EUROfusion

18th November 2024

RT-04: Physics-based machine generic systems for an integrated control of plasma discharge
Discussion about proposals and allocated priorities

M. Baruzzo

On behalf of WPTE TFLs

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Research Topic Coordinators

L. Piron, A. Mele, C. Vincent

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Introduction

ITER

RT01: Core-Edge-SOL integrated H-mode

DEMO

RT02: Alternative to type-I ELM regimes

Physics & Control integration

RT03: Disruption & RE mitigation strategies

RT04: Machine generic integrated control

RT05: Physics of divertor detachment

RT08: Physics of high β long pulse scenario

RT09: Physics of energetic particles

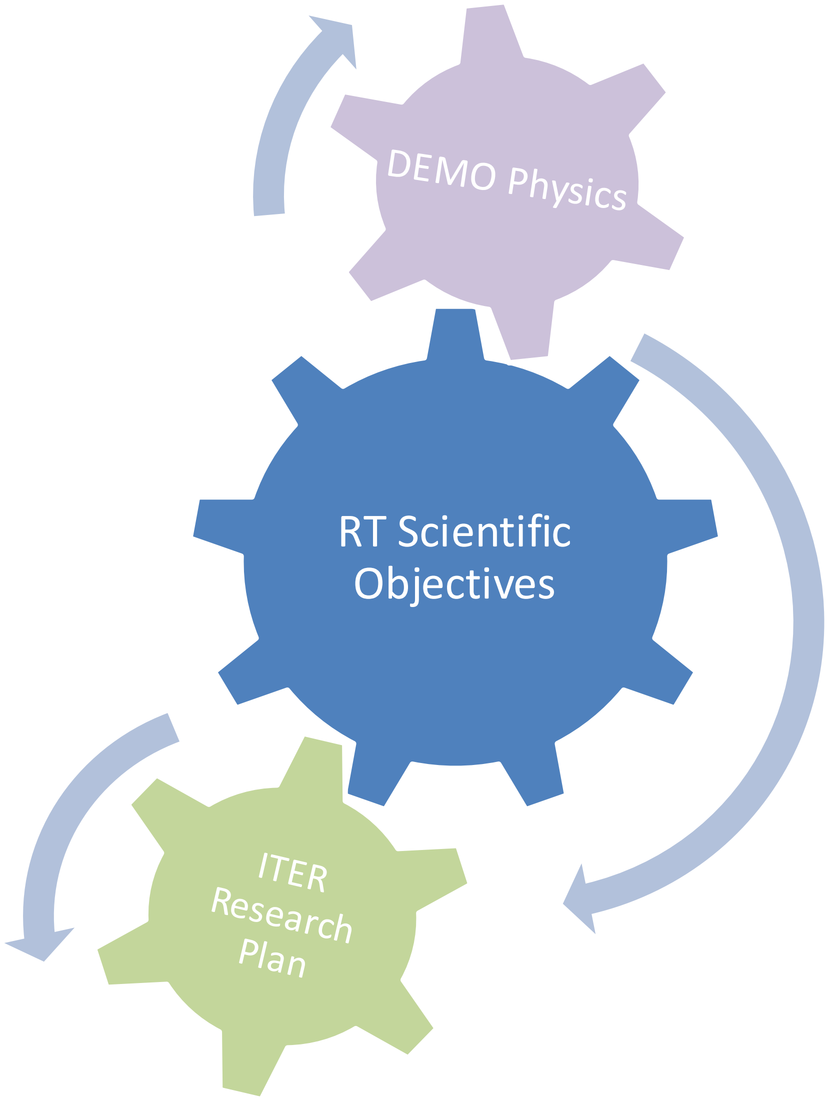
RT06: preparation of efficient PFC operation

RT07: Alternative divertor configuration

PEX

Mission 1 | Mission 2

Prioritization scheme and criteria



Proposal 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: machine time granted but pulse budget might need reduction

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

P3: back-up programme

PB: piggy-back experiment/pure analysis proposal

Scientific Objectives and Machine Time

#	
D1	Develop MIMO (Multi-Input Multi-Output) state-observers for e.g., radiative detachment control on different devices
D2	Develop machine independent strategies for the H-mode entry and exit and off-normal events supported by modelling
D3	Develop and test disruption avoidance schemes and apply them on several different devices
D4	Develop robust strategies to optimize error field corrections supported by modelling
D5	Optimize plasma start-up and current ramp-up schemes supported by modelling in ITER like scenarios

2025	AUG	TCV	MAST-U	WEST
Tentative allocation	35	60	32	15
Total proposed	176	394	66	153
Scientific/dev.	160/16	306/88	46/20	148/5

Summary of proposals (32)

No	RT	Proposal name	Proposer
63	RT04	Optimization of NTM control strategies	Luca Bonalumi
64	RT04	NTM control with an Oblique ECE diagnostics	Edoardo Alessi
65	RT04	Multimachine assessment of Locked Mode predictors: Machine Learning models vs empirical-based scaling laws	Matteo Gambrioli
66	RT04	Fast magnetic control to balance double-null divertors	Oliver Bardsley
67	RT04	Assess the role of a proxy EF in H mode entry, H-L exit in AUG and MAST-U	Lidia Piron
68	RT04	A Machine Learning approach for multi-machine disruption prediction and contribution to the EUROfusion database	Giuliana Sias
69	RT04	EF detection studies in AUG and MAST-U in preparation to ITER operation	Lidia Piron, Carlos Paz-Soldan
70	RT04	Role of rotation on EF shielding	Lidia Piron
71	RT04	Comparison of feedforward and feedback techniques for phase control of a wall-locked tearing mode	Lidia Piron
72	RT04	Machine learning aided dud detection for burning plasmas: controller design and assessment	Lidia Piron
73	RT04	Fight locked modes in low-nu* ITER baseline plasmas by edge-core decoupling control	Lidia Piron
74	RT04	Local gas injection as an actuator to improve IC and LH wave coupling in H-mode	Laurent Colas
74	RT04	Dynamic model-based Error Field correction	Leonardo Pigatto
76	RT04	Enhancements and improvements to density control	Ondrej Kudlacek
77	RT04	ICRF assisted breakdown	Ernesto Lerche, Tom Wauters, J Hillairet
78	RT04	2025 Model-based density observation and control	Chris Orrico
79	RT04	Integrated estimation and control of plasma core-edge-exhaust with real-time model-based observers	Francesco Pastore
80	RT04	Integrated control for disruption free operation and off-normal events handling	Alessandro Pau
81	RT04	Plasma termination optimization for high-performance scenarios	Alessandro Pau

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83	RT04	Optimal actuator allocation for integrated control	Adriano Mele	
84	RT04	Advanced solutions for plasma vertical stabilization	Adriano Mele	
85	RT04	NTM control at high beta	Antonia Frank	
86	RT04	Validation of breakdown and burnthrough modelling in TCV	Fabien Jaulmes, Pedro Molina-Cabrera	
87	RT04	Model-based profile control for better access to advanced scenarios	Cassandre Contré	
88	RT04	NTM exception handling at ASDEX Upgrade	Marc Maraschek	
89	RT04	Scan the NTM excitation condition and its stabilisation with full recovery at ASDEX Upgrade	Marc Maraschek	
90	RT04	Current ramp-up on bulk tungsten limiters: impact of ECRH and nitrogen seeding	Pierre Manas	
91	RT04	Plasma performances control with reflectometry	Maylis Carrard	
92	RT04	Development of real time XPR/MARFE observer for the new ASDEX Upgrade upper divertor	Bernhard Sieglin	← Moved to RT05
93	RT04	Investigation of the drift direction on the H-Mode density limit	Bernhard Sieglin	
206	RT04	Control of IRE's with optimised shape control using iterative learning on MAST Upgrade	Charles Vincent	

Summary of proposals (32)

NTM Control, Disruption Avoidance, Error field Control, Density Control, Assisted BD and ramp-up, XPR and HDL control, Shape and VS control, Integrated Control,

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63: Optimization of NTM control strategies

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	15	5
WEST		

Proponents and contact person:

Luca Bonalumi (luca.bonalumi@istp.cnr.it)
Edoardo Alessi
Natale Rispoli
Carlo Sozzi

Scientific Background & Objectives

In the context of (N)TM control with EC injected power, various parameters can impact the stabilization:
Such parameters are generally inter-dependent.
Different initial conditions impact the control strategy, corresponding to different suppression paths.
(N)TM stabilization can be approached as an optimization problem, where the parameters of the EC injection are tuned to optimize:

- the energy consumption,
- the stabilization time,
- the maximum tolerable island width.

Aim of the present proposal is to demonstrate the feasibility of the use of a Reinforcement Learning Neural Network tool to optimize the (N)TM control.

Experimental Strategy/Machine Constraints and essential diagnostic

Divided in two stages:

- A phase of off-line development, dedicated to training of a Reinforcement Learning Neural Network using available simulation environment
- Comparison with experimental stabilization data and implementation of the controller in real time
- This proposal is linked to the proposal "NTM control at high beta" by A.Frank

Background & Objectives

- An Oblique ECE imaging diagnostics with a limited number of fixed lines of sights can accurately steer ECRH/CD launcher to control NTM instabilities:
  - Demonstrate feasibility of an NTM detection and aiming technique independent from magnetic equilibrium and magnetic fluctuation measurements;
  - Definition of the minimal resolution for an Oblique Imaging ECE and define the requirement for a dedicate antenna
  - Definition of a control algorithm

Experimental Strategy/Machine Constraints and essential diagnostic

Parasitic experiments in TCV plasmas with a developed NTM

- ECE radiometer installed on a ECRH/CD RT steerable antenna as essential diagnostic

- TFL assessment: P2
- Aligned with D1

64: NTM control with an Oblique ECE diagnostics

- TFL assessment: P2
- Aligned with D1
- Parasitic experiment

- **Proponents and contact person:**

  - edoardo.alessi@istp.cnr.it
  - natale.rispoli@istp.cnr.it
  - carlo.sozzi@istp.cnr.it
  - luca.bonalumi@istp.cnr.it

- **Scientific Background & Objectives**
  - An Oblique ECE imaging diagnostics with a limited number of fixed lines of sights can accurately steer ECRH/CD launcher to control NTM instabilities:
    - Demonstrate feasibility of an NTM detection and aiming technique independent from magnetic equilibrium and magnetic fluctuation measurements;
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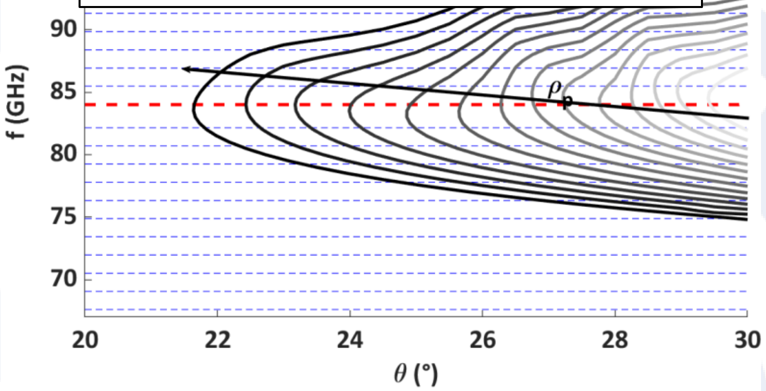
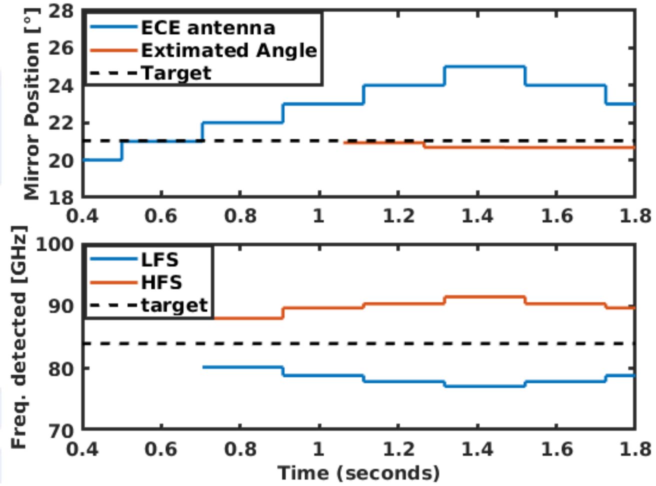
- **Experimental Strategy/Machine Constraints and essential diagnostic**

  Parasitic experiments in TCV plasmas with a developed NTM
  - ECE radiometer installed on a ECRH/CD RT steerable antenna as essential diagnostic



TCV 58680: different flux surfaces as seen by ECE radiometer (f) aiming at different direction (ϑ)



Simulation for TCV 58680: from Island localizations (Bottom plot) at limited number of direction (top) optimum launching angle is estimated.

85: NTM control at high beta

- **Scientific Background & Objectives**
  - Neoclassical tearing modes (NTM) degrade overall confinement by enhanced transport at mode location (q = m/n), can lead to disruptions if not stabilized
  - High-performance high-beta operation requires control of NTMs, typically done with EC waves whose deposition locations needs to be well aligned with q=m/n
  - Integrate model-based observer at TCV (real-time) RT control system using **Modified Rutherford equation** (MRE) in RT for NTM width and frequency evolution and estimate of EC power needed for stabilization (optimize fusion gain)
  - Demonstrate successful integration of RT-MRE, actuator management and control of NTM in high-beta discharges

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Reference high performance plasma scenarios (developed in 2024) with different plasma currents at high beta and NTM triggered, will be available from RT-04 TCV experiments on integrated control.
  - Test the integration of tools on the real-time control system
  - Essential for operation are: SOMONE, SCD & real-time observers

Proponents and contact person:

Antonia Frank (antonia.frank@epfl.ch)
Alessandro Pau
Jean Pierre Svantner
Olivier Sauter

- TFL assessment: P2, can be BP?
- Aligned with D1

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	15	5
WEST		

88: NTM exception handling at ASDEX Upgrade

- **Proponents and contact person:**
  Marc Maraschek, Bernhard Sieglin, Anja Gude, Matthias Reich, Felix Klossek, Magdalena Bauer
- **Scientific Objectives:**
  - The aim of this proposal is to establish via a include segments a prepared set of strategies for NTM stabilisation via exception handling and perform, if possible, a full recovery of the discharge performance.
  - Increase the data base for the determination of the best co-ECCD offset for NTM stabilisation for (2/1) and (3/2)-NTMs in MHD prone discharges.
  - Test alternative NTM removal strategies, such as increasing the gas puff until the mode vanishes (reduction of bootstrap current by reduction ne gradient at r_res)
  - No use of primary discharge time, but rather react on discharges with backup segments, which are no longer useful for the main experiment after an NTM excitation. If required, prove in a few final dedicated discharges, i.e. 5, the best scheme
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - No use of primary discharge time, but rather react on discharges with backup , which are no longer useful for the main experiment after an NTM excitation. If required, prove in a few final dedicated discharges, i.e. 5, the best scheme segments.
  - Test alternative NTM removal strategies, such as increasing the gas puff until the mode vanishes (reduction of bootstrap current by reduction ne gradient at r_res)

- **Scientific Background:**

NTM stabilisation has been largely performed as prof-of-concept experiments and is still lacking a full routine application in MHD prone discharges. The aim of this proposal is to establish via a include segments a prepared set of strategies for NTM stabilisation via exception handling.

The standard way of stabilising NTMs is the deposition of co-ECCD generated current drive in the vicinity of the resonant surface of the mode to be stabilised. As the most effective radial localisation of the the co-ECCD is still not finally clear, either fixed or sweeping positions with resp ... or the real islanc ... al-time ECE, is tes ... riments in NTM pror ... arious stabilisati ...

- TFL assessment: P1
- Aligned with D2
- Mainly parasitically

Proposed pulses

Device	# Pulses/Session	# Development
AUG	12 + 4 (ECCD)	5 + 4 (ECCD)
MAST-U		
TCV		
WEST		

89: Scan the NTM excitation condition and its stabilisation with full recovery at AUG

- **Proponents and contact person:**
  Marc Maraschek, Bernhard Sieglin, Anja Gude, Matthias Reich, Felix Klossek, Magdalena Bauer
- **Scientific Objectives:**
  - Document multiple NTM excitation within one discharge with developing and deliberately modified discharge conditions
  - Validate NTM stabilisation via gas puff instead of ECCD application at the resonant surface at high β_N
  - Scan the effect of the radial offset of local co-ECCD.
  - Reach full performance recovery after NTM stabilisation
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Fully implement / prepare the discharge with (un)-conditional segment at AUG.
  - Multiple (re-)excitation of NTM by P_{heat} ramps until NTM is excited and detected with subsequent removal and discharge recovery
  - Either repeat excitation as often as possible to scan long term discharge evolution,
  - or vary deliberately discharge condition for subsequent excitations.
  - Generate initially locked (N)TM's and control its position with respect to ECCD location

- **Scientific Background:**

Within the framework of disruption avoidance the H-mode density limit (HDL) has been used as a test case for continuous control or proximity control and event or exception handling. The latter allows to provoke several disruption onsets, each followed by a disruption avoidance action, within one discharge. By varying plasma parameters the stability limit of the relevant instability can be scanned without disruptions within few discharges (#41345). A repeated sequence of 'trigger'-'detect'-'remove' the instability then 'recover the discharge' and 'modify the discharge condition' has been applied. This scheme could be easily transferred to the stabilisation of NTMs.

A rotating NTM can be triggered by a raise of the plasma pressure. As actuators for NTM stabilisation and hence disruption avoidance local co-ECCD nea … tablished.

A re … sity have often bee … n in the past. Wit … reduction and the increase of the gas flux alone are sufficient to remove the NTM. This has been done feedback controlled until the NTM vanishes, while the possible onset of a MARFE has been monitored and HDL counter measures have been prepared.

- TFL assessment: P1
- Aligned with D2

Proposed pulses

Device	# Pulses/Session	# Development
AUG	12 + 4 (ECCD)	5 + 4 (ECCD)
MAST-U		
TCV		
WEST		

68: A Machine Learning approach for multi-machine disruption prediction and contribution to the EUROfusion database

- **Proponents and contact person:**
  Proponents: G. Sias, B. Cannas, A. Fanni, F. Pisano, A. Montisci, L. Milia, E. Coror
  Contact person giuliana.sias@unica.it

- **Scientific Background & Objectives**
  The group proposed ML based disruption prediction schemes for JET and ASDEX providing reliable triggers for avoidance and mitigation strategies, and contrib WEST dictionary for the EUROfusion database. Objectives for 2025 WPTE RT-04:
  1. Developing a multi-machine disruption predictor based on ML models
     - ✓ Training and test of cross-predictor ML schemes
     - ✓ Training and test of a multi-machine ML predictor
     - ✓ Training and test of anomaly detection approach from non-disrupted discharges.
  2. Contributing to the EUROfusion Database
     - ✓ Definition of the interface between the WEST and the EUROfusion databases
     - ✓ Populating the EUROfusion database with WEST data.

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  This is a pure analysis proposal. No specific experiments are required for 2025 campaigns. The data used for training and test of the proposed predictor schemes will be selected from the EUROfusion database if available, otherwise the machines databases are needed.

- TFL assessment: PB
- Aligned with D3
- Analysis proposal
- If possible get more inside on the physics behind

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

65: Multimachine assessment of Locked Mode predictors: Machine Learning models vs empirical-based scaling laws

- **Proponents and contact person:**
  - matteo.gambrioli@phd.unipd.it
  - lidia.piron@igi.cnr.it
  - alessandro.pau@epfl.ch

- **Objectives**
  - Build cross-machine ML models for LM prediction for: TCV, AUG, MAST-U and JET/Integrate ongoing efforts on this field.
  - Derive empirical based scaling laws, as the one proposed in P.C. de Vries et al 2016 Nuclear Fusion **56** 026007
  - Real-time assessment of ML vs empirical LM predictors

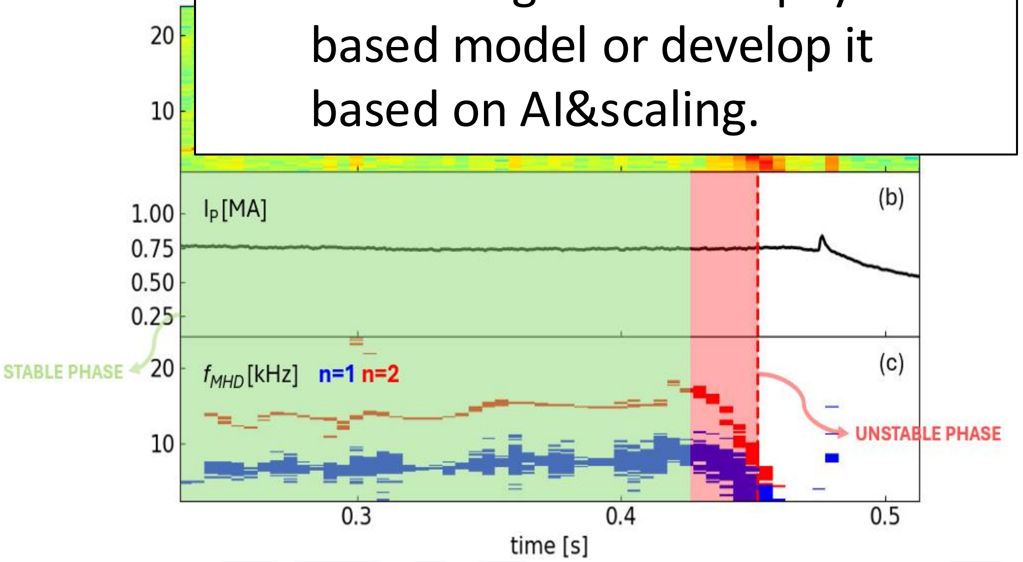
- **Experimental Strategy**

In preparation for the real-time assessment, we aim to:

- Develop ML models for LM prediction.
- Identify empirical scaling laws for LM amplitude.
- Test conventional LM metrics based on normal and tangential magnetic field measurements.

Such studies will be carried out using the DEFUSE framework and applied to MAST-U, TCV and AUG databases. JET will be included as well for the sake of comparison. Once these initial steps have been finalized, we propose to perform an assessment of LM prediction exploiting ML models and empirically derived metrics. Such assessment will require real-time implementation of these two approaches.

- TFL assessment: P2
- Aligned with D4
- Possibly parasitic?
- Try to include in addition to AI&scaling a minimal physics based model or develop it based on AI&scaling.



Proposed pulses

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

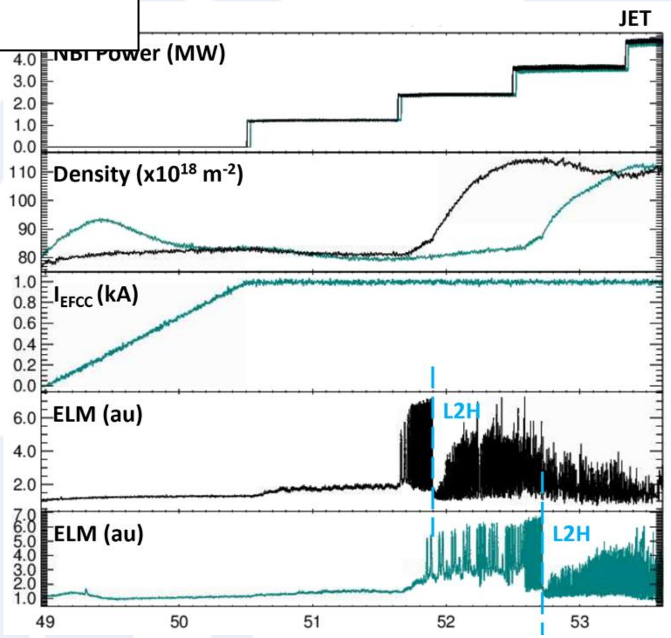
67: Assess the role of a proxy EF in H mode entry, H-L exit in AUG and MAST-U

- TFL assessment: P2
- Aligned with D4

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it & collaborators

- **Scientific Background & Objectives**
  - **investigate the role of a proxy EF in the L-H and H-L transitions,**
  - **analyze changes in the plasma rotation profile during L2H and H2L transients,**
  - **assess the maximum tolerable EF amplitude at which a LM is not triggered. This study is complementary to similar experiments carried out at JET.**

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Apply an n=1 magnetic field perturbations with different amplitude before the H mode entry and at H-L exit to study the role of a proxy EF in L-H transients.
  - This experiment will be performed in 1 MA/1.8 T AUG plasma scenario and 0.75 MA/0.5 T MAST-U plasmas



Proposed pulses

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

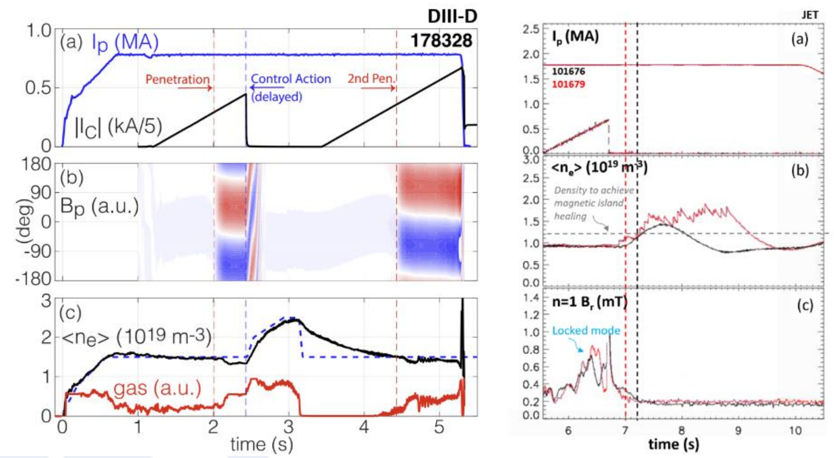
69: EF detection studies in AUG and MAST-U in preparation to ITER operation

- TFL assessment: P1
- Aligned with D4
- Continuation of 2024 exp

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it & Carlos Paz-Soldan

- **Scientific Background & Objectives**
  - **Test the non-disruptive compass scan method in plasmas with various q=2 positions in AUG and in MAST-U**
  - **Test the magnetic island healing by RF in AUG**

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - In AUG, starting from the Ohmic 0.8MA/1.5T scenario,
    - execute the non-disruptive compass scan and test magnetic island healing by gas and by pellet
    - execute the non-disruptive compass scan and test magnetic island healing by ICRH and ECRH
    - execute the non-disruptive compass scan in plasmas with q=2 at various radial positions
  - In MAST-U, starting from the Ohmic 0.75MA/1.5T scenario,
    - execute the non-disruptive compass scan in plasmas with q=2 at various radial positions
  - This experiment envisages the use of B coils in AUG and ELM coils &EFCCs in MAST-U



Proposed pulses

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

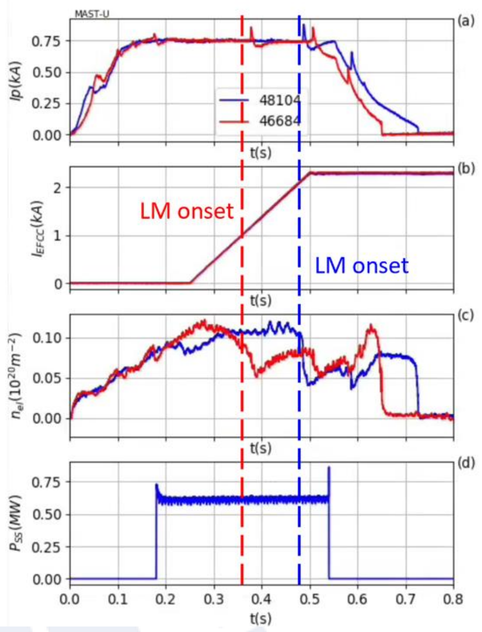
70: Role of rotation on EF shielding

- TFL assessment: P1
- Aligned with P4
- 2024 exp proposal

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it & collaborators

- **Scientific Background & Objectives**
  - **Assess the role of plasma rotation on magnetic field shielding**
  - **Perform cross-machine comparison (Similar experiments at JET and in MAST-U)**

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - In AUG, A proxy n=1 EF is applied by ramping up the current in the B coils when NBI power is injected at various levels. The NBI power needs to be low enough to keep the plasma in L-mode, without affecting the plasma density evolution.
  - This experiment envisages the use of B coils in AUG



Proposed pulses

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

71: Comparison of feedforward and feedback techniques for phase control of a wall-locked tearing mode.

- TFL assessment: P2
- Aligned with D4

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it, Paolo Zanca and Giuseppe Marchiori

- **Scientific Background & Objectives**
  - **Assess the optimal strategy for wall locked tearing mode control**

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - A simple proportional control will be implemented as control algorithm. Shot plan consists in the execution of the following discharges:
    - Test feedforward control: phase and amplitude scans of feedforward currents (5 shots)
    - Test active control with Proportional gain, amplitude and phase scan of non-zero reference
  - This experiment
    - envisages the use of B coils in AUG.
    - requires a locked mode detector (amplitude and phase), with real-time compensation of the vacuum field produced by the coils in order to provide a reliable detection of phase of the wall-locked tearing mode.

Proposed pulses

Device	# Pulses/Session	# Development
AUG	15	
MAST-U		
TCV		
WEST		

73: Fight locked modes in low-nu* ITER baseline plasmas by edge-core decoupling control

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it, Tomas Putterich, Olivier Sauter, Tomas Marcovik

- **Scientific Background & Objectives**
  - **Low-nu* ITER baseline plasmas were explored during the 2021-2022 RT01 AUG campaigns by applying n=2 RMPs. However, the discharges suffered from the presence of a locked mode. An EF correction based on purely EM modeling by the CAFÉ code was attempted, but it resulted in a delay in the onset of the locked mode.**
  - A core-edge decoupling control strategy has been derived using GPEC modelling. We aim to assess the effective LM avoidance using this strategy.

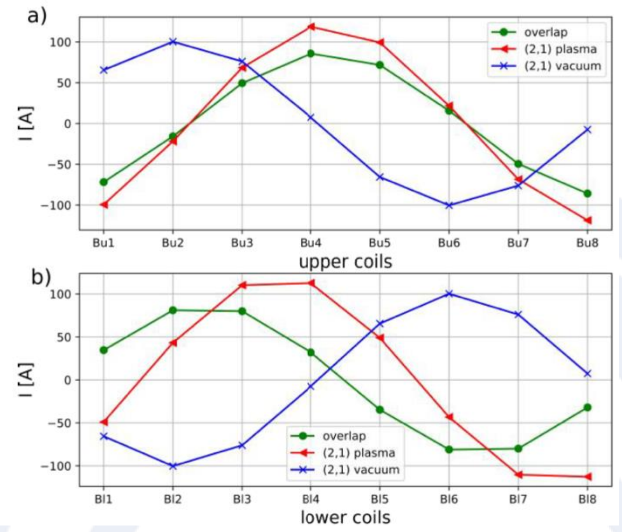
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - To validate the predictions of the GPEC code, we propose the following set of experiments: 1. repeat reference (37880) 2. and 3. repeat 1 with B-coil current phase scan (-45 deg, -18 deg) 3. to 8. B-coil current amplitude (IBU/IBL = 0.75, IBU/IBL = 0.25) and phase scan (-45 deg, -18 deg) 6. repeat 1. with the optimal B coil current amplitude and phase identified in the previous discharges
  - This experiment envisages the use of B coils in AUG

- TFL assessment: P1
- Aligned with D4
- Continuation of 2022 exp, collaboration with RT01

Proposed pulses

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

75: Dynamic model-based Error Field Correction



- **Scientific Background & Objectives**
  - The presence of EFs affects energy confinement and plasma stability in multiple ways, e.g causing MHD modes (such as tearing modes) to develop and/or lock to the wall.
  - A presently accepted metric to quantify the EF effect including plasma response is the overlap field, from which the ITER correction criterion is derived.
  - This proposal aims at implementing time-dependent EFC:
    - Varying with current in EF source
    - Varying with plasma state (e.g. betaN)
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Verify robustness of past results by testing static model-based EF correction in target scenario
  - Test time varying EFC with flat-top plasma response but rescaled with EF source currents
  - Test correction on different plasma states with varying plasma response, possibly within the same discharge
    - Ip ramp or steps
    - betaN

Proponents and contact person:

Leonardo Pigatto (leonardo.pigatto@igi.cnr.it)
Valentin Igochine
Lidia Piron
Tommaso Bolzonella

Proposed pulses

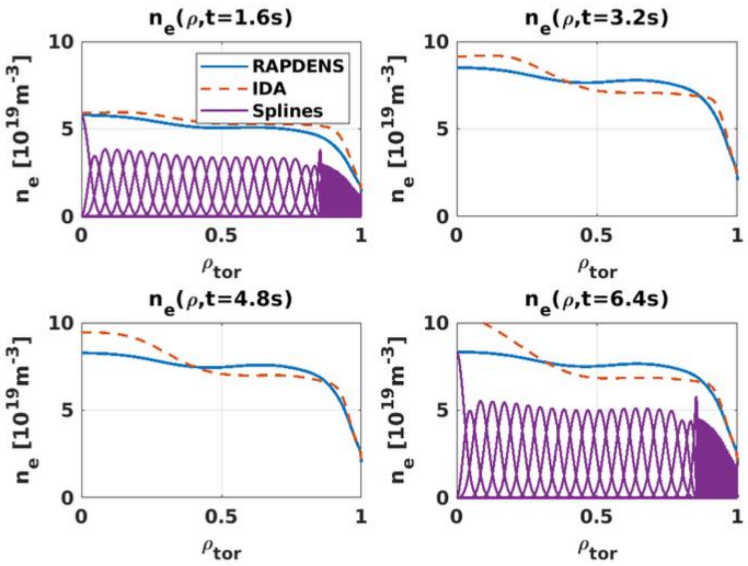
Device	# Pulses/Session	# Development
AUG	10	
MAS		
TCV		
WES		

- TFL assessment: P1
- Aligned with D4
- Continuation of 2022 exp

76: Enhancements and improvements to density control

- **Proponents and contact person:**
- **O. Kudlacek**, D. Kropackova, F. Pastore, P. Lang, W. Suttrop, C. Orrico, L. Ceelen, L. Jansen, M. van Berkel, T. Ravensbergen, D. Weldon, O. Sauter
- **Scientific Background & Objectives**
  - Improve plasma density state observers by introducing non-zero boundary condition on separatrix density and SOL model (general improvement)
  - Account for missed pellets in density control (AUG)
  - Improve density controllers by gas fueling (AUG)
  - Develop density controller using RMP coils as actuators (AUG)
  - Develop upstream density controller (TCV)
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Improve plasma state observers and implement them to the control system
  - Iteratively develop and improve the above listed controllers

- TFL assessment: P1
- Aligned with D1



Profile reconstructed by RAPDENS (blue) vs. IDA profile (red)

Figure from D. Kropackova et al, SOFT 2024

Proposed pulses

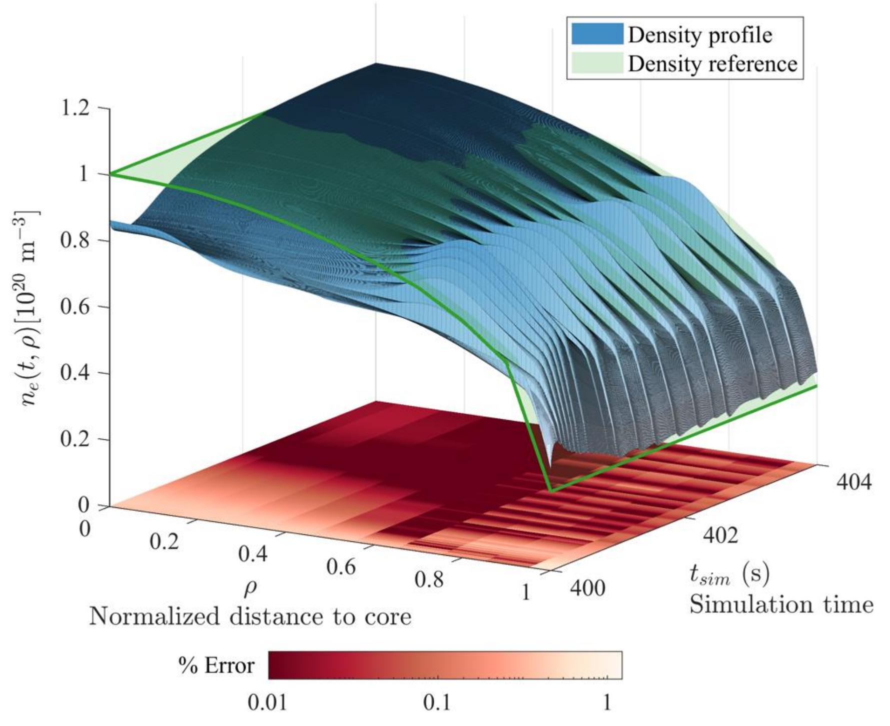
Device	# Pulses/Session	# Development
AUG	21	0
MAST-U		
TCV	10	0
WEST		

78: Density Profile Observation and Control Using Pellet and Gas Injection

- **Proponents and contact person:**
  Chris Orrico (c.orrico@differ.nl), Lennard Ceelen, Loes Jansen, Thomas Bosman, Alex Panera Alvarez, Matthijs van Berkel, Didier Mazon

- **Scientific Background & Objectives**
  - ITER and DEMO will require:
    - Reliable real-time electron density profile $n_e(\rho)$ estimation.
    - Safe control of $n_e(\rho)$ with gas and pellet fueling
  - Develop density profile observation and control on AUG and WEST. Process:
    1. Measure plasma dynamic response to fueling (System Identification).
    2. Develop lightweight plasma dynamic models (Control-Oriented Modeling)
    3. Estimate $n_e(\rho)$ in real time (Dynamic State Observer
    4. Model-based control scheme to safely regulate $n_e(\rho)$ (Controller Design)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Experimatal strategy:
    - System identification of the...
      – Gas valve response to valve voltage (no plasma required)
      – Core plasma response to pellet injection
      – Core plasma response to gas injection (Deuterium and Hydrogen)
    - Density profile estimation using dynamic state observer (WEST only)
    - Classical density control with pellets and gas injection
    - Model Predictive density profile control with pellets and gas injection
  - Essential diagnostics: Interferometry and Reflectometry



Demonstration of $n_e(\rho)$ control with MPC and fuel pellets in JINTRAC for ITER

- TFL assessment: P1
- Aligned with D1

		# Development
AUG	22	-
MAST-U	-	-
TCV	-	-
WEST	28	-

91. Plasma performances control with reflectometry

- **Proponent(s)**
  - Maylis Carrard, Roland Sabot, Yassir Moudden
  - PhD subject : plasma control with reflectometry

- **Scientific Background & Objectives**
  - Main questions: use of reflectometry for plasma performances optimisation
    - Core density gradient control for radiated power control
    - Edge density gradient control for coupling control

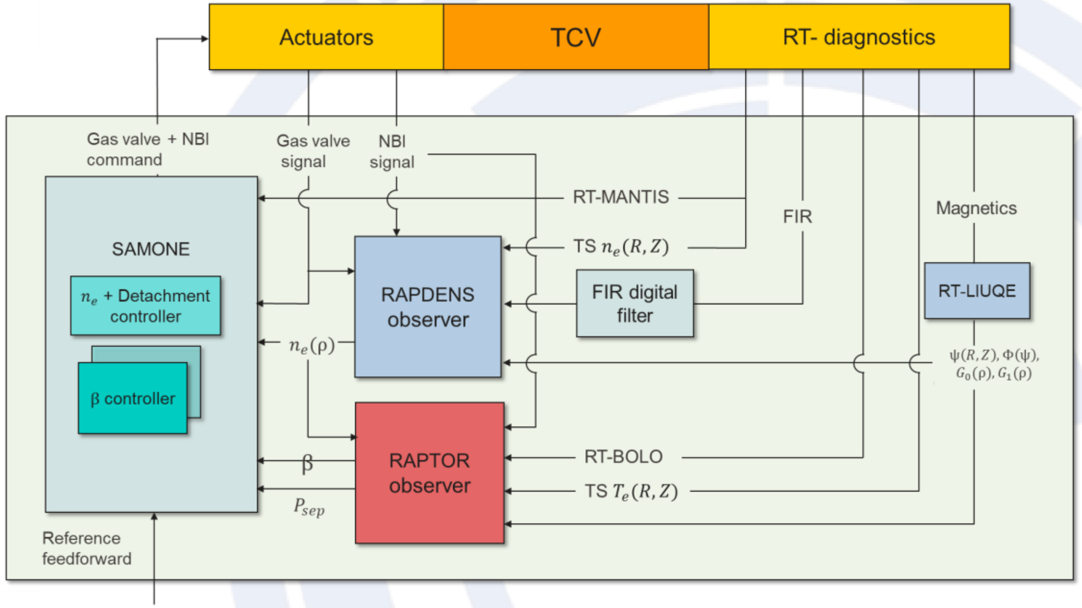
- **Experimental Strategy / Machine constraints and essential diagnostics**
    - **Preliminary step :** Validation of the control of plasma density with gaz injection. Plan to be done in C10
    - **Compare gas injection with pellet or SMBI** : analyse of the impact of the fueling of the plasma on the density by separating all the parameters
    - **Control of the core density gradient (peaking)**: First control of the core gradient in ohm add the RF heating after some possible adjustments.
    - **Control of edge density gradient** : Control the edge density gradient to control the coup and ICRH
    - **Control of the edge and core density gradient** : Control the edge and core density gradi least 3 points of measurements.

Device	# Pulses/Session	# Development
AUG	-	-
MAST-U	-	-
TCV	-	-
WEST	100	-

- TFL assessment: P2
- Aligned with D1
- Very large pulse request

79: Integrated estimation and control of plasma core-edge-exhaust with real-time model-based observers

- **Proponents and contact person:**
  - Francesco Pastore (EPFL)
  - Olivier Sauter (EPFL), Federico Felici (Deep Mind UK), Cristian Galperti (EPFL), Alessandro Pau (EPFL), Yoeri Poels (EPFL), Cristina Venturini (EPFL), Cassandre Contré (EPFL), Simon Van Mulders (ITER organization), Anna Trang Vu (ITER organization), Sara Dubbioso (UNINA), Holger Reimerdes (EPFL), Gijs Derks (DIFFER), Artur Perek (EPFL), Massimo Carpita (EPFL), Kenneth Lee (EPFL), Timo Ravensbergen (ITER organization), Ondrej Kudlacek (AUG), Daniela Kropackova (CTU), Luke Simons (EPFL), Daniele Hamm (EPFL).
- **Scientific Background & Objectives**
  - Model-based observers enable decoupling between diagnostics and controllers.
  - Integration of various diagnostics info with Extended Kalman Filter algorithm for improved plasma state reconstruction in real time.
  - RAPDENS observer extensively used for local control of density profile for **detachment studies**, **control of ne edge in high density H-mode discharges** and **control of density below cutoff in X2 ECH heated discharges.**
- **Experimental Strategy**
  - Simultaneous **control of beta, edge electron density, and CIII emission front** of an H-mode plasma with NBI heating, gas valve fueling, and impurity seeding. (10 shots scenario +20 shots control task)
  - **Recovery of the detachment conditions** (e.g. avoiding reattachment of divertor leg) **with SAMONE supervisory control** in the regulation of impurity seeding/power delivered at the separatrix. (10 shots)
  - **Develop and test scenario control strategies** and tasks controllers which are **"tokamak-agnostic"** to be later tested **on AUG and WEST** once successful.



- TFL assessment: P1
- Aligned with D1

algorithms:

ng and impurity

- RT-MANTIS, RT-BOLO, SCD, SAMONE, RAPDENS, RAPTOR

Proposed pulses

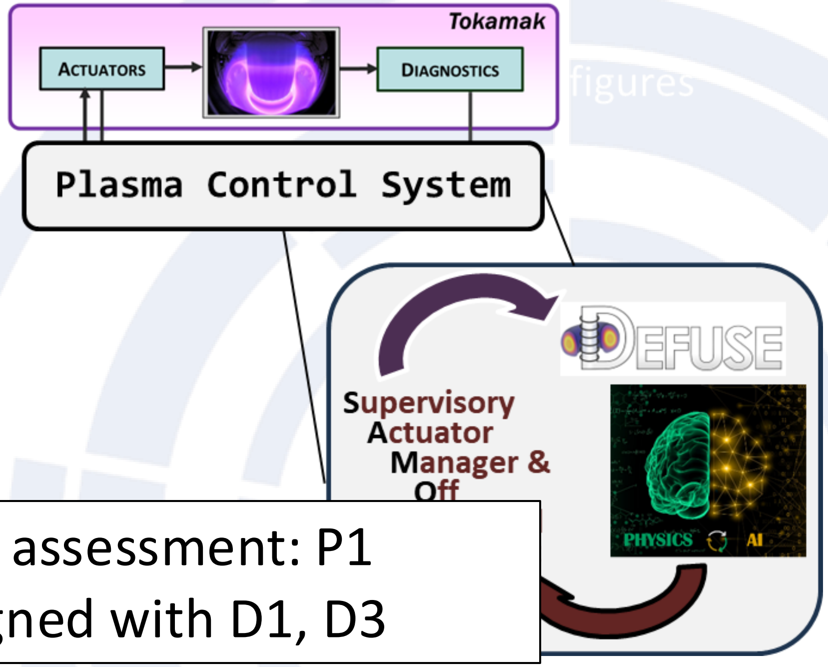
Device	# Pulses/Session	# Development
TCV	30	10

80: Integrated control for disruption free operation and off-normal events handling

- **Proponents and contact person:**
- alessandro.pau@epfl.ch et al (see Wiki)

- **Scientific Background & Objectives**
  - develop integrated control solutions for high performance scenarios while minimizing the risk of disruptions on tokamaks
    - Plasma state monitoring and active regulation of the proximity to controllability and stability disruptive boundaries (physics & data-based state observers – RAPDENS, RT-MHD, RT-MRE – DB connection/optimization with DEFUSE)
    - Active *disruption avoidance* and *off-normal events handling*
    - robust machine-independent strategies for *plasma termination*
    - machine independent strategies for the *H-mode entry* and *exit* in high-performance plasma regimes
    - (AI-assisted) *pulse schedule* design and optimization tools development.

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - High-performance (high *density* and β) plasma scenarios developed in Integrated Control experiments in 2024.
  - Few technical shots for commissioning and assess compatibility with different baffles configurations
  - test *controllers* and integration of *RT-observers/proximity monitors* in the machine generic *supervisory actuator manager* and *off-normal handling system* for routine operations



- TFL assessment: P1
- Aligned with D1, D3

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	40	15
WEST		

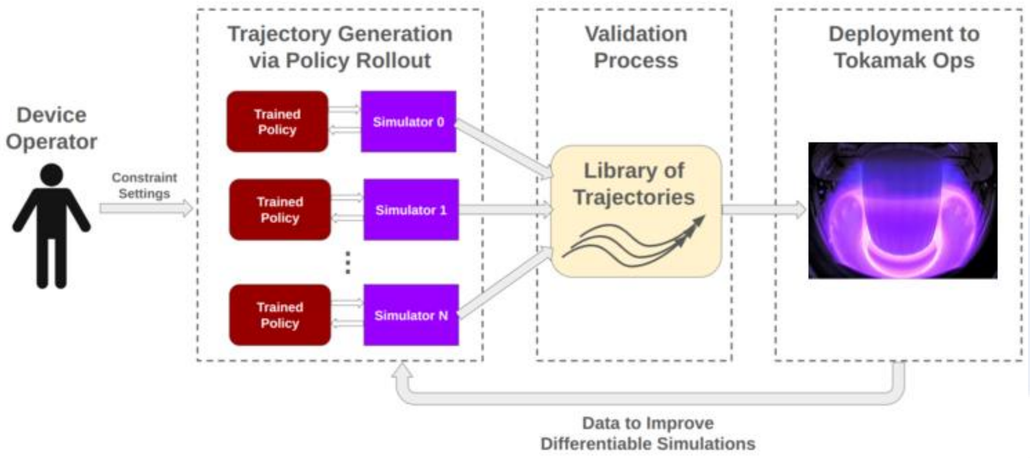
81: Plasma termination optimization for high-performance scenarios

- **Proponents and contact person:**
- alessandro.pau@epfl.ch et al (see Wiki)

- **Scientific Background & Objectives**
  - long-term goal of demonstrating reliable plasma terminations and correct exit from high-performance operation in tokamaks.
    - Integration of *physics* and *data-driven real-time proximity monitors* (MHD markers - rotating and locked modes -, vertical growth rate, etc.) to activate plasma termination.
    - Development of *robust machine-independent strategies for plasma termination* (control logic, ONE matrix response, trigger generation functions, jump-to-termination schemes)
    - Development of machine generic workflows to *optimize plasma termination trajectories* (plasma shape and current ramp-down, heating switch-off, etc.)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Builds upon high-performance (high *density* and β) plasma scenarios developed in Integrated Control experiments in 2024 and related development in 2025.
  - test *controllers* and integration of *RT-observers/proximity monitors* in the machine generic *supervisory actuator manager and off-normal handling system* for routine operations
  - Deploy different *jump-to-termination control policies* on TCV and MAST-U

Jump-to-termination and plasma termination optimization



- TFL assessment: P1
- Aligned with D2, D3

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U	30	20
TCV	25	15
WEST		

83: Optimal actuator allocation for integrated control

- **Proponents and contact person:**
  - adriano.mele@epfl.ch, saitejp@lehigh.edu,
    Eugenio Schuster, Alessandro Pau, Cristian Galperti, Simon Van Mulders, Francesco Pastore, Cassandre Contré, Antonia Frank

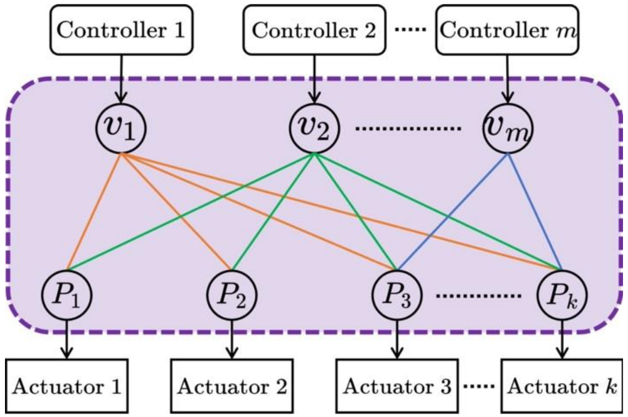
- **Scientific Background & Objectives**
  - Develop and validate an optimal actuator sharing algorithm, which optimally allocates actuators to achieve multiple, potentially competing plasma control objectives

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Extend previous work on coil current allocation for magnetic control to other control problems, such as:
    i. simultaneous control of the plasma energy and safety factor
    ii. plasma energy and density regulation
    iii. plasma energy and NTM control
  - test the allocator's ability to handle unexpected actuator failures or changes in control objectives

Proposed pulses

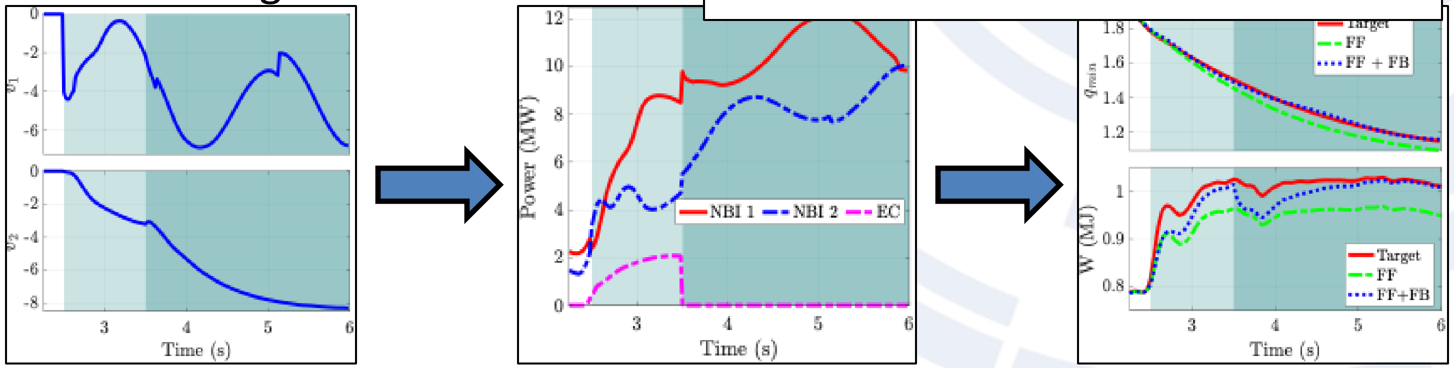
Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	20	-
WEST		

- TFL assessment: P1
- Aligned with D1
- Liase with AUG work



Controller signals

Actuator



87: Model-based profile control for better access to advanced scenarios

- **Scientific Background & Objectives**
  - Develop an integrated **model-based profile controller** at TCV using:
    - RT-RAPTOR for radial transport → $\{\psi, T_e\}$
    - RT-RAPDENS for core-edge density evolution → $\{n_e\}$
    - RT-TORBEAM for EC H&CD → $\{p_{ec}, j_{ec}\}$
    - Validate offline RAPTOR-TORBEAM-FBT coupling for pre-shot scenario prediction (can be used to inform magnetic control)
  - Optimize and control *advanced scenarios*:
    - EC current drive location for reversed-shear scenario
    - NBI + EC heat & current deposition for ITB formations
    - β, I_p control
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Advanced scenarios with strong current shaping and/or ITB formation
  - Test in PT and NT plasmas and with different density targets to check robustness of control strategy
  - Essential diagnostics: CXRS, SCD & real-time observers

Proponents and contact person:

Cassandre Contré
Antonia Frank
Francesco Pastore
Simon Van Mulders
Olivier Sauter
Chiara Piron

- TFL assessment: P1
- Aligned with D2, D5
- Use development pulses form RT08?

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	15	5
WEST		

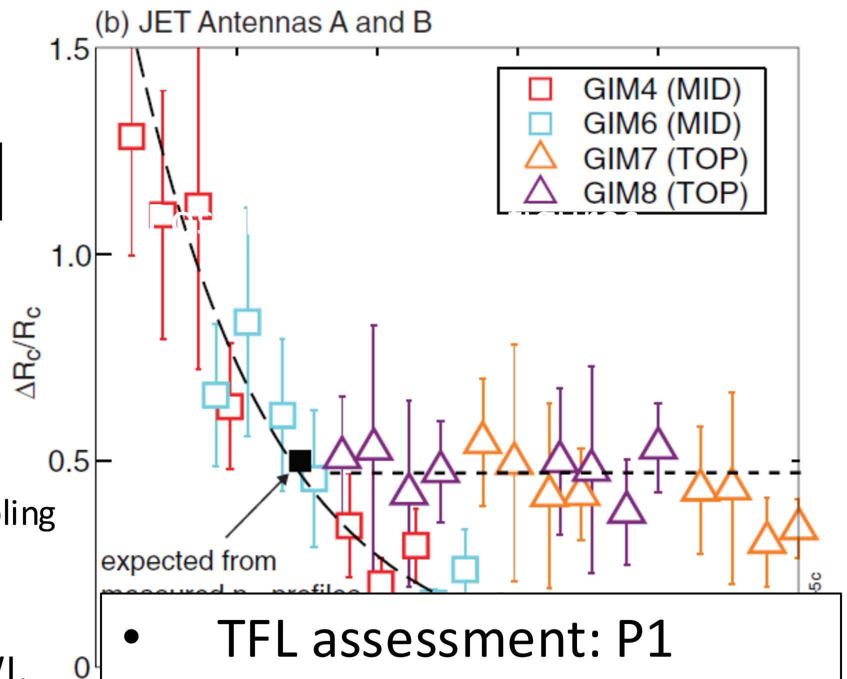
74: Local gas injection as an actuator to improve IC and LH wave coupling in H-mode

ITPA-IOS

- **Proponents and contact person:**

L. Colas, E. Lerche, J.Hillairet, W. Helou, A. Ekedahl, J. Cazabonne, E. Geulin, N. Fedorczak, J. Gunn, F. Clairet, Ch. Bottereau, L. Schiesko, Ch. Guillemaut

- **Scientific Background & Objectives**
  - RF power coupling to plasma is sensitive to details of SOL profiles
  - Varies as pedestal steepens, sensitive to SOL fuelling.
  - ITER RF antenna might be operated far from separatrix, local gas valve installed to improve RF coupling
  - **Goals**
    - Document SOL profiles & RF coupling variations over L➔H transition
    - Enhance RF coupling via adequate gas injection w/o disturbing the H-mode and PWI.
    - Prepare actuator for real-time optimization? Real-time reflectometry measurement being commissioned on WEST



- TFL assessment: P1
- Aligned with D1

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Pre-requisite: “Standard H-mode” developed in dedicated sessions ➔ reference pulse
  - Scan amounts of gas and injector location (divertor, upper + outer mid-plane near each RF wave launcher). One session IC-oriented, one session LH-oriented
  - Measure density “profiles” at several toroidal locations:
    - Edge reflectometry / antenna reflectometry / pecker probes / RCP / edge Thomson scattering Langmuir probes
  - Assess simultaneously the quality of the H-mode and the changes in PWI, using visible spectroscopy and IR thermography.

Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV		
WEST	#30 / 2	

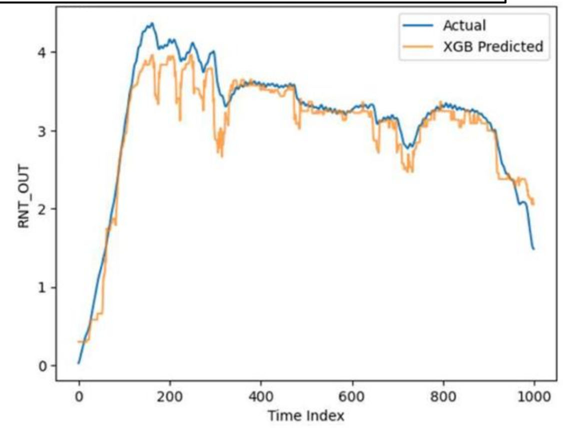
72: Machine learning aided dud detection for burning plasmas: controller design and assessment

- TFL assessment: P1
- Aligned with D1

- **Proponents and contact person:**
  - lidia.piron@igi.cnr.it, Alessandro Pau

- **Scientific Background & Objectives**
  - In preparation for DT operations in ITER, SPARC and BEST, we aim to develop a surrogate model of the neutron rate using machine learning (ML) methods. This proxy neutron rate will be utilized in real-time by the dud detector to monitor plasma performance, alongside other performance indicators such as beta and stored energy. If the plasma does not behave as expected based on the plasma state, a safe plasma termination will be initiated.
  - A surrogate model has been developed for JET using DT plasmas and there is an ongoing collaboration to use TFTR data
  - The RT control strategy is proposed to be tested in TCV

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Test the ML based dud detector in ITER relevant scenarios as the ones used in RT22-01, -02 and -08, including a safe plasma termination
  - Assess the performance of the ML algorithm in providing synthetic data in real-time



Proposed pulses

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

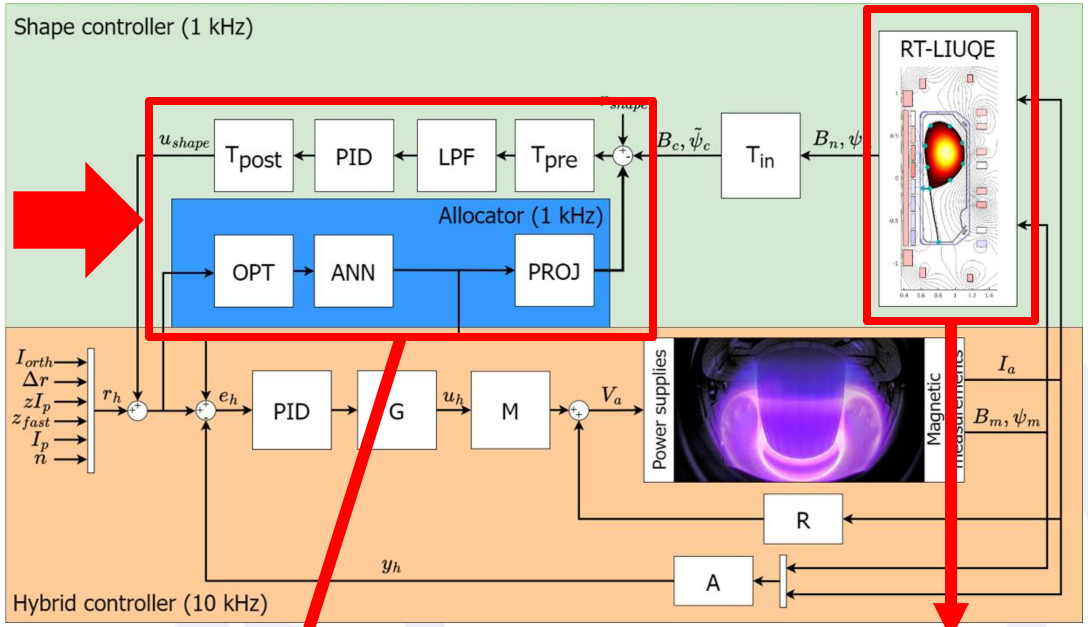
82: Advanced magnetic control at TCV

- **Proponents and contact person:**
  - adriano.mele@epfl.ch, Cosmas Heiss, Cristian Galperti, Luigi E. Di Grazia, Gianmaria De Tommasi, Alfredo Pironti, Massimiliano Mattei, Holger Reimerdes, Kenneth Lee, Allen Wang

- **Scientific Background & Objectives**
  - Implement a Model Predictive Control scheme for plasma shape
  - Export MPC tools to other control problems
  - Develop and test fast shape observers
  - Apply shape control to ADCs
  - Enhance/generalize controllers with ML techniques

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Solid sim2real transfer toolchain demonstrated in 2024
  - TCV digital control system (SCD)+RT-LIUQE requested on 'any' plasma configuration

ML



fast observers

- TFL assessment: P1
- Aligned with D1

Proposed pulses

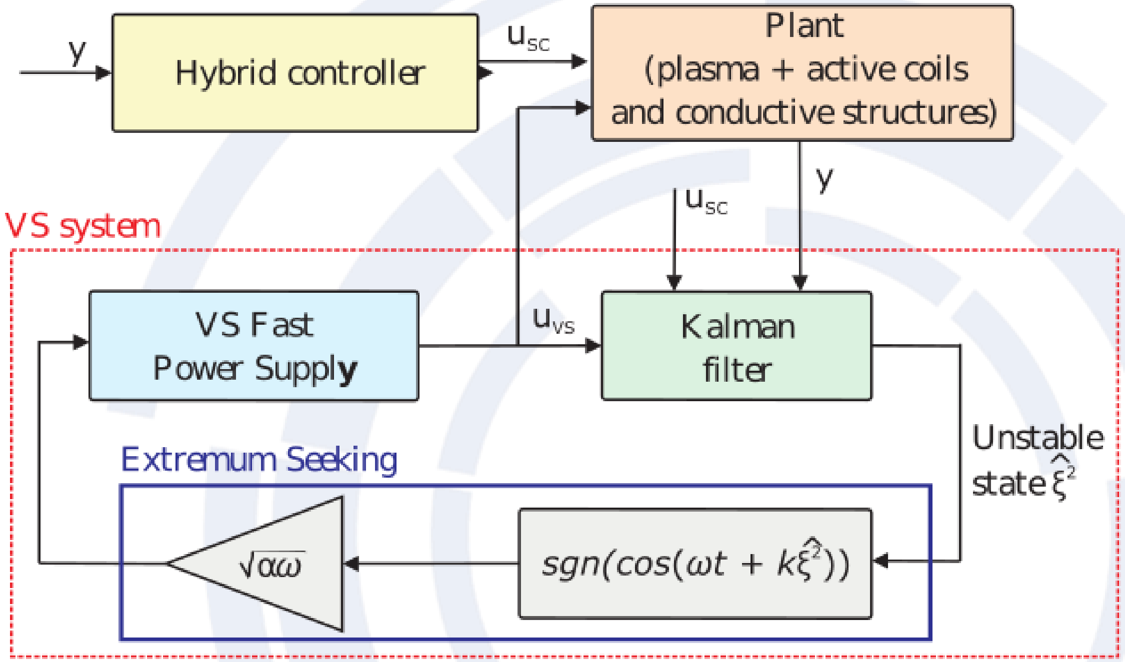
Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	45	10
WEST		

84: Advanced solutions for plasma vertical stabilization

- **Proponents and contact person:**
  - Adriano.mele@epfl.ch, sara.dubbioso@unina.it, Cristian Galperti, Luigi E. Di Grazia, Gianmaria De Tommasi, Alfredo Pironti, Massimiliano Mattei, Olivier Sauter, Stefano Marchioni

- **Scientific Background & Objectives**
  - Extremum Seeking control as a possible data-driven and model-free approach for stabilizing the n=0 mode, to assure more robustness compared with usually model-based solutions.
  - data-driven identification of simplified models for vertical dynamics

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Progressively testing on configurations at higher frowth rate
  - Needs the updated TCV Fast Power Supply driver



- TFL assessment: P2
- Aligned with D1

Proposed pulses

Device	# Pulses/Session	# Development
TCV	15	5

66: Fast magnetic control to balance double-null divertors

Proponents and contact person:

Oliver Bardsley (oliver.bardsley@ukaea.uk), Morten Lennholm, Mark Lafferty, (Hendrik Meyer)

Scientific Background & Objectives

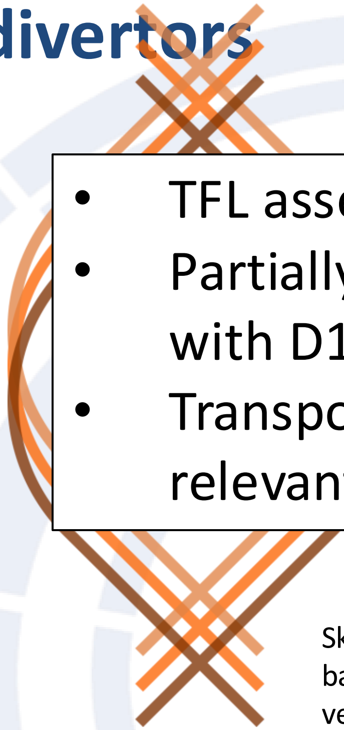
The Double-Null (DN) configuration offers advantages for tokamak reactors in halving the loads to each divertor, insulating the inner strike points from the outer scrape-off layer, and a favourable plasma scenario. However, it is uncertain whether it will be possible to ‘balance’ the DN – keep the two nulls on substantially the same flux surface – in light of the plasma’s vertical instability. The objectives of this proposal are:

- Assess performance of a novel fast control scheme for balancing the magnetic topology of DN;
- Use new in-vessel coils in AUG to feedback control poloidal flux difference between the two nulls (equivalently “dr-sep”);
- Use ex- and/or in-vessel coils in TCV to implement a similar control scheme;
- Improve confidence in successful implementation of DN as a viable alternative divertor configuration for DEMO and other reactor-class devices;
- Explore benefits of operating in a balanced DN on core/edge confinement, ELM regime, and divertor heat/particle loads.

Experimental Strategy/Machine Constraints and essential diagnostic

- DN H-mode scenario.
- Real-time fast reconstruction/estimation of X-point locations and poloidal flux levels.
- Feedback control on X-point flux difference actuated using in-vessel coil(s), responding at least as fast as the standard vertical control system.
- Diagnostic capability to determine heat/particle loads at ideally all four divertor legs and/or strike points.
- Indicative shot plan:
  - Use various reference waveforms for vertical position (constant, steps, etc…) and demonstrate fast control of dr-sep to zero (8 pulses).
  - Improve dr-sep controller gains and attempt both SISO and MIMO control to decouple vertical and dr-sep control (4 pulses).
  - Evaluate effect of dr-sep controller on QCE regime and/or H-mode access (4 shots)

- TFL assessment: P2
- Partially aligned with D1
- Transport part more relevant to RT07



Sketch: DN remaining balanced at finite vertical displacement

Proposed pulses

Device	# Pulses/Session	# Development
AUG	16	
MAST-U		
TCV	16	
WEST		

77: ICRF assisted breakdown

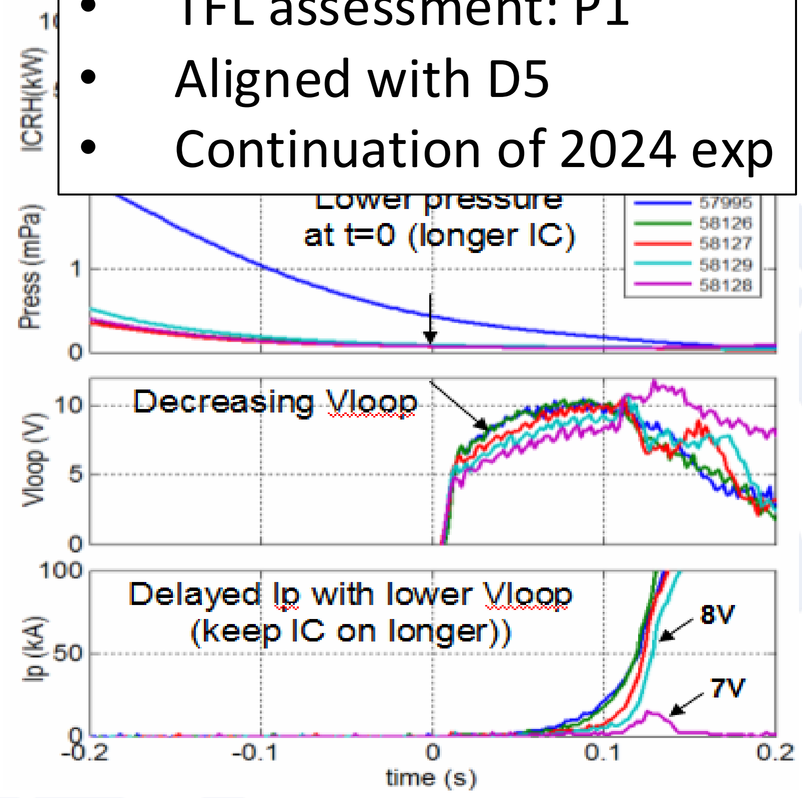
- TFL assessment: P1
- Aligned with D5
- Continuation of 2024 exp

- **Proponents and contact person:**

Ernesto Lerche, Tom Wauters, Julien Hillairet, Eléonore Geulin, Laurent Colas, Charles Vincent, Pierre Dumortier, Johan Buermans, Alexandre Fil, Cedric Reux

- **Scientific Background & Objectives**
  - ICRF assisted breakdown is considered in ITER to help plasma initiation when the machine is contaminated
  - Initial studies have started in WEST: the loop voltage at breakdown was decreased from 10V (minimum without RF) to 7.5V (with RF) but the ITER target value of V_{loop}=5V was never reached. Shape optimization for the RF start-up also started but was never concluded.
  - **The main objective is to obtain successful breakdown at the lowest possible loop voltages (mimicking ITER) by optimizing the IC pre-ionization plasma in terms of magnetic configuration (e.g. TCP), RF power and IC plasma duration**

- **Experimental Strategy and essential diagnostics**
  - Start with the best ICWC plasma obtained in 2024 with duration > 10s
  - Test different magnetic configurations by dynamically transiting from the standard config. during the ICWC discharge; Identify the best shape in terms of density / emission
  - Start reducing the loop voltage from 10V to the minimum achievable with both the standard and the optimized magnetic configurations
  - 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	25 pulses (5 for shape development, 2 x 10 for comparing the configs.)	

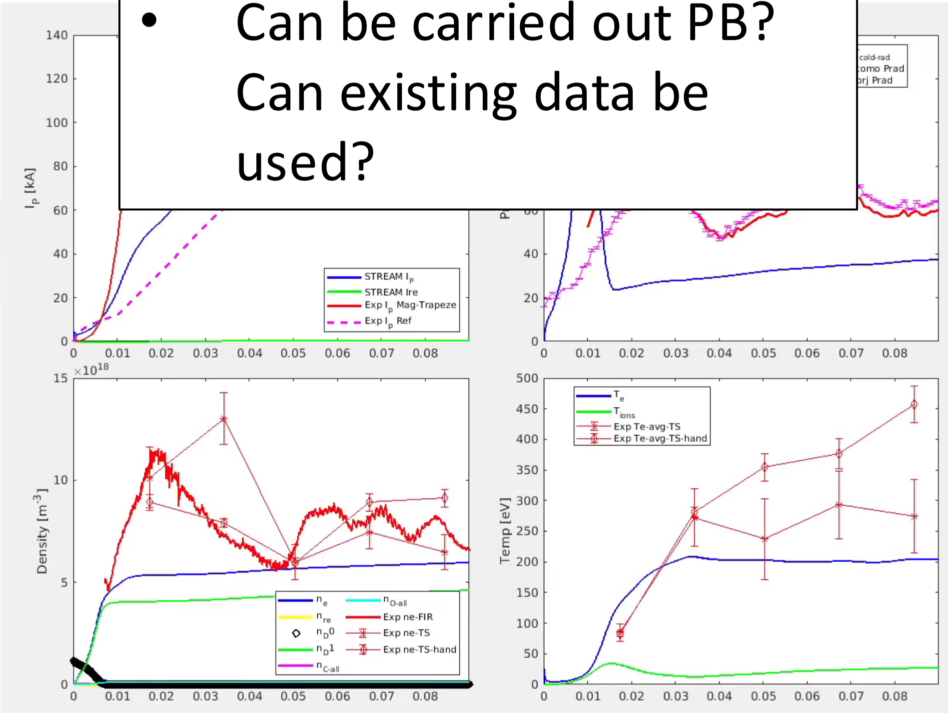
86: Validation of breakdown and burn-through modeling in TCV

- TFL assessment: P2
- Aligned with D5
- Can be carried out PB? Can existing data be used?

- **Proponents and contact person:**
  - **Fabien Jaulmes (jaulmes@ipp.cas.cz), Pedro Molina-Cabrera (pedro.molina@epfl.ch)**

- **Scientific Background & Objectives**
  - Experimental validation of burn-through simulations in TCV
    - Implement the DYON-FIESTA and METIS 1-D workflow in TCV and compare with experiments
    - Continue STREAM 0-D simulations in parallel to compare/contrast
  - Study experimentally the effect of varying input loop voltage on the appearance of startup MHD activity
  - Study experimentally the effect of ECH-assisted burn-through and compare with simulations

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Start modeling existing discharges and decide on specific experimental parameters to vary during experimental sessions (pressure, fueling, V-loop, etc...)
  - Use both 0D and 1D codes to do predictive modelling of plasma evolution before and after experiments and compare pre/post-discharge simulations.
  - ECH X2 heating is required for the last 1/3 of the proposal
  - Thomson scattering triggering can be changed to improve temporal resolution
  - Special startup diagnostics are required: DSS (Ti), CXRS (Ti), APG, MANTIS, FastCam



Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	50	20
WEST		

90: Current ramp-up on bulk tungsten limiters: impact of ECRH and nitrogen seeding

- **Proponents and contact person:**
  P. Manas (pierre.manas@cea.fr), J. Hobirk, R. Pitts, P. Maget, N. Fedorczak, N. Varadarajan, G. Ciraolo, C. Guillemaut, C. Desgranges, R. Guirlet, Léna Delpech
- **Scientific Background & Objectives**
  Ramp-up on tungsten limiter critical and complex phase to model and predict, high radiated power fraction: strong core edge coupling
  Complement existing data on WEST with limited plasmas
  Make use of WEST bulk W limiter and new available ECRH
  - Characterise the impact in terms of flux consumption, radiated power fraction, tungsten sources and core transport
  - of central to off-axis ECRH
  - of nitrogen seeding for future active control during current ramp-up phases
- **Questions addressed:**
  - Nitrogen seeding on detached limiter plasmas, impact on flux consumption, tungsten contamination, ohmic heating, tungsten sources
  - Core to off-axis ECRH heating on limiter plasmas, impact on flux consumption,
  - tungsten contamination, core impurity transport
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Start from reference cases of limited plasmas performed in 2024 and apply ECRH
  heating on/off axis for scans in plasma current and density
  - Nitrogen seeding based on results of 2024 on 3 different plasma current and similar Greenwald fractions and test ideal signal for active control
  - Main diagnostics: ECE, Thomson scattering (edge and core), bolometry, UV/Visible spectroscopy, Langmuir probes, SXR, TC, IR

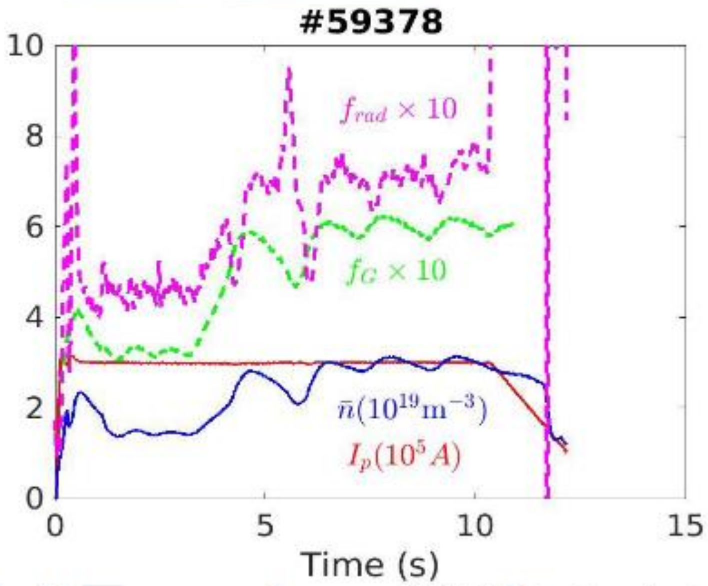


Fig.1: Time traces from a WEST limited plasma (on BN tiles) with close to stable detached conditions

Proposed

- TFL assessment: P1
- Aligned with D5
- ITPA exp

Device		
AUG		
MAST-U		
TCV		
WEST	20/1	

Control of IRE's with optimised shape control using iterative learning on MAST Upgrade

- **Proponents and contact person:**
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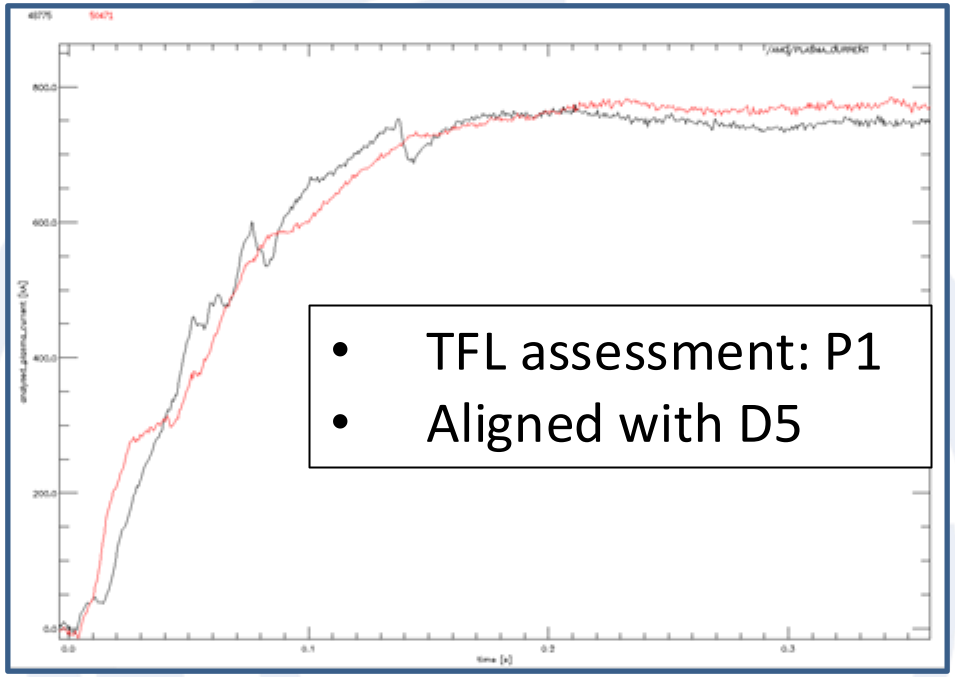
- **Scientific Background & Objectives**
  - IRE's occur during the ramp-up and can set the scenario trajectory by causing uncontrolled changes to the magnetic configuration and density
  - Affects H-mode entry and MHD
  - Investigate effects of shaping on IRE timing
  - Investigate control of IRE timing for increased IP ramp-rate and optimised Q-profile

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - Modelling and iterative learning with CREATE-NL
  - DN and LSN scenarios (reference 50471, 50467)
  - 750kA and 1MA scenarios
  - MSE diagnostic essential



- TFL assessment: P1
- Aligned with D5

Proposed pulses

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

92. Development of XPR/MARFE real time observer for the upper divertor in ASDEX Upgrade

- **Proponents and contact person:**
  Bernhard Sieglin, Matthias Bernert, Marc Maraschek, Anja Gude, Felix Klossek, Alessandro Pau
- **Scientific Objectives**
  - Implement real time AXUV diode bolometry on ASDEX Upgrade (diagnostic is available, setup needs to be commissioned for real time use for the upper divertor)
  - Implement the additional evaluation process and the corresponding signals into the discharge control system.
  - Implement and commission the signals to be used for feedback control and exception handling.

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  To achieve the objectives we propose to
  - implement the required real time diagnostics and observers.
  - perform H-Mode density limit discharges in USN to validate the observers.
  - Commission the exception handling capabilities for disruption avoidance.
  - If needed perform system identification for detachment control to obtain feedback control parameters.

- **Scientific Background**
  ASDEX Upgrade is currently being equipped with a new upper divertor. The control capabilities for detachment control and disruption avoidance are currently implemented for the lower divertor. These capabilities will be required for the upper divertor as well. The observation of the XPR/MARFE is desired for both detachment control where continuous control is applied as well as for disruption avoidance using e.g. exception handling. This proposal aims to implement and commission these divertor on ASDEX Upg

- TFL assessment: P1
- Aligned with D1
- To be moved to RT05

Proposed pulses

Device	# Pulses	
AUG		5
MAST-U		
TCV		
WEST		

93: H-Mode density limit state space investigations

- **Proponents and contact person:**
  Bernhard Sieglin, Matthias Bernert, Marc Maraschek, Anja Gude, Felix Klossek, Alessandro Pau

- **Scientific Objectives**
  - Perform the automated scan in favorable drift direction.
  - Repeat the automated scan in unfavorable drift direction.
  - Perform the triangularity scan in both favourable and unfavourable drift direction.
  - Perform a fine scan of the triangularity around the density threshold in favourable drift direction.
  - Perform a fine scan of the heating power around the turnover point between XPR/MARFE onset and HL-transition.

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  To achieve the objectives we propose to
  - Perform gas ramps with different levels and compositions of auxiliary heating.
  - Three discharges per field direction are proposed (15 heating levels in total per direction).
  - Two discharges for the triangularity scan (both drift directions) from delta = 0.0 - 0.3
  - Fine scan around the triangularity threshold e.g. 0.22-0.27.

- **Scientific Background**
  Previous work showed that order of the occurrence the HDL and the HL-transition depends on the applied auxiliary heating. The new upper divertor in ASDEX Upgrade now allows operation with both toroidal field directions with high power without having to change the plasma current direction. This capability is proposed to be exploited by repeating an automated HDL state space scan which has been demonstrated previously on ASDEX Upgrade. With this the HDL state space can be explored using only a few discharges (5 scans per discharge). In addition to this a scan of the triangularity at the passive X-Point is proposed at a constant heating mix that is to be determined by t
  triangularities can

- TFL assessment: P1
- Aligned with D2
- Makes use of new AUG divertor

Proposed puls

Device	# Pu	
AUG	15	2
MAST-U		
TCV		
WEST		