WPTE Program 2022-2023

Experimental program and modelling needs

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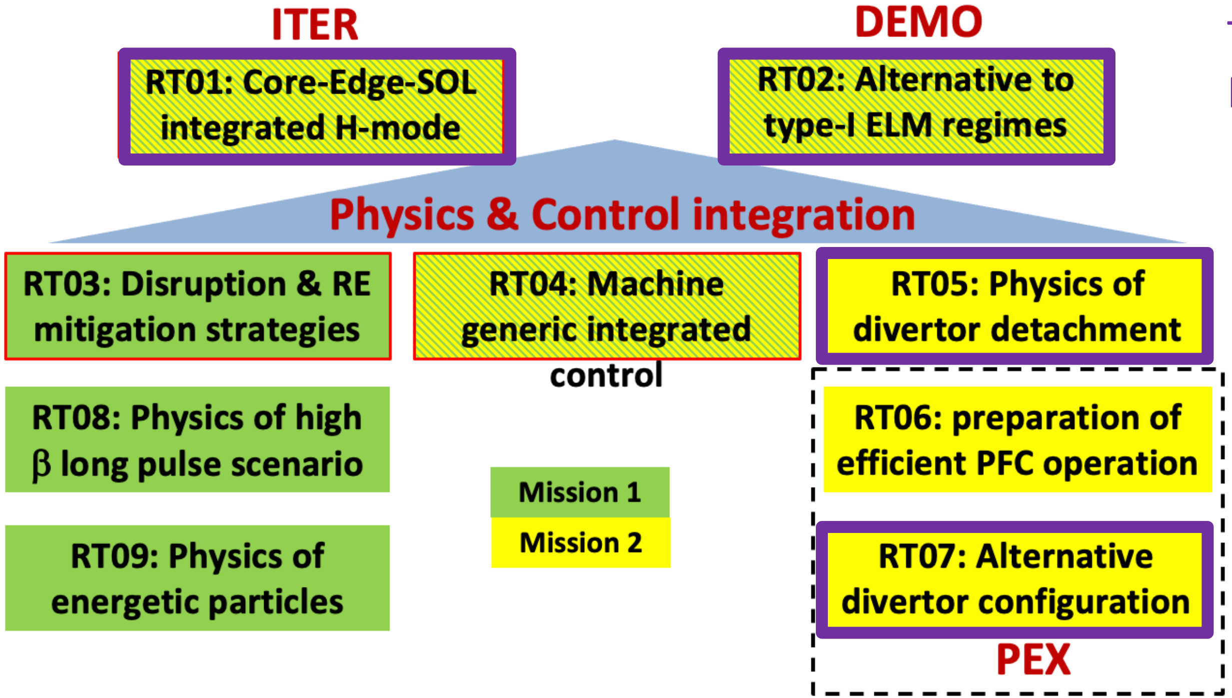
The WPTE 2022-2023 Program in support of ITER and DEMO



Thrust 1: related Research Topics

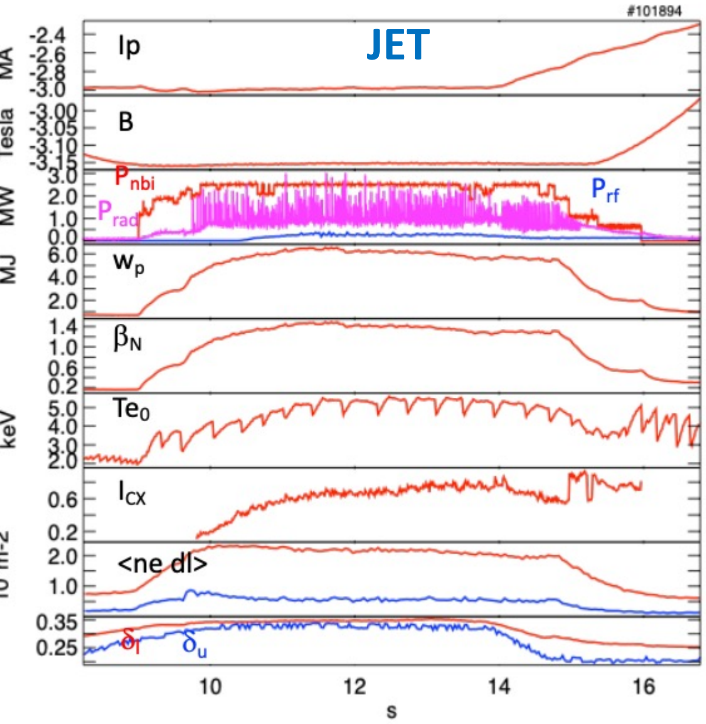
Mission 1 – Plasma Regimes of Operation
Mission 2 – Heat Exhaust Systems

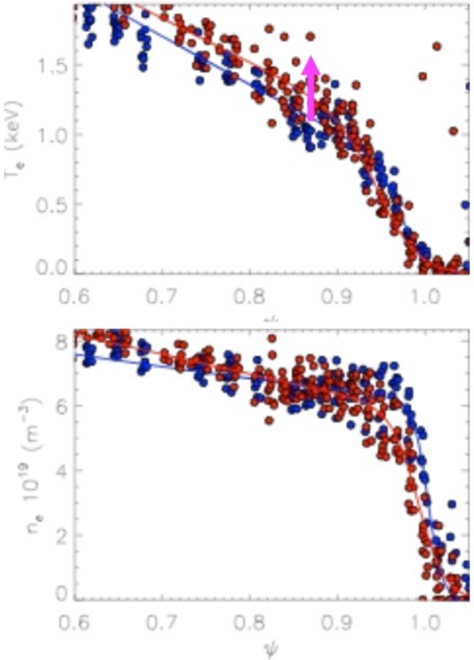
RT22-01 Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER

#	Scientific Objectives
D1	Develop stationary high power H-mode scenario at low core and pedestal collisionalities compatible with detached divertor
D2	**Provide physics-based cross-field transport coefficients to TSVVs (1, 3, 4 and 11) for turbulence modelling**
D3	Compare different impurity mixes for partially detached divertors in high power operations in view of ITER radiative scenarios
D4	Assess pedestal performances with large SOL opacity
D5	Understand pedestal physics at large plasma current (>3MA)
D6	Quantify impurity screening for high temperature pedestals
D7	Assess the compatibility and stability with X-point radiator regimes with confinement

	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	20	50	34	15
2023	15	110	30	0

Highlight and new experimental progress on RT22-01

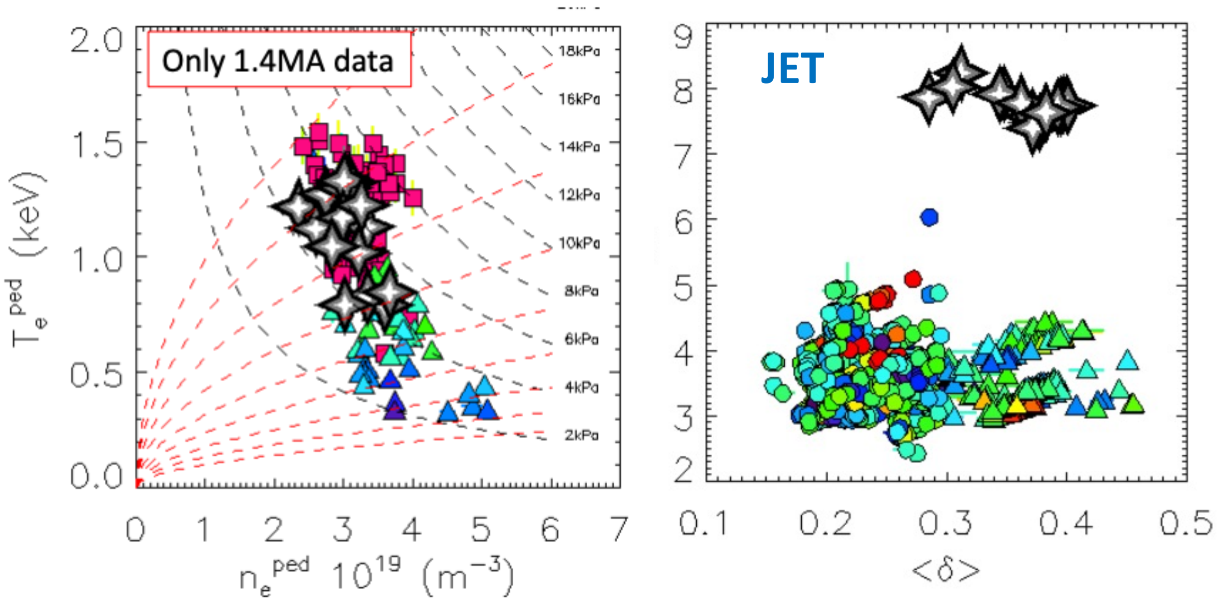




- Progress towards extending ITER Baseline Ne seeding discharges to higher current on JET (2.5 --> 3.2 MA)
- First indication of pedestal improvements
- Clearly **need to address microturbulence in pedestal region** and **dependence on plasma current and seeding species** (2.5 MA chases addressed by I. Predebon)

Highlight and new experimental progress on RT22-01

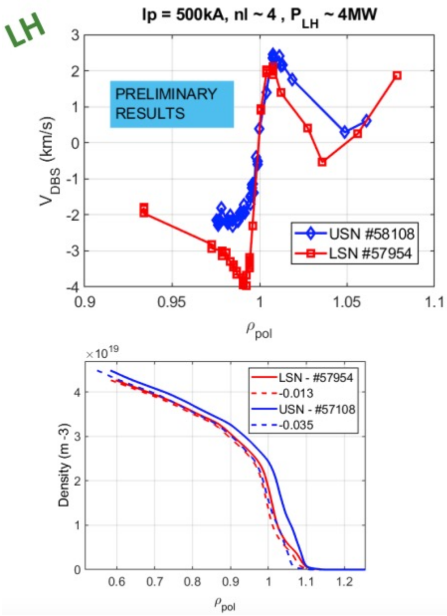
- Exploration of peeling limited plasmas on JET (achieved at high q_{95})
- Achieved low ν^* pedestal (with similar values w.r.t. C-wall)
- **Exploring GK simulations at these collisional/shaping values (B. Chapman)**

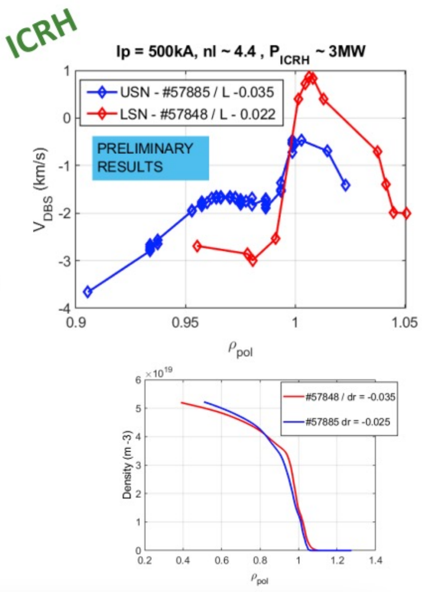


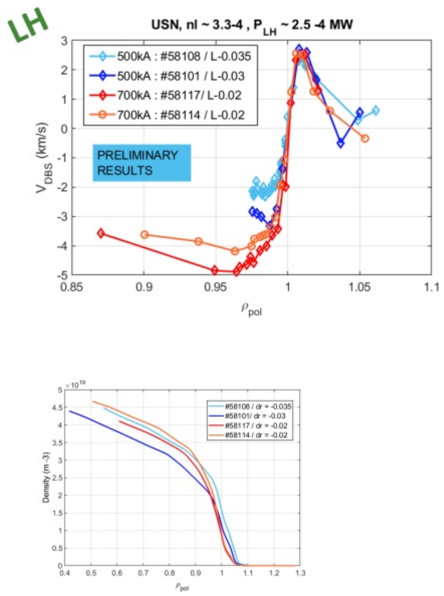
- Exploring modification from peeling limited to balloning limited pedestal on TCV (**GENE GK simulation O. Krutkin**)
- Need to strengthen the synergy with the corresponding effort in TSVV1

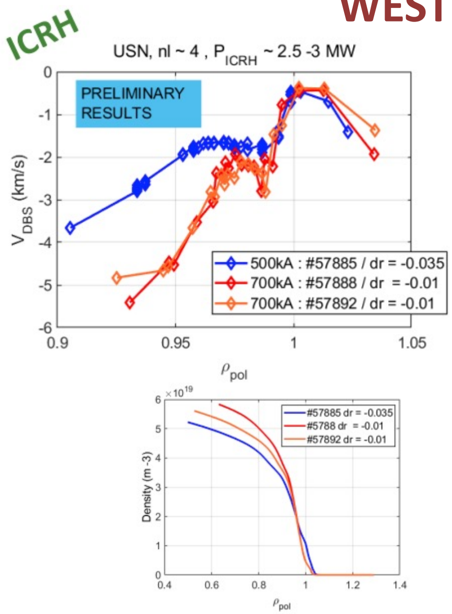
Highlight and new experimental progress on RT22-01

WEST



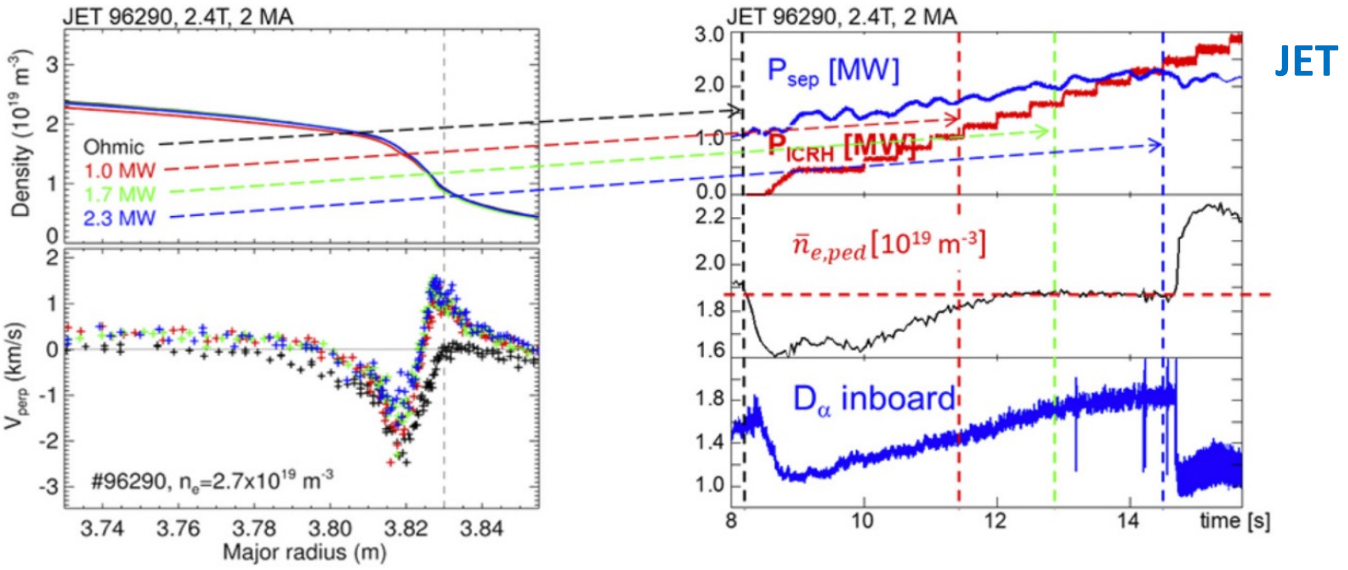






Exploring radial electric field dependence on heating scheme and plasma current

Further points on L-H transition studies



- Detailed investigation of perpendicular velocity during power ramp up to L-H transition does not exhibit increasing of Er shear close to H-mode transition
- JET data exhibit inconsistency with respect to Turbulence suppression theory of L-H transition

C Silva et al 2021 Nucl. Fusion 61 126006, and E.R. Solano et al 2022 Nucl. Fusion 62 076026

RT22-02 Physics understanding of alternatives to Type-I ELM regime

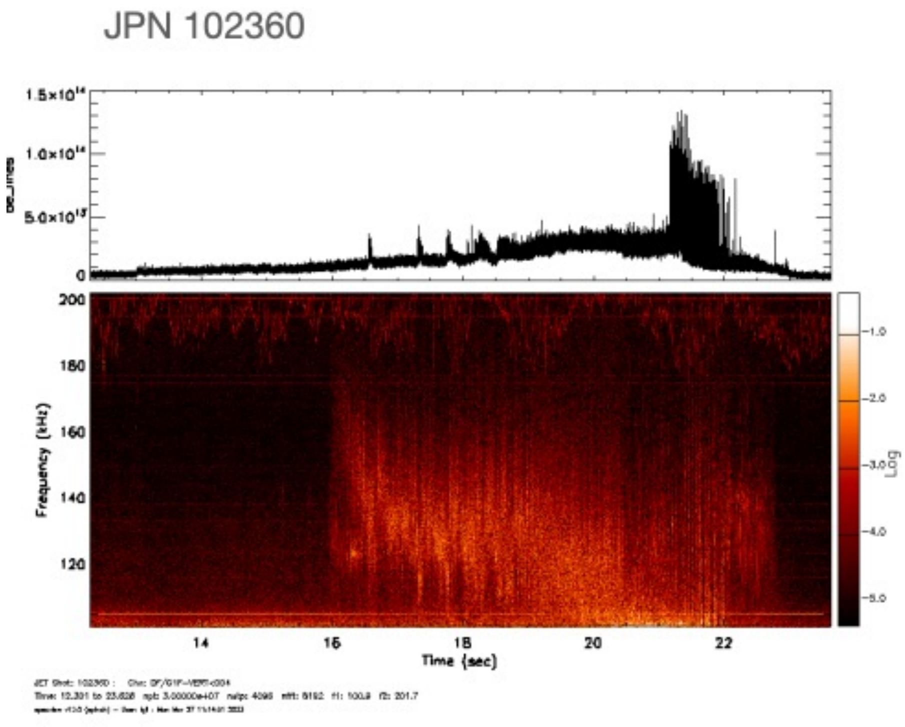
#	
D1	Quantify turbulent and MHD driven transport in the vicinity of the separatrix and implications for predictions for ITER and DEMO
D2	Quantify first wall load in no-ELM scenarios and provide model for SOL transport extrapolation
D3	Extend the parameters space of no-ELM scenarios to large Psep/R and/or pedestal top collisionallities relevant for ITER and DEMO
D4	Determine the key physics mechanisms regulating edge transport in order to access no-ELM regimes
D5	Determine access window and physics understanding for RMP ELM suppression and its compatibility with ITER FPO scenarios
D6	Quantify the overall performance of negative triangularity plasmas in view of DEMO

	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	10	50	40	15
2023	15	100	35	0

Highlight and new experimental progress on RT22-02

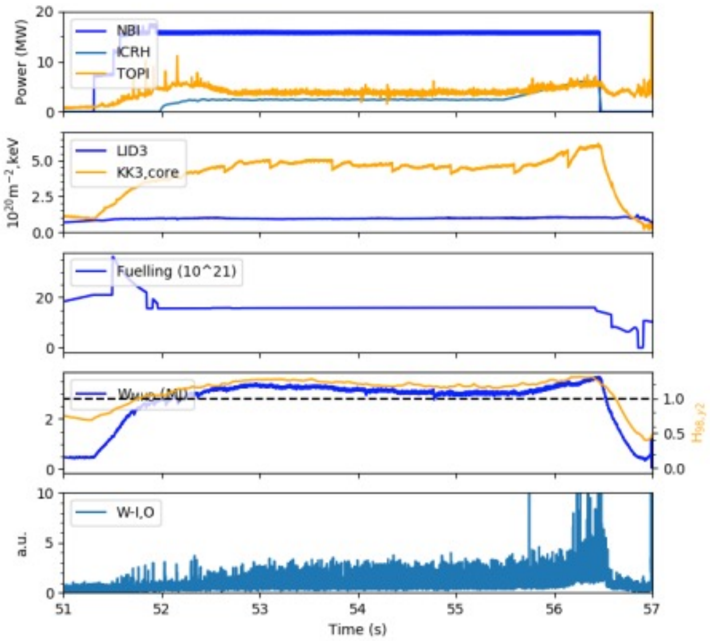
EDA H-Mode:

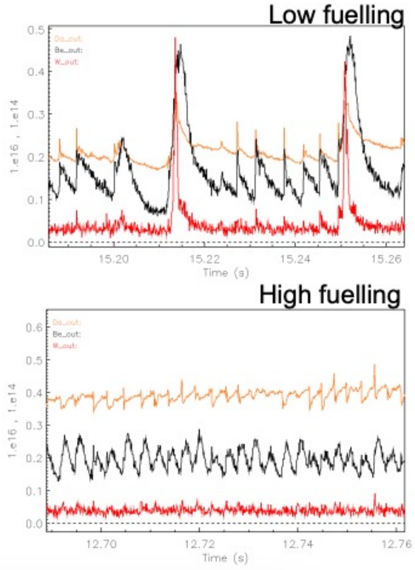
- Established at both 1.5 and 2.0 MA
- All pulses with RF and NBI ramp to assess EDA and ELMy H-mode access
- Quasi-coherent mode (QCM) well visible at both plasma currents
- At highest NBI power, see ELMs coming back
- **Possible extension of the already started validation of EDA H-Mode in AUG** (*Stimmel, K. et al. J Plasma Phys 88, 905880315 (2022)*) **to higher current, larger device**



Highlight and new experimental progress on RT22-02

- Robustly established at 1.5 MA/2.8 T
- Final shape in most pulses from ca 52.5 s onwards
- High Pnet, low Prad
- Responds very well to increased RF power
- High normalised confinement (Invalid) SCAL H98,y2 = 1.2
- Sees only noise in W-I signal at slightly higher fuelling





See qualitative difference in typical signals at low vs high fuelling

- Low fuelling - “typical” ELMs, with interELM events
- High-fuelling - only fluctuations with no real frequency or peak
- **Provide Current and size scaling for already started exercise of GK QCE simulations**

RT22-05: Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation

#	
D1	Characterize detachment access and core plasma performance in scenarios using different fuelling schemes, different impurity mixtures
D2	Develop Control schemes for radiative detachment, transferable to DEMO/ITER
D3	Quantify edge-SOL particle and heat transport in detached conditions
D4	Characterize the interaction between plasma transport, neutral and molecules and the impact of baffling
D5	Quantify the degree of ELM heat load mitigation achievable by impurity seeding, investigating the dependences on relevant machine parameters
D6	Assess the evolution of detachment under slow transients (L-H transitions, sawtooth, loss of impurity seeding)

- Ideal test bed for TSVV3 and TSVV4 code
- Well diagnosed plasmas with strong program also in L-mode
- Both metallic and carbon devices
- Space for further joint definition of validating excercise

	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	7	70	40	0
2023	6	70	45	30

Highlight and new experimental progress on RT22-05

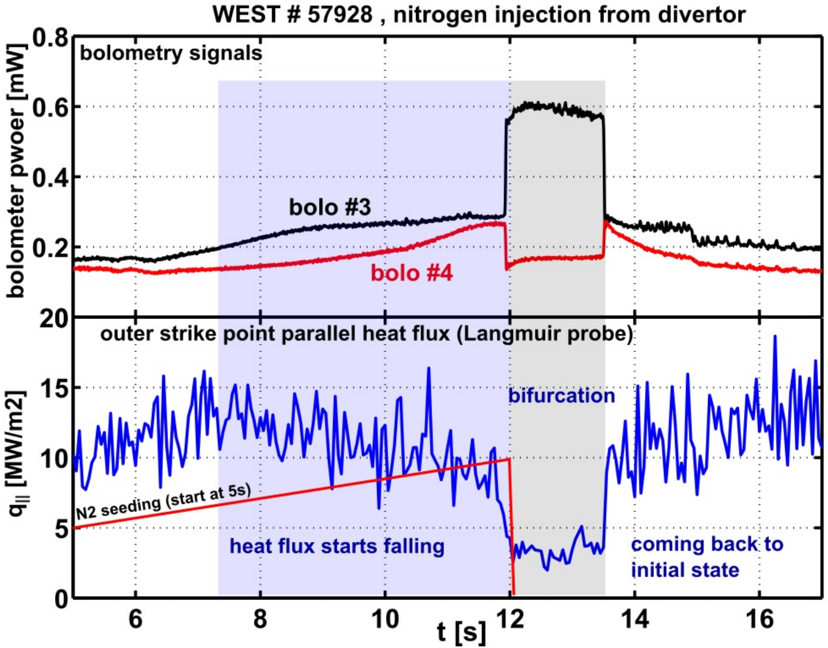
- TCVX21 like shape at reduced field and different levels of recycling available for turbulence code validation. Effort on-going
- High-power attached TCV case at full filed available as well

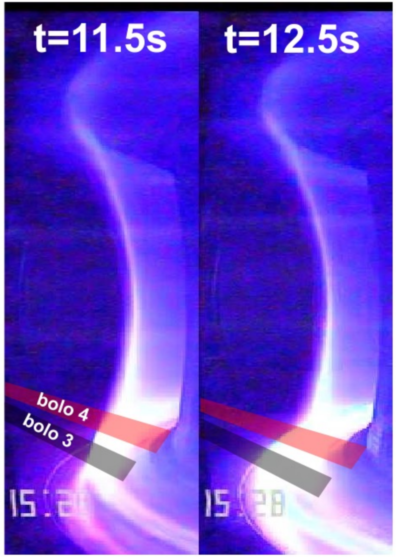
Highlight and new experimental progress on RT22-05

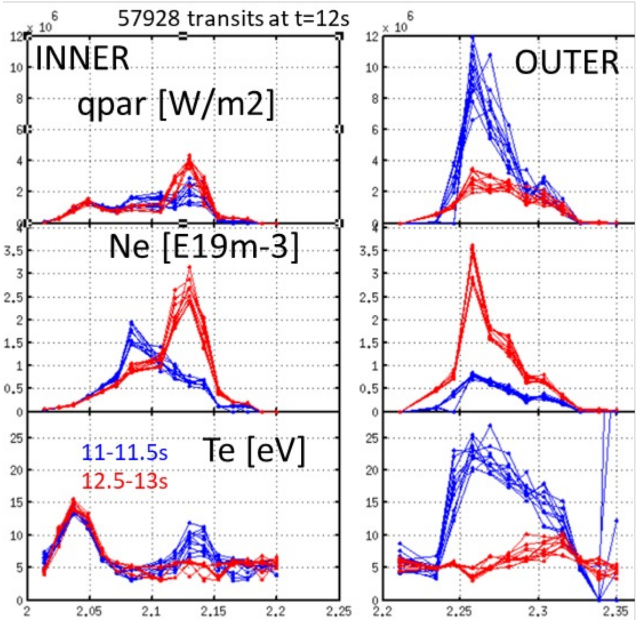
WEST

- L-mode scenario at 4MW LHCD with N2 ramp from the divertor region
- Enhanced & localised radiation in the X-point /divertor volume
- Reduced heat loads to divertor targets (Langmuir-probes, Infra-red, TC, FBG)
- Te drops to a few eV, ne increases, Pe~cst (condensed / high recycling regime). Almost constant SOL profiles

Good test case to challenge dynamical simulations

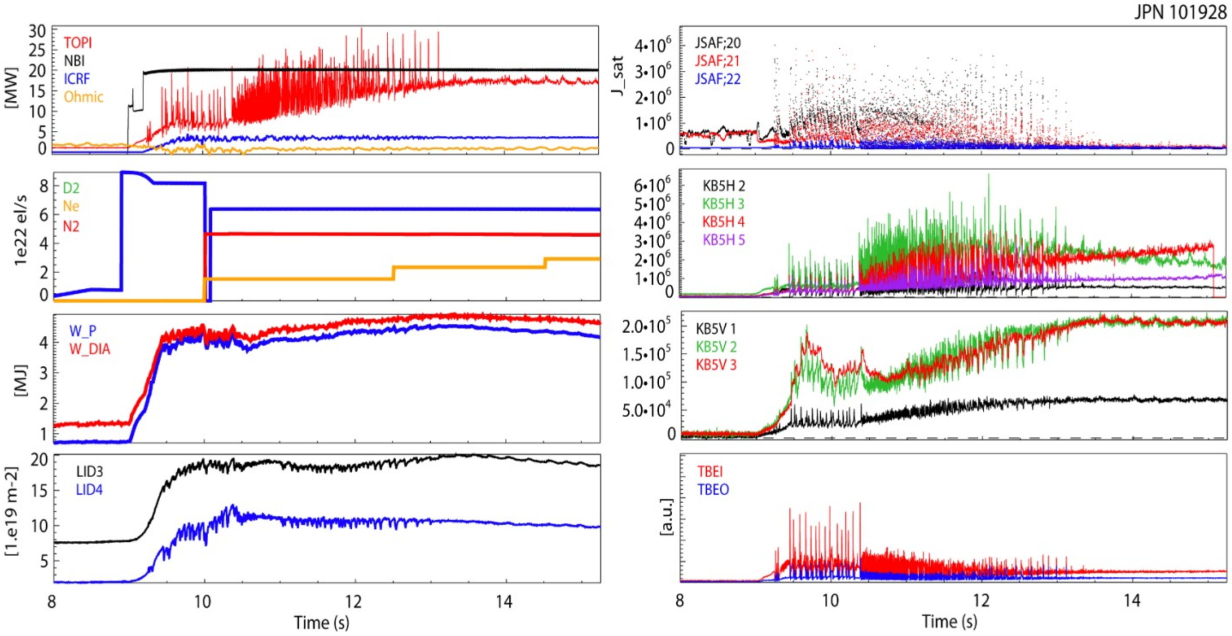






Highlights and new experimental progress on RT22-05

- High radiation fraction investigation on JET
- With a combination of N + Ne, ELMs strongly reduced since the beginning
- Transition into XPR with stable no-ELM phase and XPR movement
- Need investigation of pedestal transport (to assess the transport mechanism ensuring no ELM



- Might provide test bed for fluid turbulence simulations (high collisionality, no ELM) but requires multi-species

RT22-07 Physics understanding of alternative divertor configurations as risk mitigation for DEMO

#	
D1	Determine detachment onset, radiated power fractions, and core compatibility in H-mode for the alternative divertor configurations (ADCs) and characterization of ELM activity in view of pedestal, heat flux and control in ADCs
D2	Characterize possible benefits of the snowflake configuration for X-point radiation stability and dissipated power in H-mode
D3	Quantify the degree of ELM heat load mitigation achievable by impurity seeding, investigating the dependences on relevant machine parameters
D4	Test existing reduced SOL models against ADCs

	TCV	MAST-U	WEST
	Shots	Shots	Shots
2022	70	50	15
2023	100	50	0

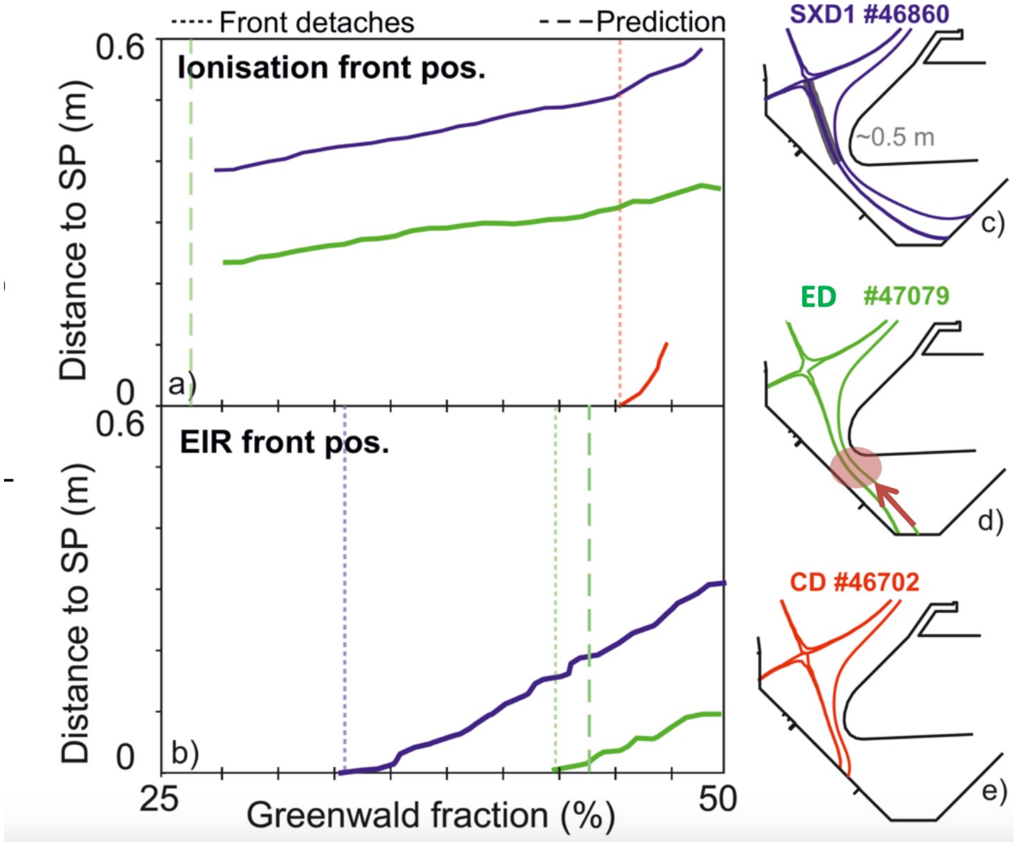
Highlights and new experimental progress on RT22-07

Density ramps (25% -> 50% n_{GW}) in beam heat L-Mode plasmas:

- SXD & ED remain detached.
- CD detaches near 45% nGW
- Electron-Ion & Molecular Activated Recomb. (EIR/MAR) important in ED & SXD.

Low ionisation front sensitivity for SXD & ED

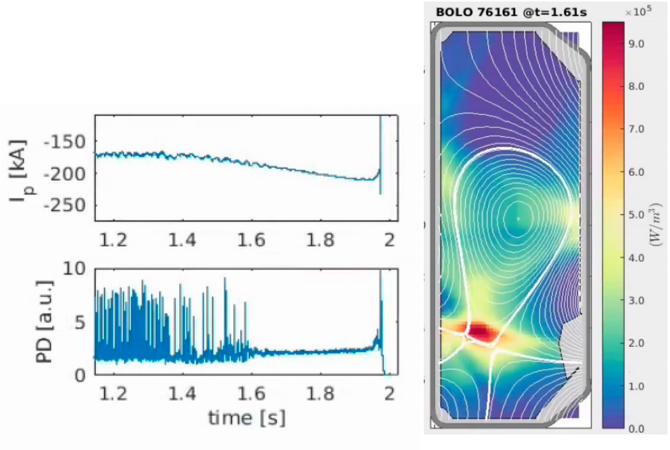
- Indicates detachment front 'stability' to density/power perturbations
- Analytic predictions detachment threshold compared against SXD: +120% CD; +60% ED – in agreement with experiment

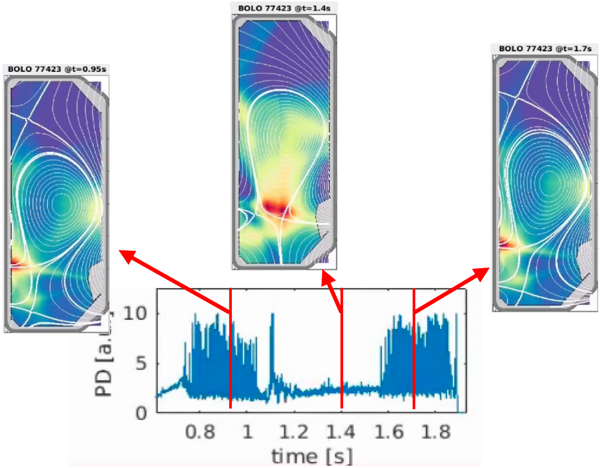


MAST-U

Highlights and new experimental progress on RT22-07

- ELM-suppressed Snowflake XPR reproduced in non-baffled TCV





- ➢ Regime achieved with and without baffles
- ➢ Regime rather sensitive on geometry and/or I_p
- ➢ Several other ADC geometry investigation available (including XPT, XD, Long-leg …) Ideal candidate for code benchmarking (including geometry and shaping effect)

Conclusions

- Remarkable progress achieved during late 2022 beginning 2023.
- Some key ingredient require adeguate interpretative modelling resources:
  - Role of impurity in high-performance pedestal
  - No-ELM regimes: achieved and fully document in different devices (with corresponding current and size scan)
  - LH transition and radial electric field
- Smaller devices provide ideal test-bed for boundary code validation including different wall-materials, intrinsic/extrinsic impurities, neutrals. Code should be able to cope with these Machine sizes. Need a feedback on status of validation as well as missing dataset/diagnostics
- Interpretative modelling started within the Research Topics. Not always clear if fully integrated into TSVVs. Which is the right mechanism to strenghted such an integration?