WPTE Program 2022-2023

Experimental program and modelling needs

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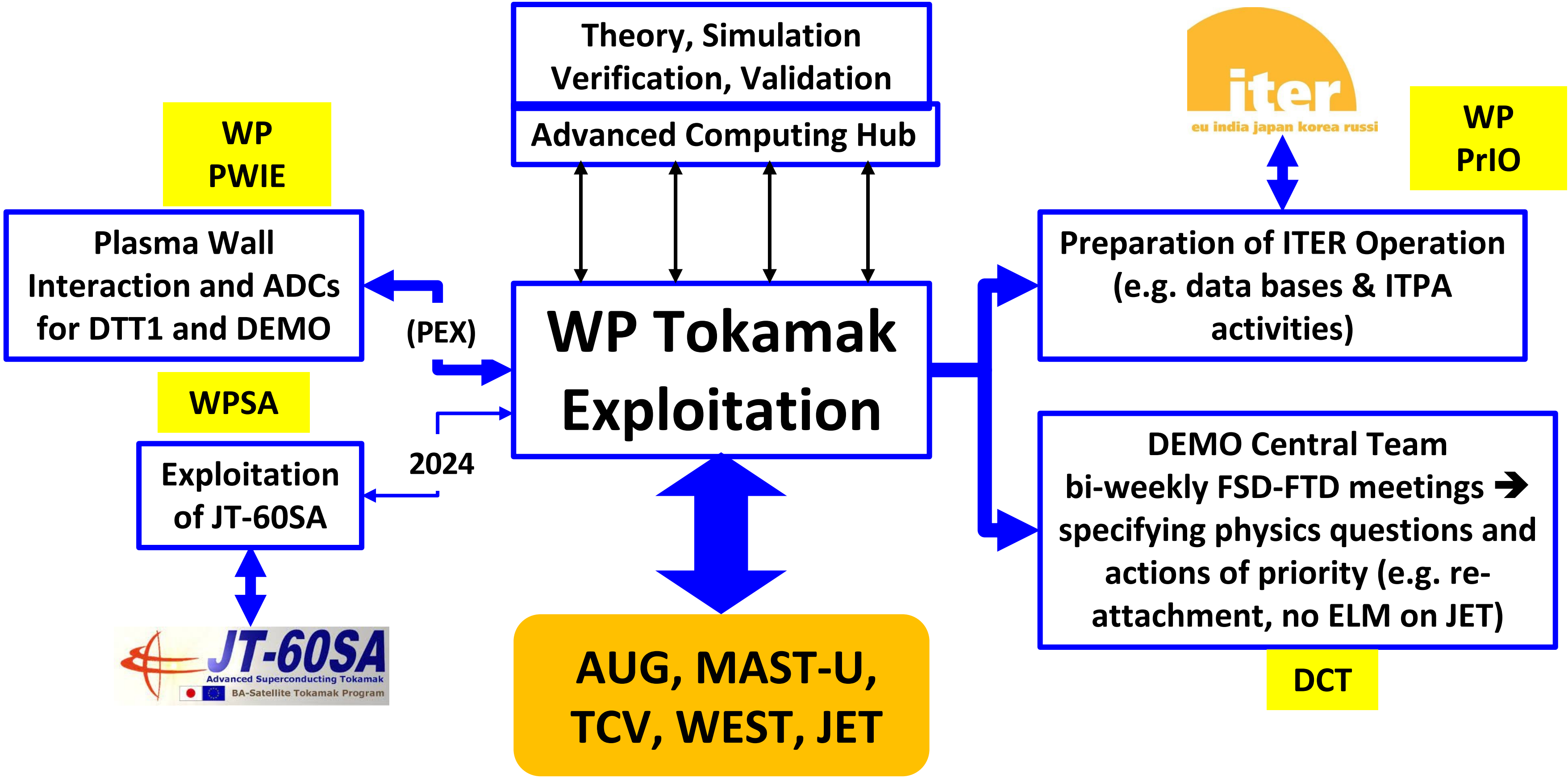
WP TE in FSD with overarching priorities: ITER & DEMO & PEX



WPTE Programme definition

- Overarching priorities based on ITER RP, DEMO physics gaps and exploitation of PEX
- EUROfusion Grant Deliverables, GD, as defined in the Consortium Work Plan and submitted to the European Commission (EC) – need to be achieved for money to flow from EC to EUROfusion
- Milestones (as step stones to progress towards these Grant Deliverables)
- Priorities defined by the EUROfusion Roadmap towards Fusion Electricity – need to be achieved for aiding ITER to succeed and designing a power plant extending beyond GDs (e.g. no GD for the entire He campaign in 2022 or a possible DTE3 campaign in 2023):
  - derived from the ITER Research Plan and discussed with IO
  - derived together with the DEMO Central Team to close DEMO physics gaps for developing viable operational scenarios for DEMO

The WPTE Grant Deliverables

TE.D.03	High fluence operation on actively cooled divertor at WEST assessed, and documented.	Dec. 2022
TE.D.04	Achievement of ELM control during the transient phases (I_p ramp-up and down, entering and exiting H-mode etc.) integrating ITER operational constraints.	Dec. 2022
TE.D.05	The role of turbulent and MHD driven transport in the vicinity of the separatrix for the stability of the pedestal quantified and the implications for predictions for ITER and DEMO reported.	Dec. 2022
TE.D.06	Achievement of state-observer based control of radiative detachment using multiple diagnostics.	Dec. 2023
TE.D.07	The disruption and run-away electron mitigation efficiency by single and multiple shattered pellet injectors on different sized devices to validate the ITER Strategy assessed and documented.	Dec. 2023
TE.D.08	Balance between gross and net erosion of W under different operational conditions in full-metallic toroidal devices	Dec. 2023
TE.D.09	Establishment and comparison of N and Ne-seeded partially-detached divertor in high-power operations in view of ITER radiative scenario.	Dec. 2023
TE.D.10	The role of electron and ion heat channels and plasma rotation on the access to H-mode for hydrogen, helium and mixed plasmas in view of the ITER non-active phase quantified.	Dec. 2023
TE.D.11	Incorporation of turbulence in multi-fluid calculations using physics-based diffusion coefficients (with TSVV1, TSVV3 and TSVV4).	Dec. 2023

Research Topic Scientific Objectives

WPTE Main goals is provide support for:

- **Preparation of ITER Operation**
- **Provide the physics basis for DEMO design via interaction with the DEMO-central Team**
- **Exploitation of the PEX**

Predefined Scientific Objectives identified to guide the Call for Proposal based on several inputs

ITER Research Plan → DEMO Physics Needs → FSD Work-package interaction → EUROfusion Grant Deliverables → Research Topic Scientific Objectives Definition

The new WPTE Program

	Research Topics 2021
RT1	ITER Baseline scenarios towards low collisinality and detachment
RT2	H-mode entry and pedestal dependence with impurities and isotopes
RT3	RF-assisted breakdown and current ramp-up optimization
RT4	Disruption avoidance and control for ITER and DEMO
RT5	Run-away electron generation and mitigation
RT6	ELM mitigation and suppression in ITER/DEMO relevant condition
RT7	Negative triangularity scenarios as an alternative for DEMO
RT8	QH-mode and I-mode assessment in view of DEMO
RT9	Extension of EDA and QCE performance towards DEMO
RT12	Development of the steady state scenario
RT10	Fast-ion physics with dominant ICRF heating
RT11	Impact of MHD activity on fast ion losses and transport
RT13	X-point radiation and control
RT14	Physics of plasma detachment / impurity mix/ heat load patterns
RT15	Extrapolation of SOL transport to ITER and DEMO
RT18	Alternative divertor configurations
RT16	PFC damage evolution under tokamak conditions
RT17	Material migration and fuel retention mechanisms in tokamaks

ITER Scenario

DEMO Scenario

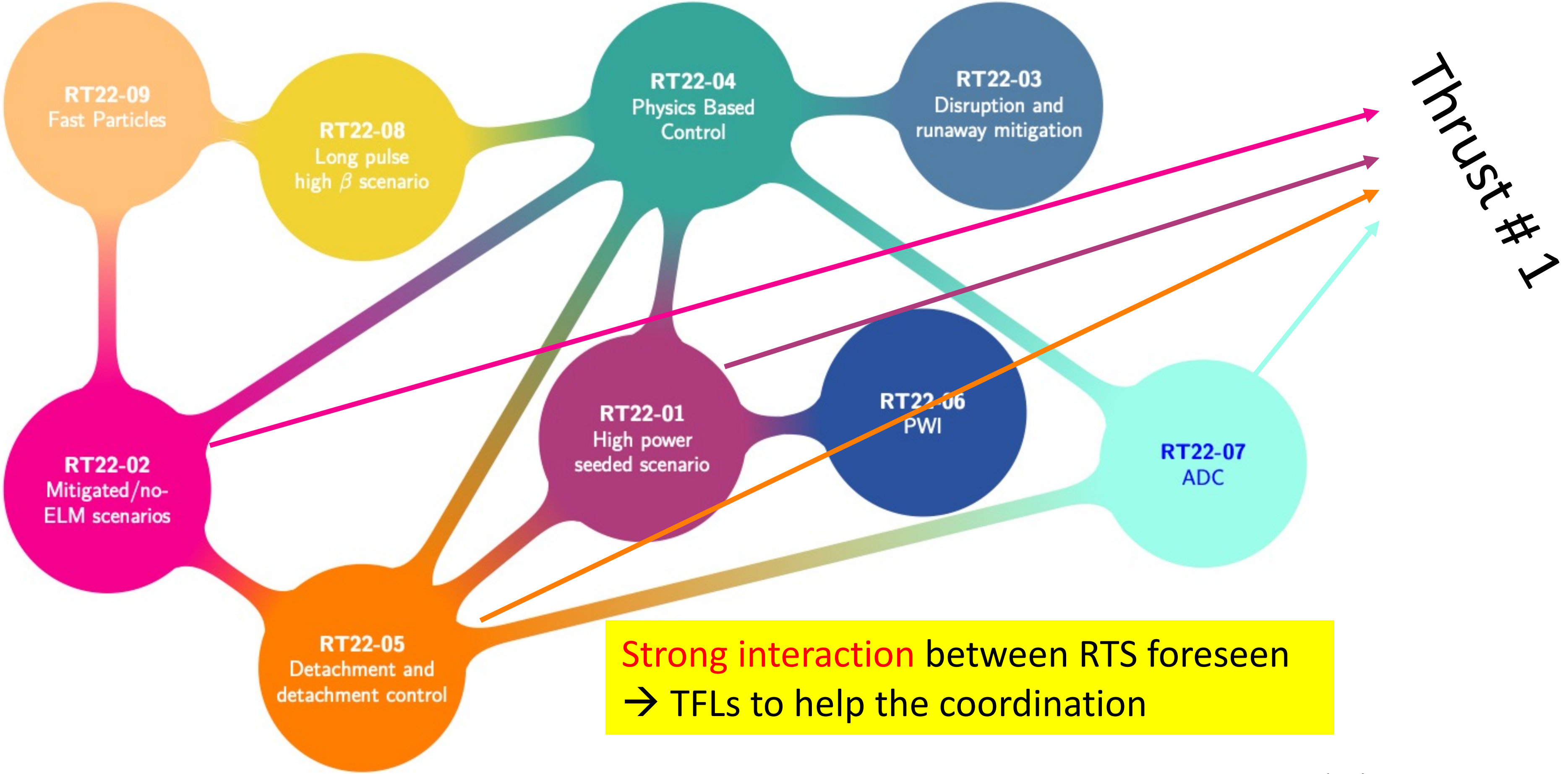
Burning plasma

Exhaust

PFC

	Research Topics 2022-2023
RT1	Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER
RT3	Strategies for disruption and run-away mitigation in support of the ITER DMS
RT4	Physics-based machine generic systems for an integrated control of plasma discharge
RT8	Physics and operational basis for high beta long pulse scenarios
RT2	Physics understanding of alternatives to Type-I ELM regime
RT9	Physics understanding of energetics particles confinement and their interplay with thermal plasma
RT5	Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation
RT7	Physics understanding of alternative divertor configurations as risk mitigation for DEMO
RT6	Preparation of efficient Plasma Facing Components (PFC) operation for ITER, DEMO and HELIAS

Integration and TSVVs relation



Strong interaction between RTS foreseen
→ TFLs to help the coordination

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

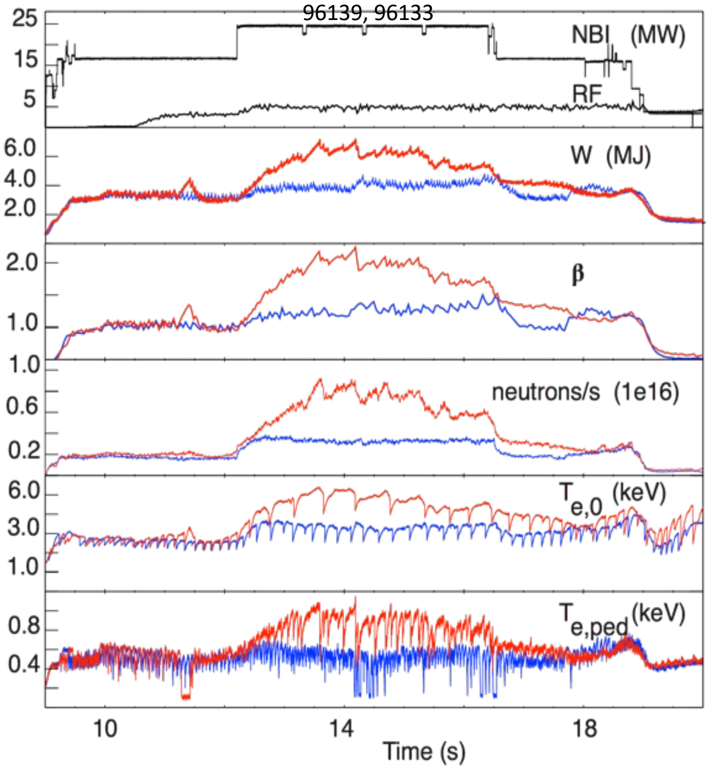
#	Scientific Objectives
D1	Develop stationary high power H-mode scenario at low core and pedestal collisionalities compatible with detached divertor
D2	**Provide physics-based cross-field transport coefficients to TSVVs (1, 3, 4 and 11) for turbulence modelling**
D3	Compare different impurity mixes for 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

Understanding the role of impurities in setting global performances

I_p=2.5MA, B_T=2.7T, q_{95}=3.3, δ_u=0.4, VV, D-gas =3.0 x10^{22} el/s

C. Giroud, S. Brezinsek, M18-39/M18-06 JET experiment



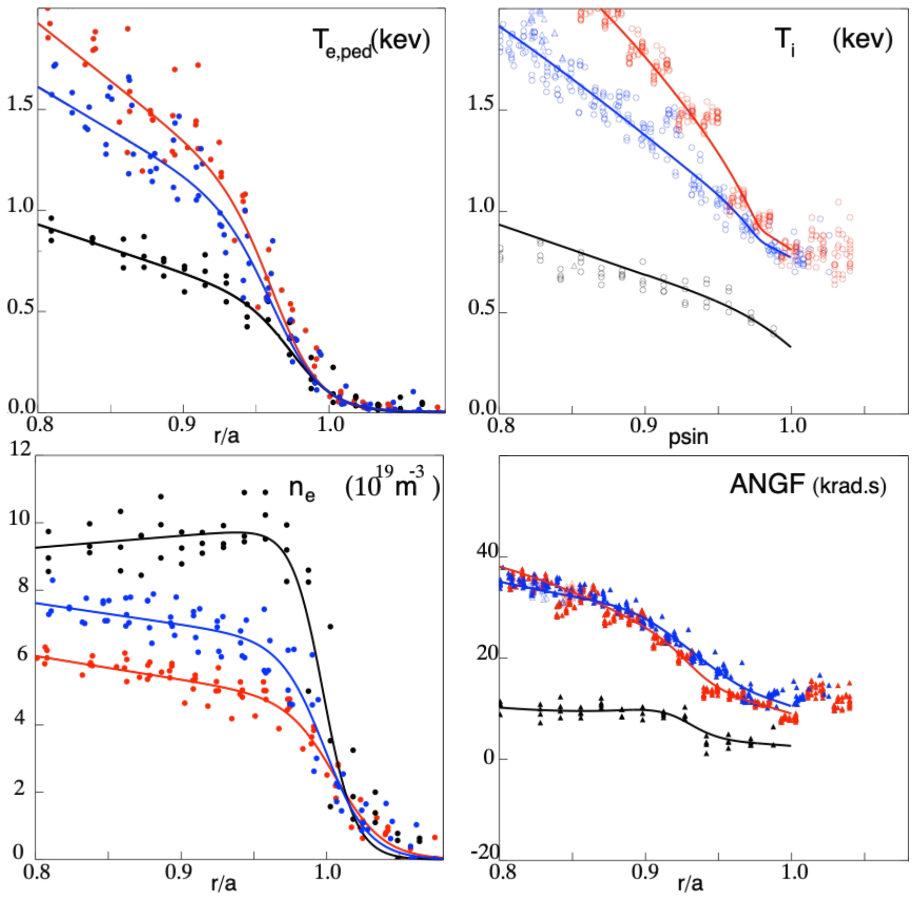
With Neon **w/o neon**

$H_{(98,y2)}$ =0.9
β_N = 2

f_{GW}: 0.82
n_{ped}/n_{GW}:0.7
Z_{eff}: 2.0
f_{rad}: 0.8
C_{Ne}=1.3 % (top pedestal)
$H_{(98,y2)}$ =0.9
β_N = 2

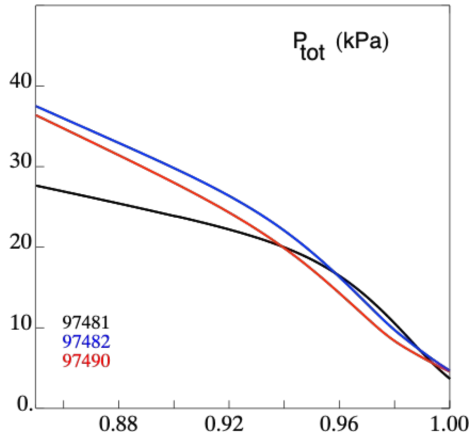
With Pin >30MW , C_{Ne}>1%, good confinement can be obtained with Ne

Pedestal modification

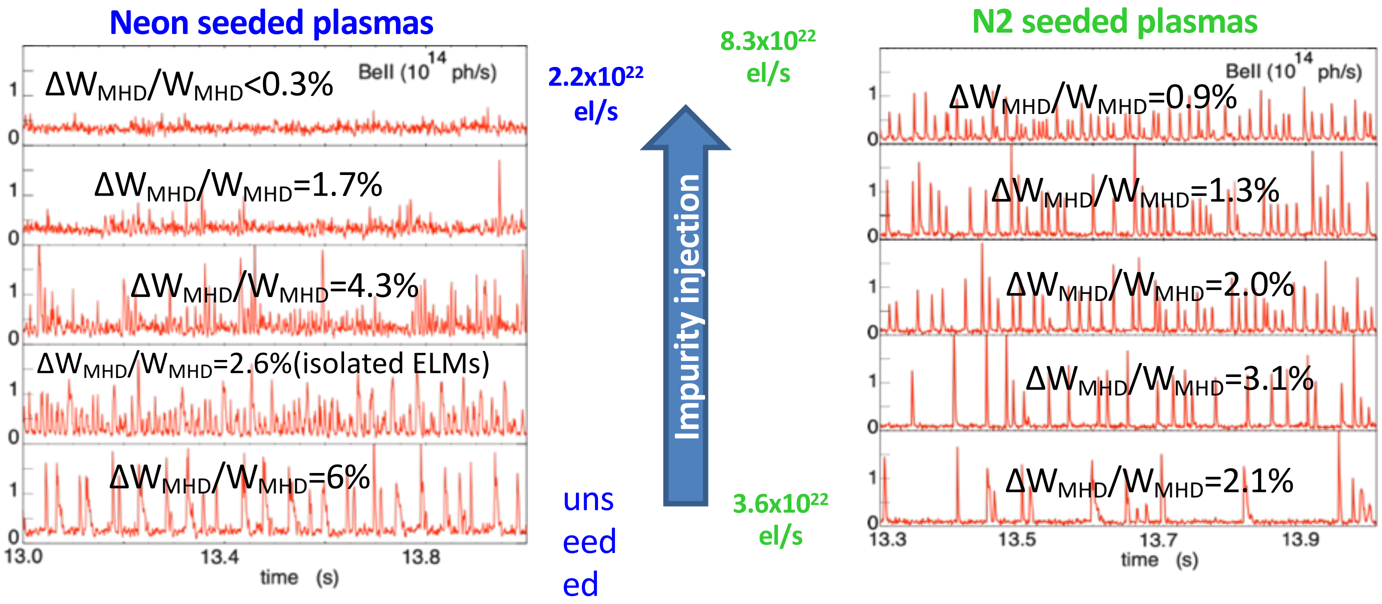


I_p=2.5MA, B_T=2.7T, q_{95}=3.3,
δ_u=0.4, VV, D-gas =3.5 x10^{22} el/s.
P_{IN} = 32-34MW

As C_{Ne} increases, T_{ped} increases, ANGF increases, ne drops, width and P_{tot} increases



ELM behaviour

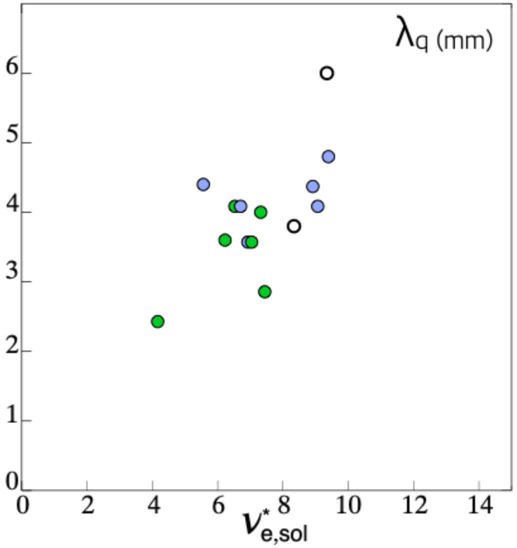


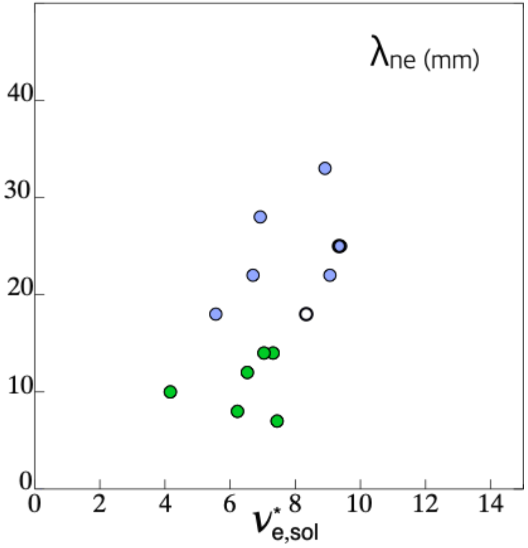
The ELMs are very different between Ne and N-seeded plasmas as the impurity seeding rate increases.

P_{heat} =27- 32MW, P_{rad} variation 8-20MW

Giroud IAEA 2021

Broadening of λ_{ne} with Ne but not with N





- Both density and temperature SOL width increases at high ν^*_e : trend consistent with previous AUG, JET and DIII-D results.

- A clear difference in the value of the SOL width between Ne and N-seeded plasmas is observed: flatter density profiles in the separatrix region

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

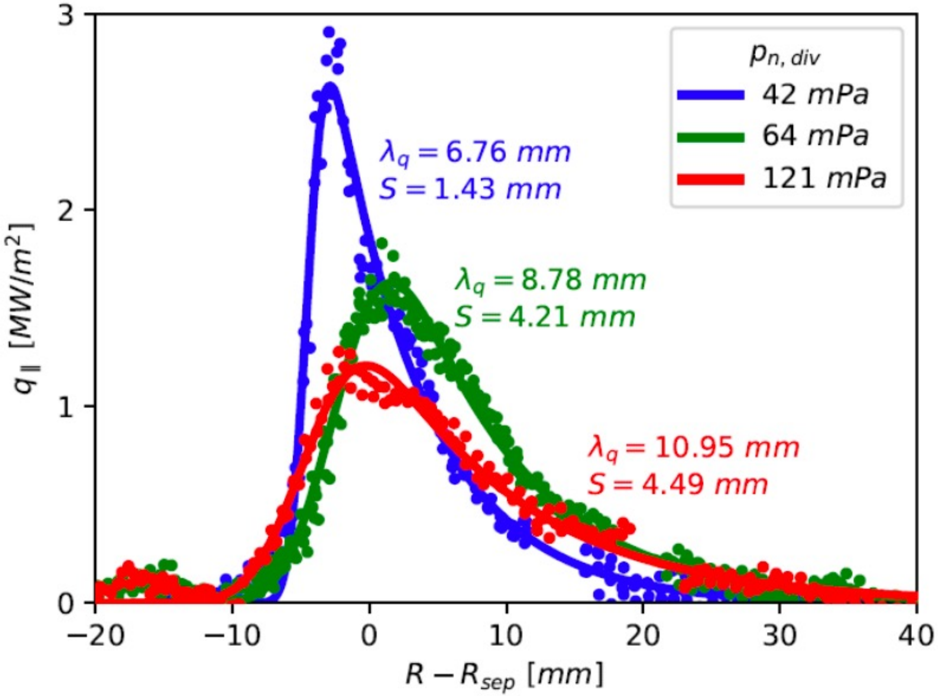
#	
D1	Quantify turbulent and MHD driven transport in the vicinity of the separatrix and implications for predictions for ITER and DEMO
D2	Quantify first wall load in no-ELM scenarios and provide model for SOL transport extrapolation
D3	Extend the parameters space of no-ELM scenarios to large Psep/R and/or 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

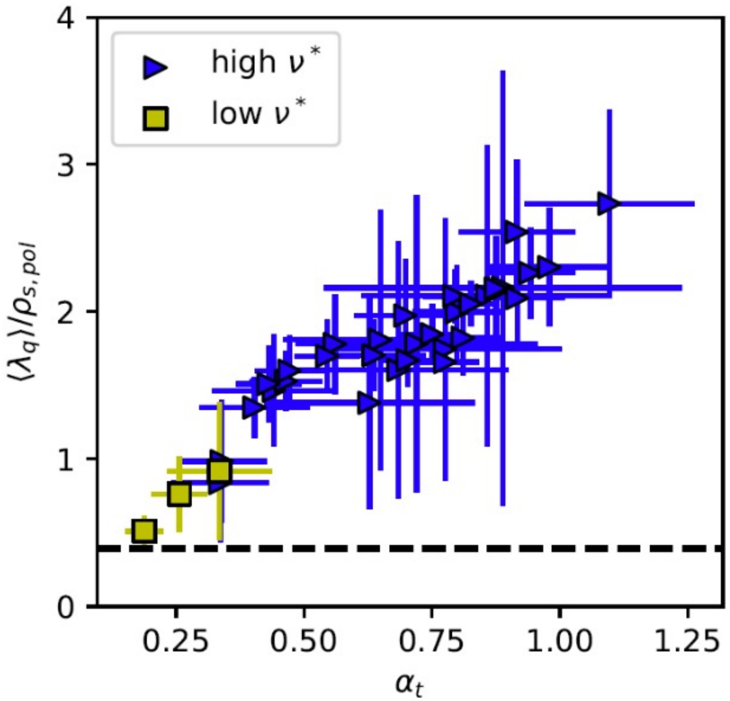
	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	10	50	40	15
2023	15	100	35	0

On the role of separatrix in setting transport and turbulence

$$\alpha_t = C\omega_B = q_{cyl}^2 R \sqrt{\frac{m_e}{\bar{M}}} \frac{1.02 e^2 \log \Lambda n_{e,sep}}{12\pi^{\frac{3}{2}} \epsilon_0 T_{e,sep}^2} \sqrt{\bar{Z}} \left(1 + \frac{1}{\bar{Z}}\right) Z_{eff} f_{Z_{eff}}$$

Defined in Rogers, Drake and Zeiler; Scott; Eich and Manz





A. Stagni PSI 2022 confirming observation from Faitsch NME 2021

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

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

Conclusions

- Ambitious program built for 4 devices in 2022-23
- This will sum up to extended campaign in He in metallic devices
- The validation exercise of the TSVV is fully embedded into WPTE program up to the level of GD
- With a program extending till end of 2023 the code development in the TSVV should have been in advanced state and ready to be applied to “real data”. Interpretative model expertise from TSVV need to be embedded into our RT framework