Radiation (XPR) regimes

XPR compatibility with pellets (as perturbative events) shown on JET. Not for pellet fuelling discharges
Might be planned in part of the discharge if feasible
P1-WEST-2027
P2-AUG-2027

Proponents and contact person:

- **Contact: Eléonore GEULIN eleonore.geulin@cea.fr**
- Nicolas RIVALS nicolas.rivals@cea.fr
- Nicolas FEDORCZAK nicolas.fedorczak@cea.fr
- Louis FÈVRE louis.fevre@cea.fr
- Hao YANG hao.YANG(
- Matthias BERNERT m

Scientific Background & Objectives

- Operation in XPR regime is attractive for a Fusion Power Plant
  - Reduces thermal fluxes on the wall
  - Enhances plasma confinement
- Operation at high density and using pellet for fueling is mandatory for powerplant

Objective - Establish whether XPR can be sustained under pellet fuelling and the impact on :

- Plasma confinement
- Thermal fluxes on the divertor
- Core impurity levels
- Assess the feasibility of achieving high density during XPR using pellets

Experimental Strategy/Machine Constraints and essential diagnostic

- Reference N2 XPR (58089) for WEST and standard LSN scenario with a well established XPR at 2 different heights for ASDEX.
- Fire pellets from HFS + notching 50ms (for WEST- because of LH) make a frequency scan for pellet injection
- Fire pellets from LFS
- Diags : Plasma density & wall temperature, (bolometry, VUV, SXR, Infrared), W sources (visible spectroscopy), Langmuir probes, ECE, reflectometry, high speed camera in front of pellet injection point

Proposed pulses

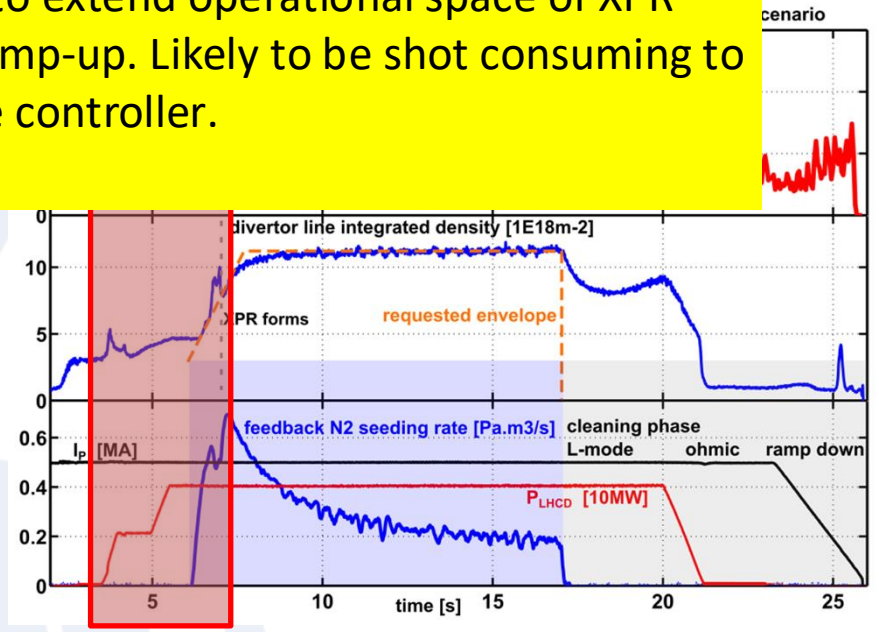
Device	# Pulses/Session	# Development
AUG	4 / 1 session	
MAST-U		
TCV		
WEST	15 / 1 session	(included in session)

#103 - Integral XPR scenario from X-Point formation to current ramp-down at WEST – Towards "Zero divertor erosion scenarios"

Proposal aiming to extend operational space of XPR during current ramp-up. Likely to be shot consuming to fine tuning of the controller.
P1-WEST-2027

- **Proponents and contact person:**
  - Nicolas RIVALS (nicolas.rivals@cea.fr), Nicolas FEDORCZ GEULIN, Louis FÈVRE, Hao YANG

- **Scientific Background & Objectives**
  - The XPR regime at WEST has shown to reduce divertor tungsten sources drastically (by factors up to 50)
  - Current XPR scenarios still involves an attached phase at the start: erosion at scenario start.
  - AUG showed an XPR sustained through the L-H transition.
  - Objective: develop scenario to maintain XPR during power ramp up in WEST without reattachement ➔ XPR state with non-eroding divertor from end-to-end.
  - Controller envelope shape development
  - Assess whether envelope is compatible with several injected power levels (2 MW, then 4 MW, LH power)
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Restart from scenario from pulse WEST #62352, with controller envelope, and scan shape. If fails, go back to feedforward forms.



Avoid attached start

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	1 session (15 pulses)	Included in session

#104 - H-mode density limit with impurity seeding

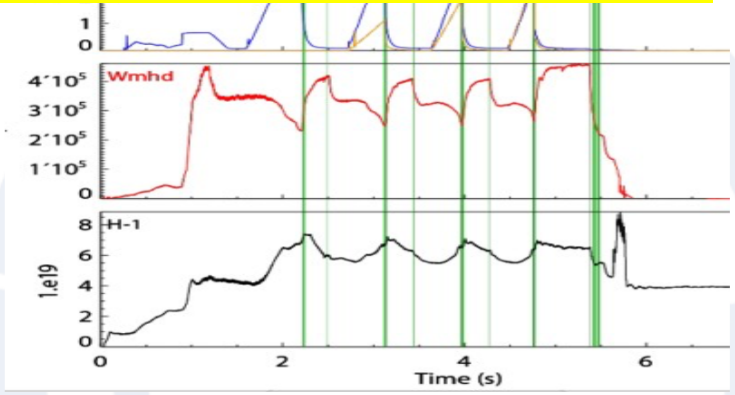
To be combined with proposal #106 and partially with proposal #96. Overall effort towards establishment of Zeff effect on separatrix/near/far SOL transport (and turbulence).
P1-AUG-2026

Proponents and contact person:

C.Perez von Thun, M. Bernert, B. Sieglin, M. Maraschek, A. Gude, T. Gle

Scientific Background & Objectives

- For power exhaust in future reactors a combination of high nesep and impurity seeding will be required [PittsNME2019]. Optimum operation window constrained to be somewhere above detachment roll-over and below HDL. Zeff dependence of HDL essentially unexplored (until AUG#43519).
- AUG pulse #43519 (last week before shutdown): 4 density ramps in USN up to HDL with different levels of N2 seeding until MARFE detection (RT)
  → established working recipe for assessing Zeff dependence of HDL (4 levels) with single pulse (already in first attempt!)
  → Closer inspection shows HDL decreases monotonically with increasing Zeff
  → But: want much slower density ramps for good edge profiles (separatrix) assessment just before HDL



Experimental Strategy/essential diagnostics

- Straightforward repeat of 43519 with ~factor 3 slower ramp rate (=**top priority**, **easy**).
- Rerun once at higher Paux (also straightforward) to check power dependence
- Optional additions: other Ip levels (800kA,1MA), impact of drift: 1 pulse with flipped Bt
- Diagnostics: suite of edge profile diagnostics (TS, LiBES, reflectometry, dispersion interferometer for additional constraining), divertor diagnostics (→ detachment vs HDL operational window shrinks or expands with increasing Zeff?), divertor TS

Links with: RT05 D1 & D2

Proposed pulses

Device	# Pulses/Session	# Development
AUG	1-2 (if doing main part only)	0 (already shown to work)
MAST-U	-	-
TCV	-	-
WEST	-	-

#105 - Cross-machine scaling for far-SOL density decay with metallic walls (unseeded)

Proponents and contact person:

- C.Perez von Thun, A. Stagni, N. Rivals, R. Mitteau, Y. Corre

Scientific Background & Objectives

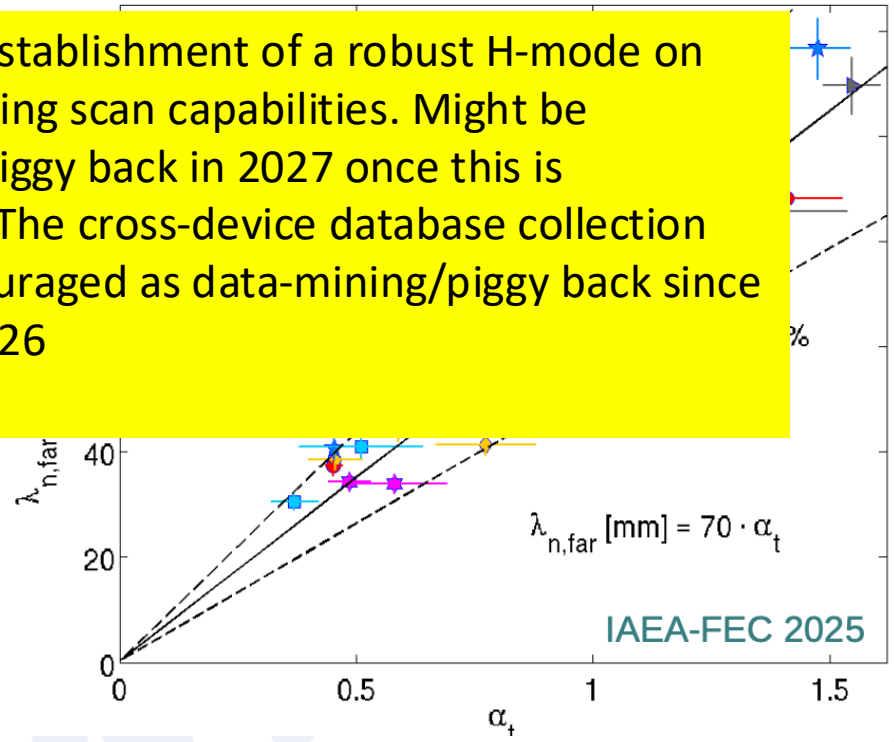
- Main chamber could far outweigh other W sources in ITER but strongl background plasma assumptions [PittsNME2025]
- Need to find a way to extrapolate far-SOL density flattening from curr ITER to correctly predict main chamber W-source
- Correlation between flattening and turbulence parameter αt,sep foun JET. On AUG, αt,sep unifies QCE and std H-mode wall fluxes [Redl NF2024]. On JET, diverse H-mode dataset follows unified scaling with αt,sep [von Thun IAEA 2025].
- To capture machine size in unified scaling, need to combine far-SOL data from different devices.

Experimental Strategy/essential diagnostics

- Use consistent profile / separatrix / α_t / λ_n,far evaluation methodology for all machines
- Test/expand suitability of multimachine-scaling also to L-mode (α_t captures implicitly?)
- For AUG, JET and tentatively (non-metallic) TCV: rely on existing/new parasitic far-SOL data (Li-beam, reflectometry, TS,...)
- At WEST: run "standard" LSN scenario and build far-SOL profiles and FW heat fluxmeasurements. Scan the position of the outboard mobile antenna limiter equipped with pecker Langmuir probes. Vary limiter position from far away to flush with antenna. Combine with RCP measurements and reflectometry.

Links with: RT05 D2 & D3, ITPA DSOL-34

Need first the establishment of a robust H-mode on WEST with fuelling scan capabilities. Might be considered as piggy back in 2027 once this is establishment. The cross-device database collection should be encouraged as data-mining/piggy back since beginning of 2026
P2-WEST-2027



Device	# Pulses/Session	# Development
AUG	Existing/parasitic	
MAST-U		
TCV	Existing/parasitic	
WEST	1 session (15 pulses)	Included in session

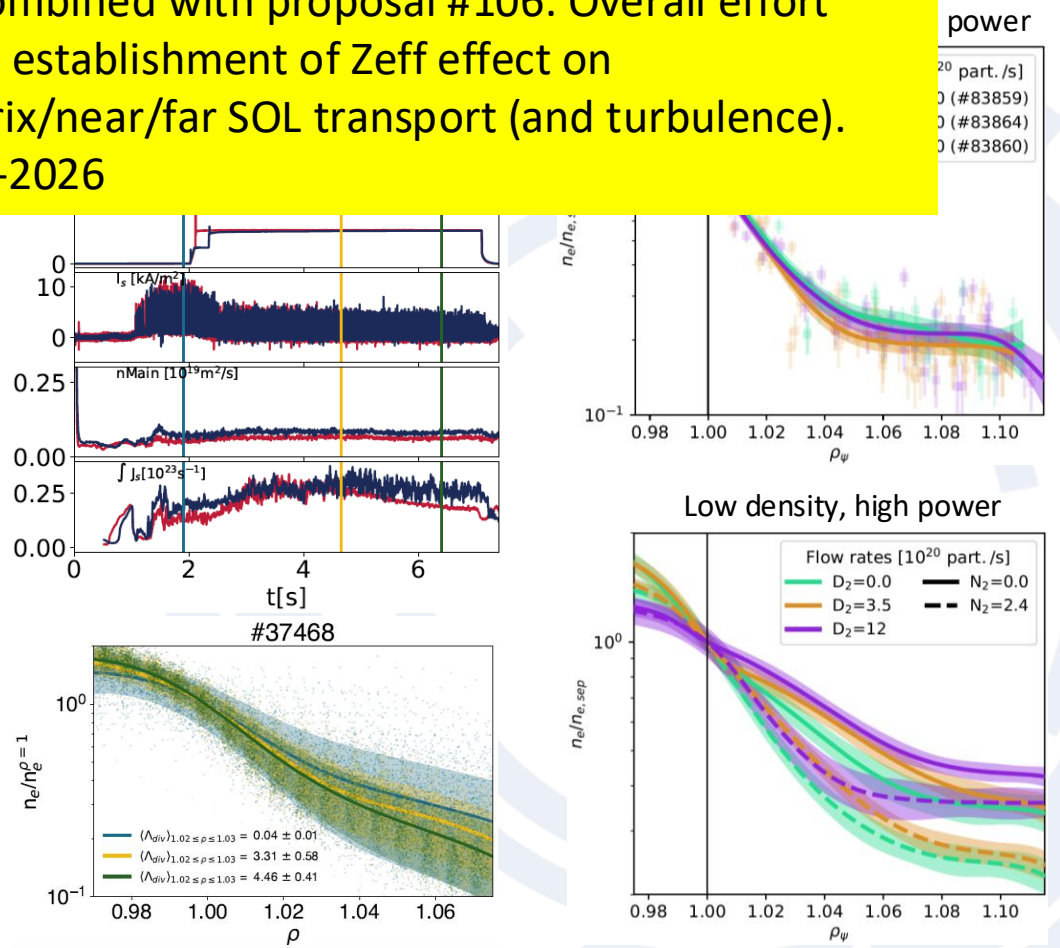
#106 - Seeding effect on scrape-off layer profiles and fluctuations

To be combined with proposal #106. Overall effort towards establishment of Zeff effect on separatrix/near/far SOL transport (and turbulence). P1-AUG-2026

- **Proponents and contact person:** adriano.stagni@igi.cnr.it
- **Scientific Background & objectives**
  - Impurity seeding essential for H-mode detachment, but underst of its effect on SOL properties is missing
  - In TCV observed little effect of N2 seeding on SOL density decay in high density, medium power type-I ELMy scenario whereas significant profile steepening and shoulder mitigation at low density, high power
  - Unclear how seeding affects upstream parameters and plasma conditions, effect of edge Z_{eff} not quantified yet
  - Goal: disentangle the role of main gas and impurity seeding injection rates on SOL profile and fluctuation properties, comparing LSN vs USN in AUG
- **Experimental Strategy/Machine Constraints and essential diagnostic**

Experiments on AUG, 0.8MA/2.45T scenario: 6 shots

- 4 LSN discharges at fixed D2 gas + N2 injection rate in steps including initial unseeded reference phase
- 2 USN repeats of the previous scheme at lowest and highest D2 levels
- Diagnostics: all the main edge and SOL systems for profiles and fluctuations, spectroscopic data for impurity distribution



Proposed pulses

Device	# Pulses/Session	# Development
AUG	6	0

#107 Investigating the impact of plasma-neutral interactions on detachment

Most of the proposal is likely to be done parassitically ensuring enough diagnostic coverage, with possible repeat to complete the dataset. The only different experiment is on MAST-U with C2D4 impurity injection P2-MAST-U-2026

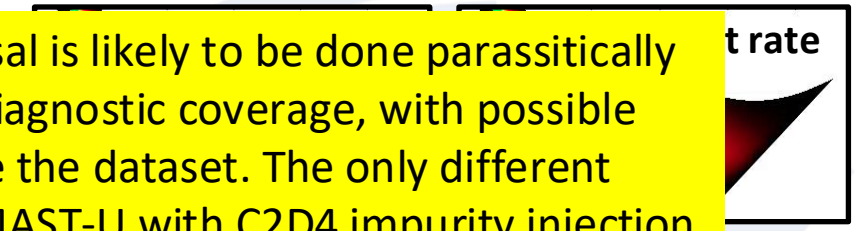
- **Proponents and contact person:**
  - K. Verhaegh, E. Pawelec, et al.

- **Scientific Background & Objectives**
  - Last year: both **plasma-molecule collisions** and **reactions** play a **critical role on detachment** and **model comparisons/improvements**
  - Errors molecular CX rate further solidified -> corrections needed for simulations ITER & beyond
  - Limited data **on metallic machines**, in **higher power conditions**

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - CD_4 puffs in MAST-U to delineate impact carbon wall and put TCV & MAST-U results in perspective
  - Use molecules as a sensor for kinetic effects and validate against kinetic codes (REMKiT1D)
  - Long-pulse molecular transport in metallic devices on WEST using D2 Fulcher emission
  - Work towards porting TCV & MAST-U results to metallic machines, starting with synthetic diagnostics & data-mining
  - Work towards porting this sophisticated analysis to XPR regimes to investigate the roles neutrals play in XPRs

D* emission -> Plasma-molecular reactions

Reproduced with improved rates [Verhaegh, et al. 2024, NF; arxiv]



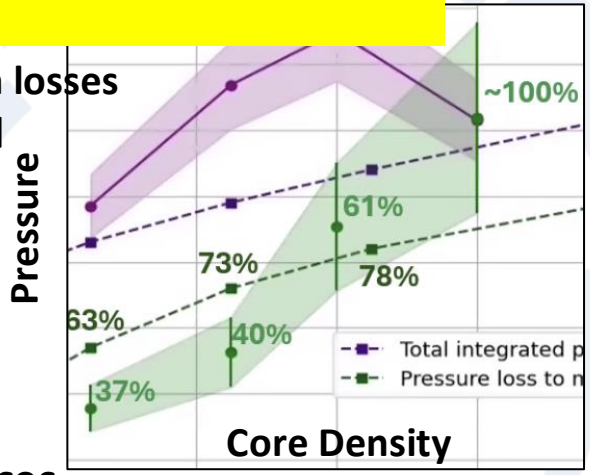
-> power/momentum losses

[Osborne, et al. NF 2025]

Upstream pressure

Pressure loss

ion-mol. collision



Proposed pulses

Device	# Pulses/Session	# Development
AUG	? (<4)	0
MAST-U	4	0
TCV	0 (TBLLD RT07)	0
WEST	5-10	0

#108 Detachment control in EDA H-mode

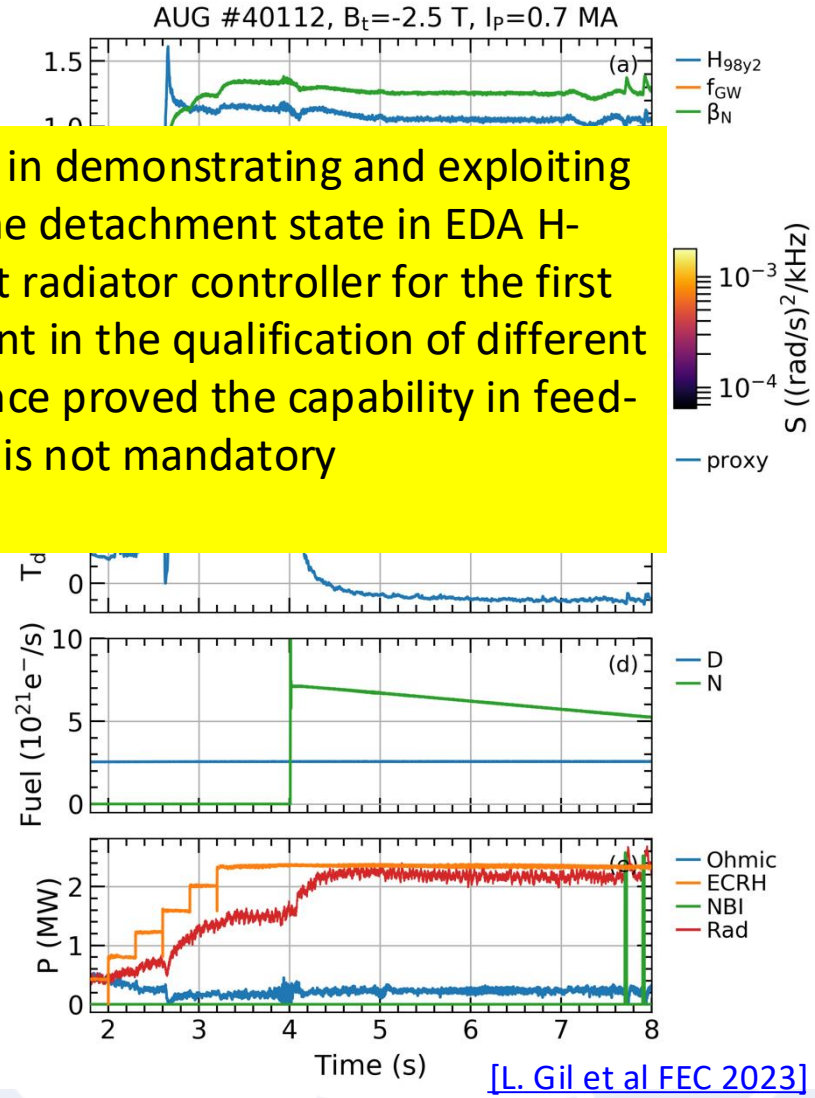
- **Proponents and contact person:**

L. Gil (luis.gil@tecnico.ulisboa.pt), M. Bernert, D. Brida, G.D. Conway, M. Fai

- **Scientific Background & Objectives**
  - EDA H-mode: promising no-ELM regime, compatible with impurity se
  - However:
    - Feedforward seeding for detachment not applicable to reactors
    - Shunt current feedback not possible with fully detached divertor
  - Main objectives (more on the wiki):
    - Demonstrate real-time, XPR-control of EDA H-mode detachment for the first time
    - Investigate the effect of seeding on the EDA power window and extend it to higher P_{sep}/R
    - Develop robust EDA scenarios with different impurity mixes for future exploitation

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - High δ, dominant wave heating (mostly ECRH), N/Ar/Ne seeding:
    - Feedforward seeding first to adjust setup XPR controller, then real-time control
    - XPR height steps at constant power
    - Power ramps at constant XPR height
    - Vary D fueling levels
    - Try different impurity mixes

This proposal consists in demonstrating and exploiting real-time control of the detachment state in EDA H-mode with the X-point radiator controller for the first time. May be important in the qualification of different no-ELM regime but once proved the capability in feed-forward the feedback is not mandatory
P2-AUG-2026



[L. Gil et al FEC 2023]

Proposed pulses

Device	# Pulses/Session	# Development
AUG	10	

#110 - Evaluation and Comparative Study of Fluctuation-Induced Transport in the SOL and First-Wall Interaction in Different Plasma Conditions in TCV

Propose to piggy-back/data mining for not intrusive diagnostics. Might increase priorities once RP will be available. Not indicated the capabilities of RP P2-TCV-2026

- **Proponents and contact person**

Kaushlender Singh, Alysée Khan, Elena Tonello, Christian Theiler, Yinghan Wang, Margherita Ugoletti, Matteo Agostini, and Olivier Février

kaushlender.singh@epfl.ch

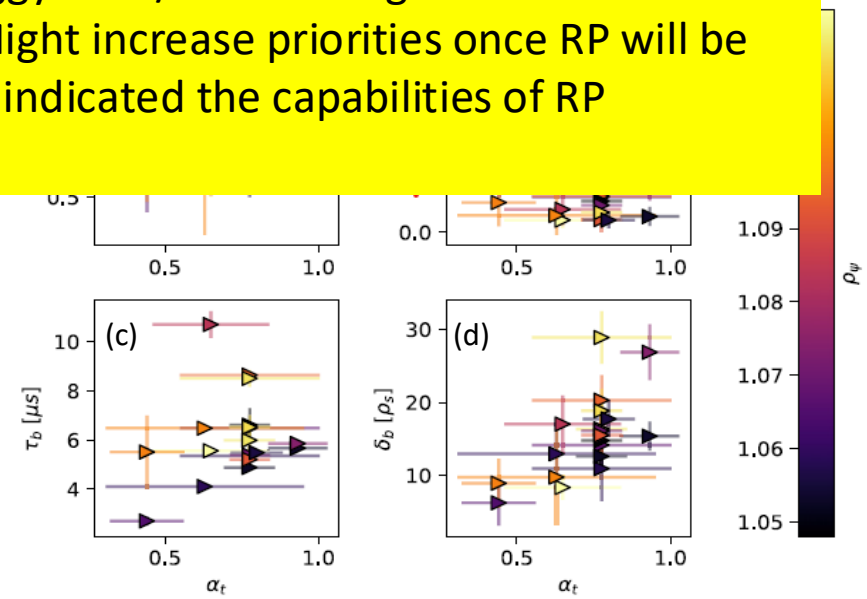
- **Scientific Background & Objectives**

Understanding and evaluating particle and energy exhaust in the divertor and scrape-off-layer (SOL) regions of a tokamak are fundamental prerequisites for the safe and reliable operation of ITER.

- We aim to evaluate fluctuation-induced radial transport in the SOL and assess its parametric dependencies in L-mode, attached, and detached plasma conditions.
- We aim to extend this study to the QCE regime in both attached and detached conditions.

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

- Conduct gas-puff scans in L-mode plasmas, spanning the transition from attached to detached regimes, to characterize fluctuation-induced transport in the SOL.
- Carry out a gas-puff scan in the QCE regime to correlate SOL parameters with the resulting particle and heat flux profiles.
- Assess the extent to which first-wall interaction can be mitigated by increasing the outer wall gap, both in L-mode and in the QCE regime.



Variation of filament properties with α_t: (a) radial velocity, (b) poloidal velocity, (c) FWHM, and (d) radius. The Color bar indicates the average measurement position. (#A. Stagni et al 2022 Nucl. Fusion 62 096031)

Proposed pulses

Device	# Pulses/Session	# Development
AUG	0	0
MAST-U	0	0
TCV	22	0
WEST	0	0

#111 - WEST detached L-mode plasmas at reduced Btor for the validation of turbulence simulations (RT05)

To be understood what already availableas reference scenario for modelling validation on WEST. If not piggyy back on main scenarios at different recycling condition. Do we really need reduced Btor also in view of modelling optimization under TSVV-B?
P2-WEST-2027

- **Proponents and contact person:**

Diego Sales de Oliveira (diego.salesdeoliveira@cea.fr)
Jorge Morales, Guido Ciraolo, Patrick Tamain

- **Scientific Background & Objectives**

  - Develop a stable L-mode WEST detached plasma at reduced Btor optimized edge diagnostic coverage for modeling
  - Produce a dataset for the validation the first edge turbulence simulations of WEST using SOLEDGE3X
  - Characterize the turbulent transport in the simulations and compare with DBS and RCP measurements
  - Quantify turbulent flux arriving at first-wall PFCs and possible implications for operation
  - Assess the parallel and perpendicular mechanisms underlying the power exhaust and confirm the code predicitions with experiments

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

  - Start from the reference discharges LSN 1.9T/300kA (60208,60117+more) and change magnetic geometry parameters and current gain stability
  - Once stable, perform a density scan step letter to acquire data at different levels of detachment
  - Langmuir probes in the max and min probe locations, DBS, RCP, McPherson, TS, spectroscopy, IR

Proposed pulses

Device	# Pulses/Session	# Development
WEST	5	10

#112 - First-principles investigation of boundary turbulence in seeded detached plasmas in the TCV-X21 scenario

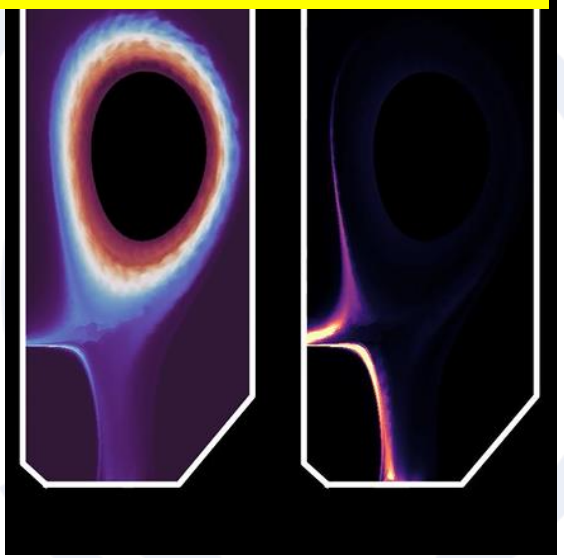
Full dataset collection supported. Not if the mentioned code are already capable of self-consistent treatment of impurity species. If so will be good to discuss this within RT05 team
P1-TCV-2026

- **Proponents and contact person:**

Diego Sales de Oliveira (diego.salesdeoliveira@cea.fr)
Hugo Bufferand, Patrick Tamain, Guido Ciraolo, Christian Theiler, Paol
Reimerdes, Riccardo Morgan, Giuseppe Drago

- **Scientific Background & Objectives**

- Achieve a seeded detached TCV-X21 scenario and produce an extensive dataset for turbulence validation
- Validate the first edge turbulence simulations to assess the predictive capabilities of the code
- Investigate the on the filament transport activity in seeded plasma
- Determine the amount of impurities transported by cross-field turbulent transport and its direct impact on detachment
- Determine if divertor-localized filaments in the X-point region represent important for core contamination



- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Start from a reference shot in the TCV-X21 scenario in sheath-limited conditions and perform a N ramp to observe detachment
  - Take the nitrogen flow value for the detached plasma and perform an FF injection in both field directions
  - Discharges performed with (ideally) LILO baffles to increase divertor closure and facilitate detachment; we didn't observe a clear roll-over in the unseeded detachment attempts in the TCV-X21 and TCV-X23 cases
  - Repeat the shots to have the LPs in different operational modes and to collect data for statistics

Proposed pulses

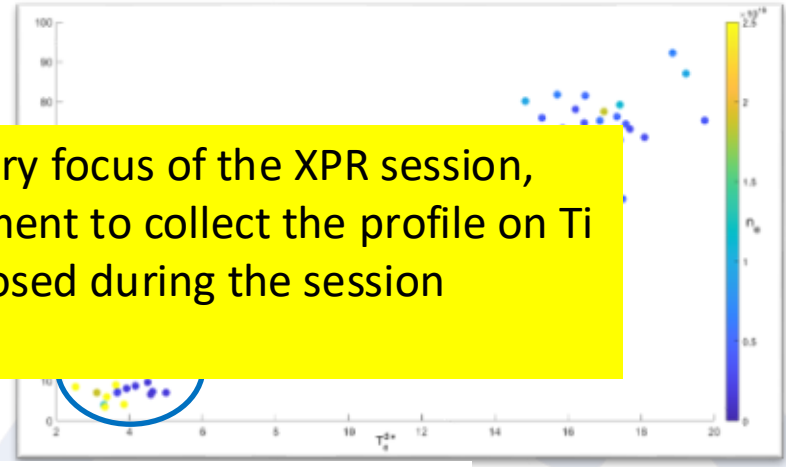
Device	# Pulses/Session	# Development
WEST	15	4

#113 - Divertor Ti profile in XPR

RT05: Physics of divertor detachment and its control for ITER, DEMO and HELI

- **Proponents and contact person:**
- Miglena Dimitrova (dimitrova@ipp.cas.cz), Jernej Kovačič, F
  Bianca De Martino, Jamie Gunn, Tomaž Gyergyek

Should not be the primary focus of the XPR session, but sweeping/SP movement to collect the profile on Ti might be envisage proposed during the session P2-WEST-2026



- **Scientific Background & Objectives**
- XPR reduces W sources in WEST tokamak and is suitable for long pulse operation (already several 10s of seconds).
- Using divertor RFA and LPs retrieve Ti and Te profiles pre-, during and post-XPR regime at various levels of LHCD power.
- Experiment addresses **deliverable D3**.

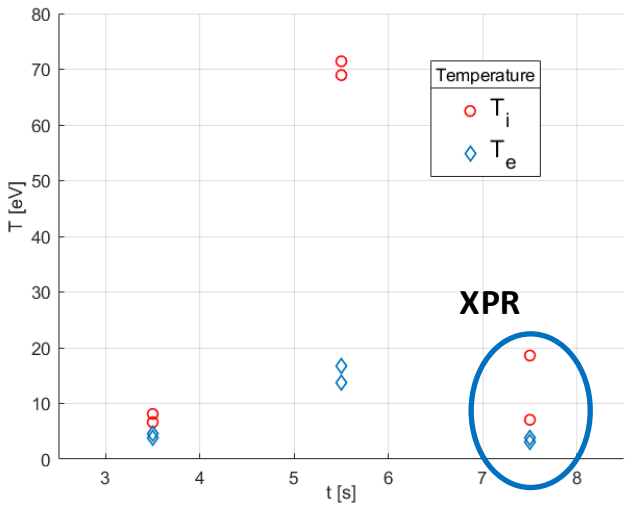


Fig.: T_i^{div}/ T_e^{div} (up) database with density colorbar;

Radial profile of T_i^{div} and T_e^{div} for WEST during #61357 – XPR @7.5 s (left)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
- LH power scan with LSN
- RFA is fixed at MB#28/#29-> use fixed strike point with power ramp
- Next shot move the strike point position to obtain radial profile of Ti and Te
- 4-5 radial points needed to define Ti decay length (profile)
- Needed: RFA + LP + Pecker probes + IR

Proposed pulses

Device	# Pulses/Session	# Development
AUG	-	-
MAST-U	-	-
WEST	15 pulses / 1 session	2 pulses

Summary of P1 and budget proposal

	AUG		TCV		MAST-U	WEST	
	2026	2027	2026	2027	2026	2026	2027
Tentative allocation	**24**	**26**	**70**	**110**	**24**	**30**	**30**
Total proposed	137		189		74	213	
Scientific/dev.	101/36		135/54		62/12	194/19	
P1 proposals	#88, #95,#96, #98,#101 #104 #106	#92	#89,#95, #97, #98, #112		#91, #96, #98	#98	#102, #103

JET analysis plan RT-05

- Focused on mixed Ar+Ne seeding:
- Analysing Ar & Ne core concentrations – Ash Patel
- Analysing Ar & Ne div. concentration – S.Henderson
- Compression analysis – A.Patel & S. Henderson
- Mixed Impurity modeling SOLPS – Ou Pan
  - Offset between different impurity species
  - Radiation distribution (Lz curves with transport)
- Document (technical?) limits for Ar & Ne seeding – M.Bernert ->PSI
- Start of integrated modelling – P.Manas/S.Korving
- Pellets in XPR – M.Bernert/E.Geulin?

Strongest missing points:

- Edge modelling of XPR and its onset
- Pedestal analysis – Why does the pedestal not degrade in ELM suppression
- Main chamber SOL characteristics
- Integrated modelling?
- TRANSP modelling
- Calculation of ITG stabilization by impurities

It’s the biggest dataset of mixed impurity seeding existing (including DT discharges)!

Join us to help understanding it!

Full set of open points of analysis

- Impurity concentrations and their comparison between species partially M.Bernert
- Trade-off between Ne and Ar: optimal ratio / changes to plasma partially M.Bernert
  - Is there a benefit of the mixes vs single impurity
- Edge modelling:
  - Mixed Seeding
  - Comparison of N, Ne, Ar O. Pan
  - XPR vs onset partially O. Pan
  - DT – isotope effects (with seeding)
  - Time dependent modelling (gas cut discharges)
- SOL transport (notably changes with Ar), far SOL fluxes, first wall loads
- Radial electric field unseeded vs seeded

- He concentrations/behavior/built-up in DT
- TRANSP simulations (with correct imp. conc.)
- Quantify ITG effect, turbulence behavior with high Zeff
- Influence of pellets
- ELM analysis: Are ELMs suppressed? partially M.Bernert
- Pedestal stability analysis
- Highest power pulses: Performance & comparison
- Impact of XPR on confinement partially M.Bernert