WPTE Program 2022-2023

Experimental program and modelling needs

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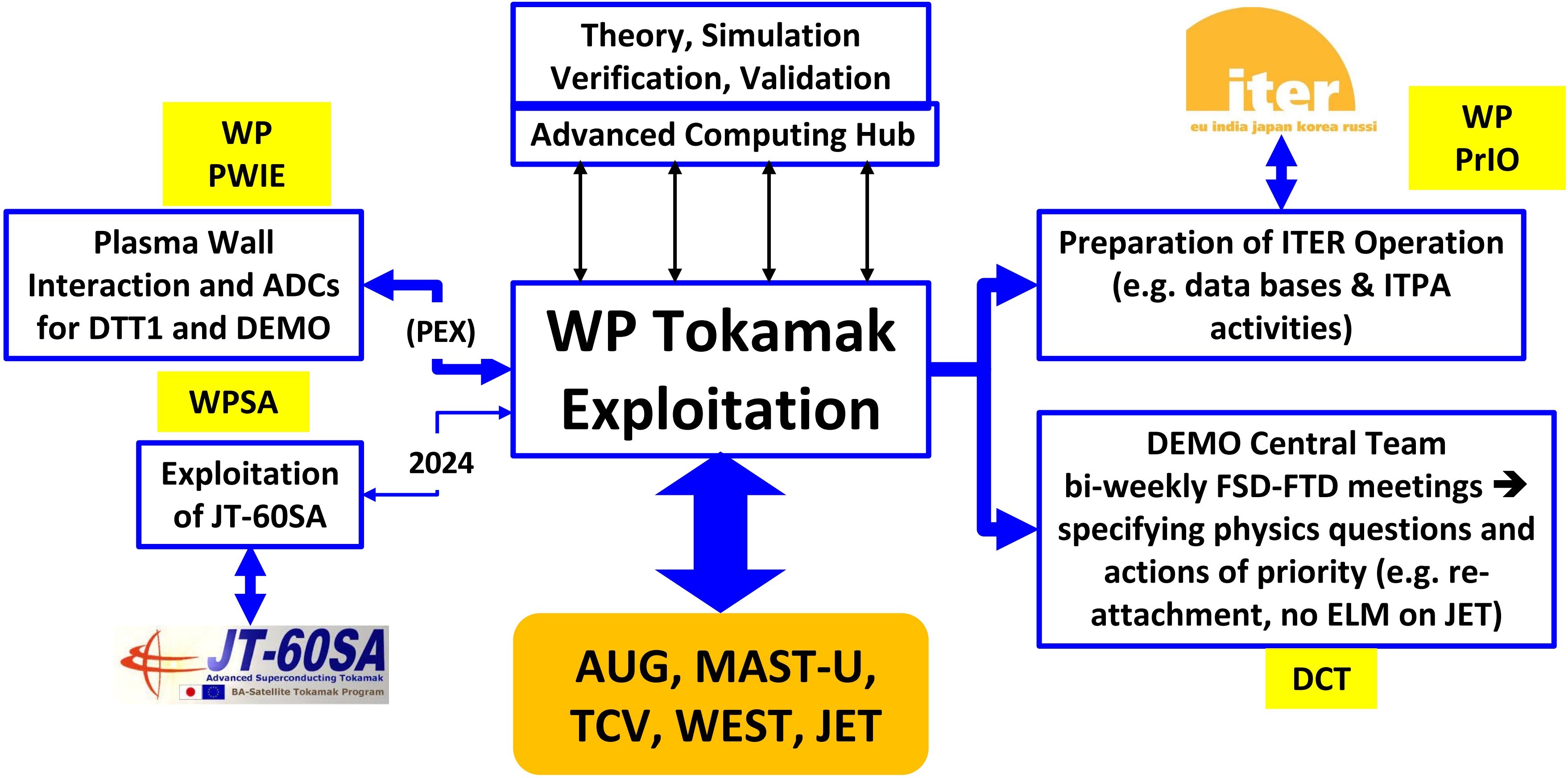
WP TE in FSD with overarching priorities: ITER & DEMO & PEX



Theory, Simulation Verification, Validation

Advanced Computing Hub

WP PWIE

Plasma Wall Interaction and ADCs for DTT1 and DEMO

(PEX)

WPSA

Exploitation of JT-60SA

2024

WP Tokamak Exploitation

AUG, MAST-U, TCV, WEST, JET

WP PrIO

Preparation of ITER Operation (e.g. data bases & ITPA activities)

DEMO Central Team bi-weekly FSD-FTD meetings → specifying physics questions and actions of priority (e.g. re-attachment, no ELM on JET)

DCT

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

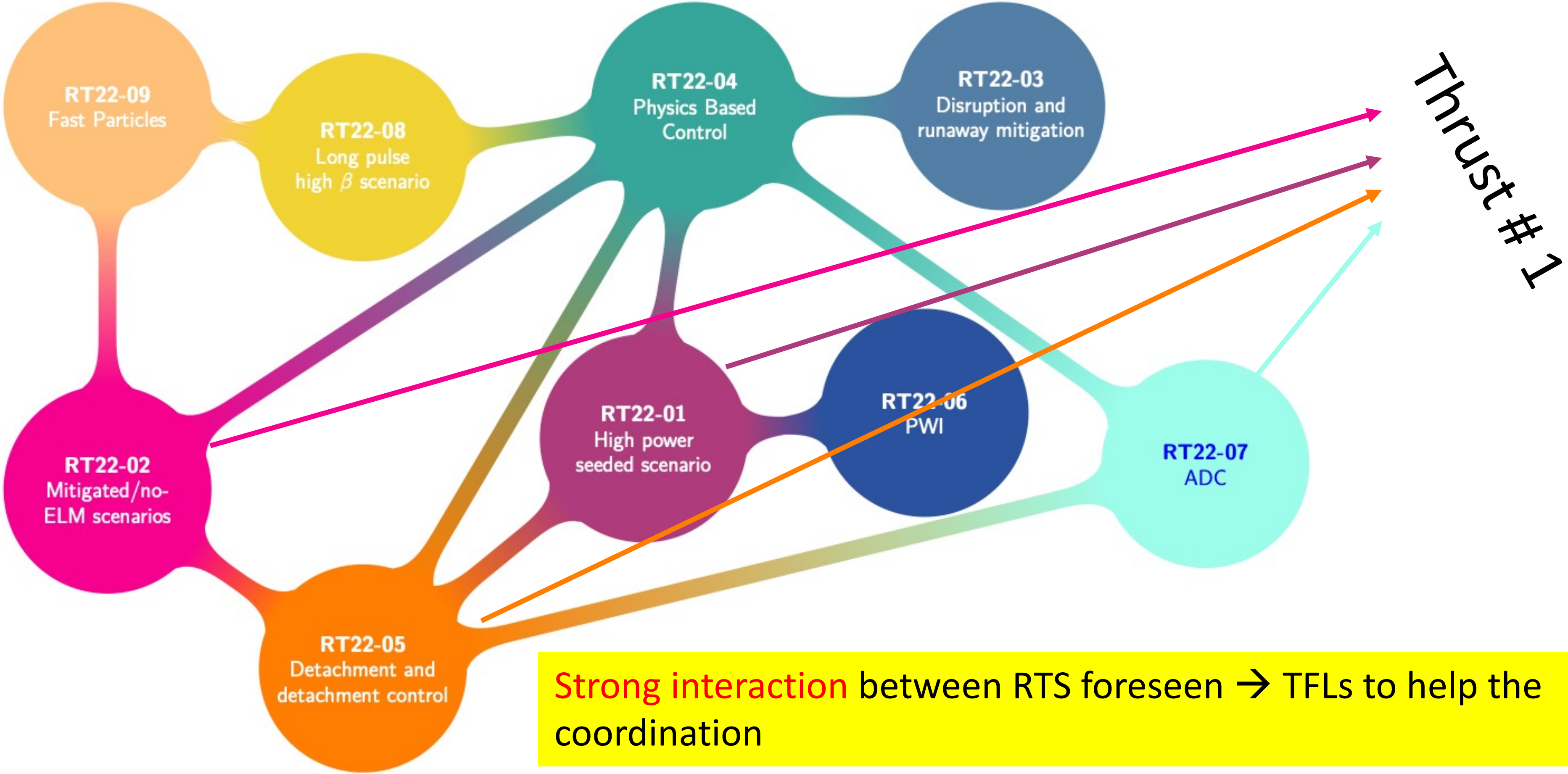
EUROfusion Grant Deliverables

Research Topic Scientific Objectives Definition

WPTE research topics for the period: 1st of July 2022 to 31st of December 2023

	Research Topics	
RT1	Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER	ITER Scenario
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	DEMO Scenario
RT2	Physics understanding of alternatives to Type-I ELM regime	
RT9	Physics understanding of energetics particles confinement and their interplay with thermal plasma	Burning plasma
RT5	Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation	Exhaust
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	PFC

Integration and TSVVs relation



RT22-09
Fast Particles

RT22-08
Long pulse
high β scenario

RT22-04
Physics Based
Control

RT22-03
Disruption and
runaway mitigation

RT22-02
Mitigated/no-ELM scenarios

RT22-01
High power
seeded scenario

RT22-06
PWI

RT22-07
ADC

RT22-05
Detachment and
detachment control

Thrust # 1

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

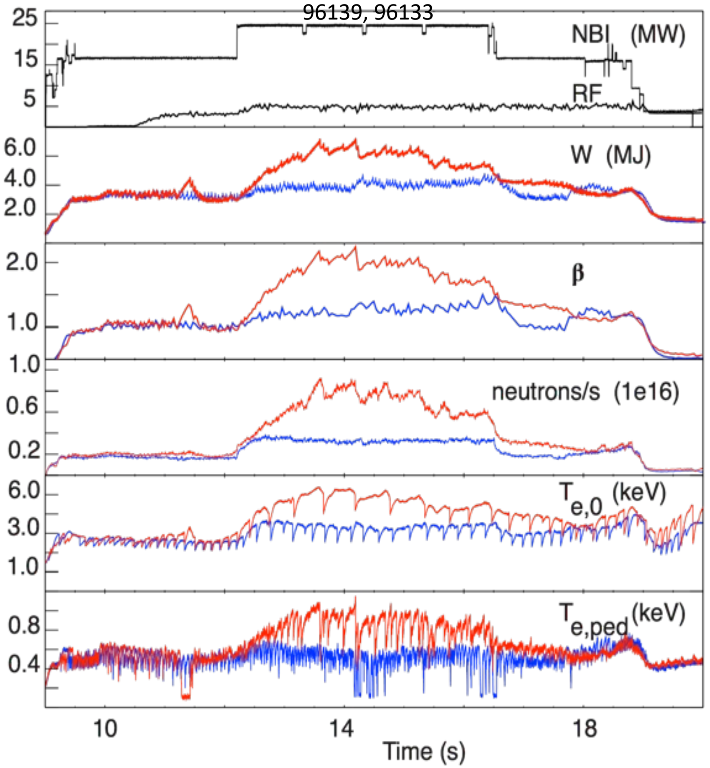
#	Scientific Objectives
D1	Develop stationary high power H-mode scenario at low core and pedestal collisionalities compatible with detached divertor
D2	**Provide physics-based cross-field transport coefficients to TSVVs (1, 3, 4 and 11) for turbulence modelling**
D3	Compare different impurity mixes for 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	7	50	40	0
2023	28	100	35	15

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



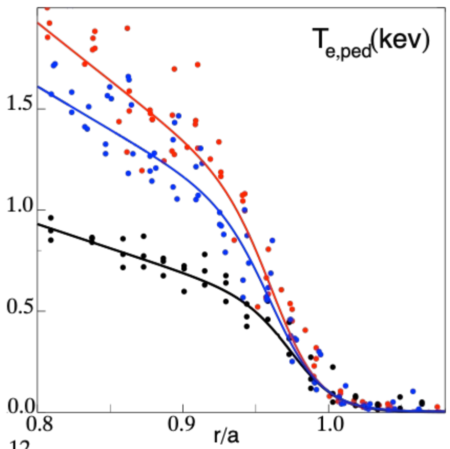
With Neon **w/o neon**

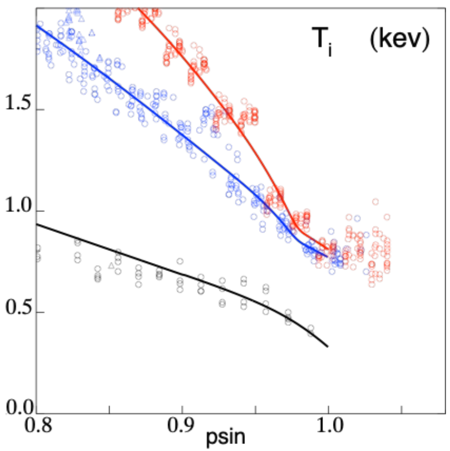
$H_{(98,y2)}$ =0.9
β_N = 2

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

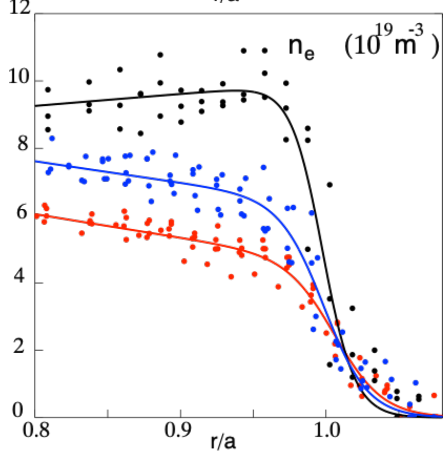
Pedestal modification

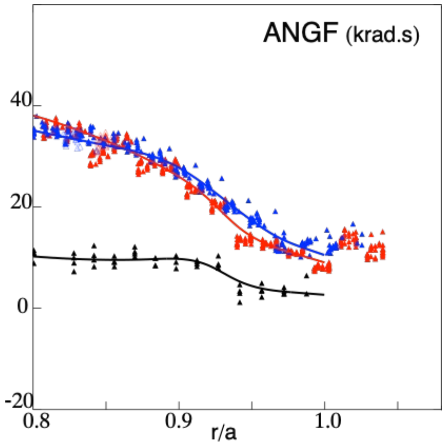


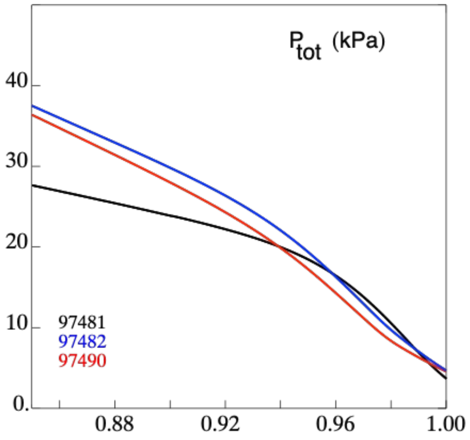


I_p=2.5MA, B_T=2.7T, q_{95}=3.3,
δ_u=0.4, VV, D-gas =3.5 x10^{22} el/s.
P_{IN} = 32-34MW

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

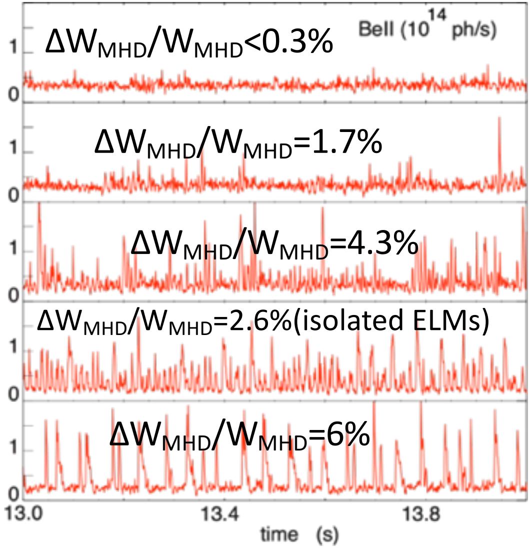






ELM behaviour

Neon seeded plasmas



2.2×10^{22} el/s

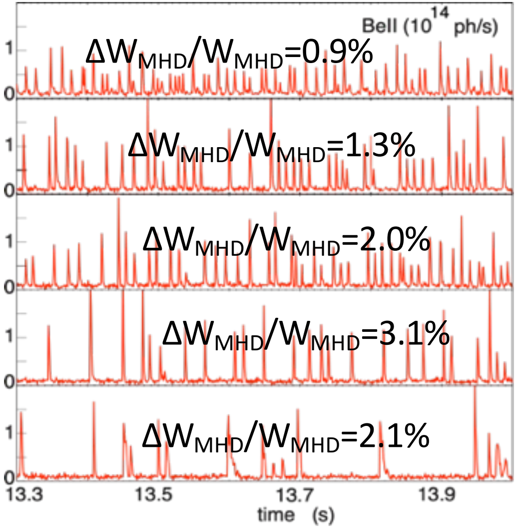
unseeded

8.3×10^{22} el/s

Impurity injection

3.6×10^{22} el/s

N2 seeded plasmas

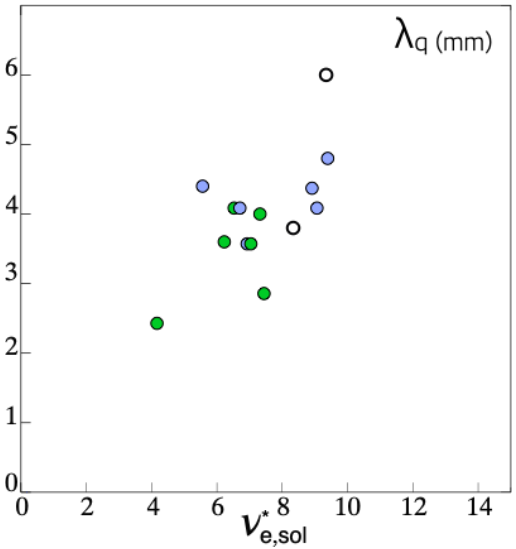


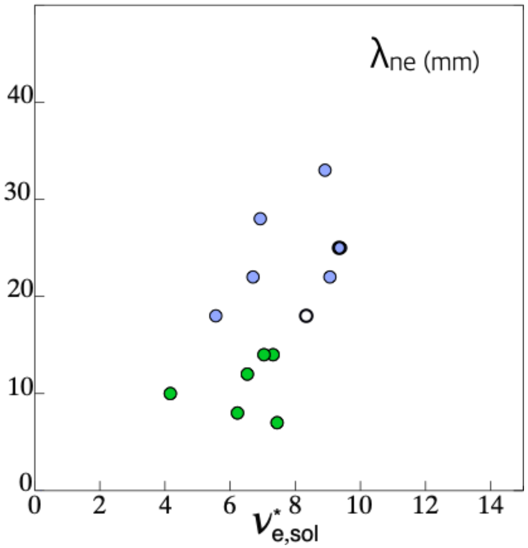
The ELMs are very different between Ne and N-seeded plasmas as the impurity seeding rate increases.

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

Giroud IAEA 2021

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



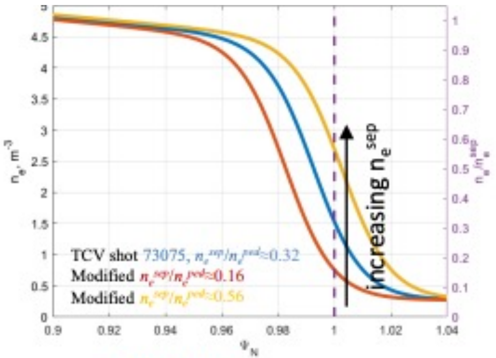


- Both density and temperature SOL width increases at high ν^*_e : trend consistent with previous AUG, JET and DIII-D results.
- A clear difference in the value of the SOL width between Ne and N-seeded plasmas is observed: flatter density profiles in the separatrix region

Link to separatrix condition

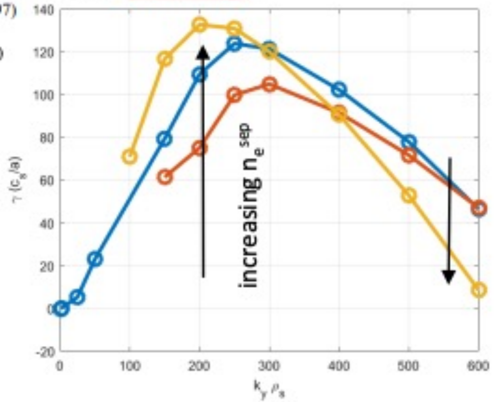
By O. Grutkin

- **Work in progress**
  - Two key pulses analyzed: 170kA/1.4T, low-δ , P_{NBH}=1MW
    - Low gas rate (high $(\nabla n_e/n_e)_{\psi=1}$ and low n_e^{sep}/n_e^{ped})
    - high gas rate (low $(\nabla n_e/n_e)_{\psi=1}$ and high n_e^{sep}/n_e^{ped})
  - Why $(\nabla n_e/n_e)_{\psi=1}$ and n_e^{sep}/n_e^{ped} are changing?
    - Experimental analysis: neutral density and ioniations source (with MANTIS), **A. Perek**
    - SOLP modelling: **C. Colandrea**
  - How the variation of $(\nabla n_e/n_e)_{\psi=1}$ and n_e^{sep}/n_e^{ped} affect the pedestal transport?
    - GK analysis with GENE (**O. Krutkin** with support from B. Chapman)
    - Turbulent transport in the SOL, with mainly experimental work to investigate resistive interchange turbulence (**A. Stagni**)



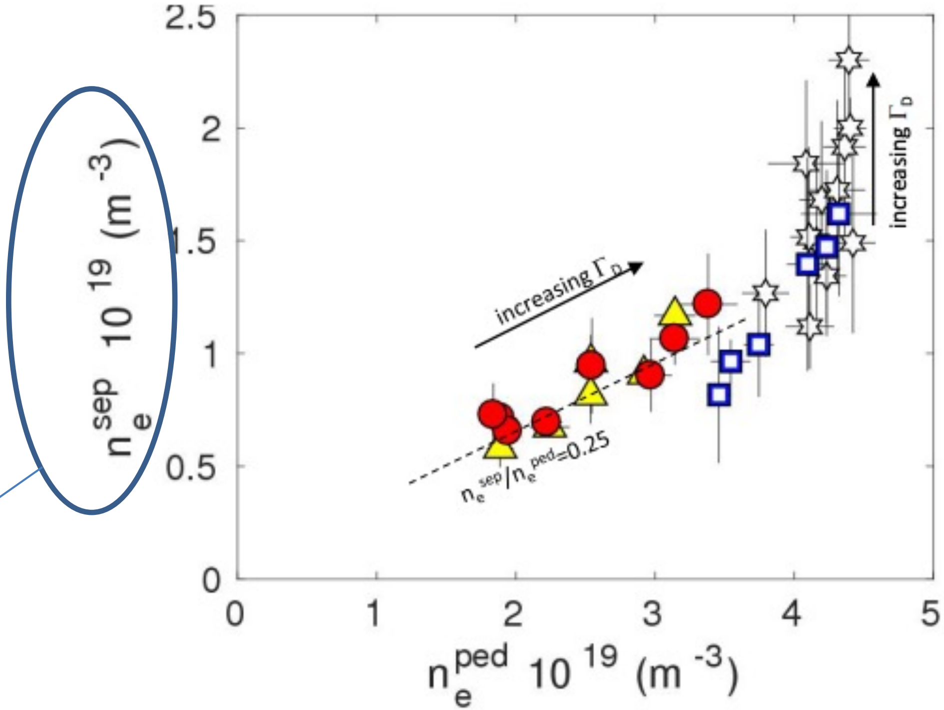
Linear GENE growth rates (preliminary):

- Flux tube (ρ_{tor} = 0.97)
- Adiabatic ions
- Collisions (no FLR)
- T_e=T_i



Link to separatrix condition

- Low collisionality reached
  (155kA/1.4T, $\beta_N \approx 1.3$, low-δ
  P_{NBH}=1.0MW, P_{ECRH}=1.1MW (X2).
- Pedestal at low ν^* limited by peeling instabilities
- Europed can qualitatively reproduce the several (not all) experimental results.
- n_e^{sep}/n_e^{ped} behaviuor:
  - low ν^*: n_e^{sep}/n_e^{ped} is constant (DIII-like)
  - high ν^*, n_e^{sep}/n_e^{ped} increases with Γ_D (JET-like).



[Frassinetti EPS2022]

Which adimensional parameter can be derived?

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

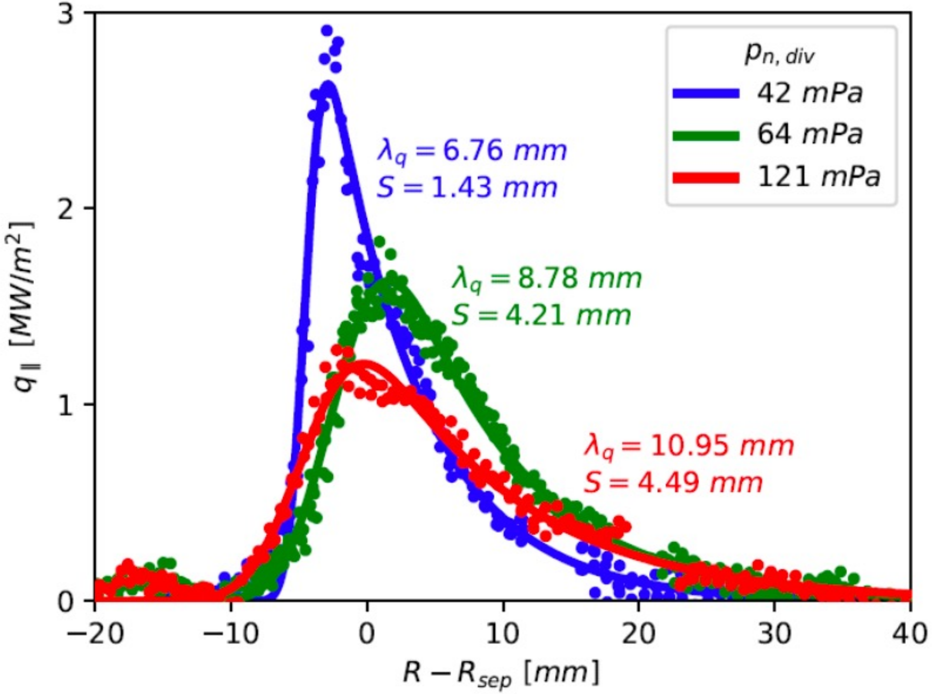
#	
D1	Quantify turbulent and MHD driven transport in the vicinity of the separatrix and implications for predictions for ITER and DEMO
D2	Quantify first wall load in no-ELM scenarios and provide model for SOL transport extrapolation
D3	Extend the parameters space of no-ELM scenarios to large Psep/R and/or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

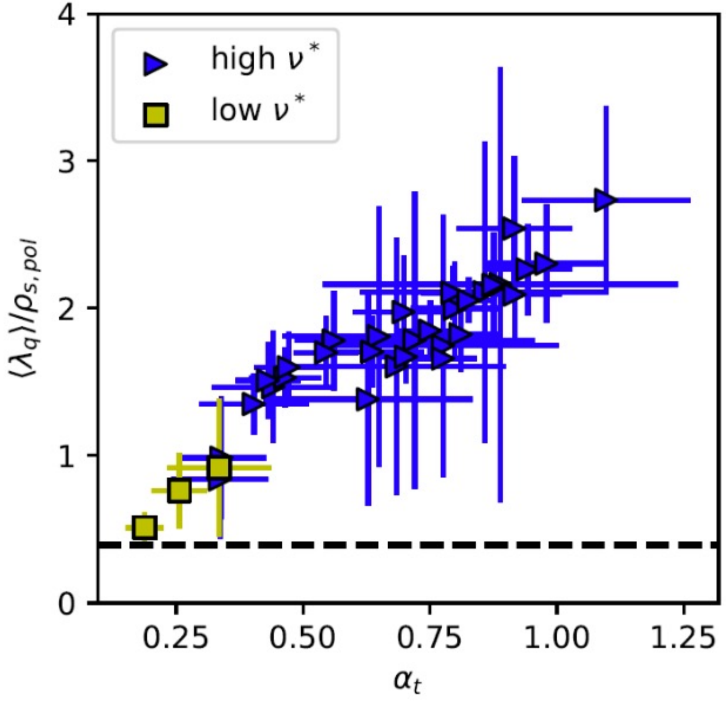
	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	10	50	40	15
2023	15	100	35	0

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

On the role of transport in small-ELM regimes

- Clearly determining the role of pedestal transport in smal— ELM is mandatory for proper extrapolation
- Nature and role of WCM or QCM in QH/EDA/QCE regimes as well and its dependence on shaping/collisionality/flow
- Remember that WPTE program on JET will be the last chance to test geometrical size dependence on large devices

Already allocated resources under WPTE

- RT22-01:
  - M. Hamed: GENE simulations for JET with impurities
  - P. Donnel: Globa Gysela simulations on WEST
  - I. Predebon: Pedestal transport modelling for high current JET operation with local/global GENE simulations
  - S. Mazzi: Core GENE simulations for TCV
  - C. Angioni: JET GKW for inpurity transport in the core/pedestal
  - O. Krutin: TCV pedestal simulations with GENE for assessing the role of separatrix density
  - Interest?

Already allocated resources under WPTE

- RT22-02:
    - O. Krutin: TCV pedestal GENE simulations
    - M. Giacomin: JET and MAST-U GK simulations (GENE/GKW)
    - Interest?

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 but **we are almost completely missing experimental proposals targeted to validation excercise**
- With a program extending till end of 2023 (and with the last chance to collected data from JET) 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