EUROfusion

WPTE Program 2022-2023

Experimental program and modelling needs in view of TSVV1 deliverables

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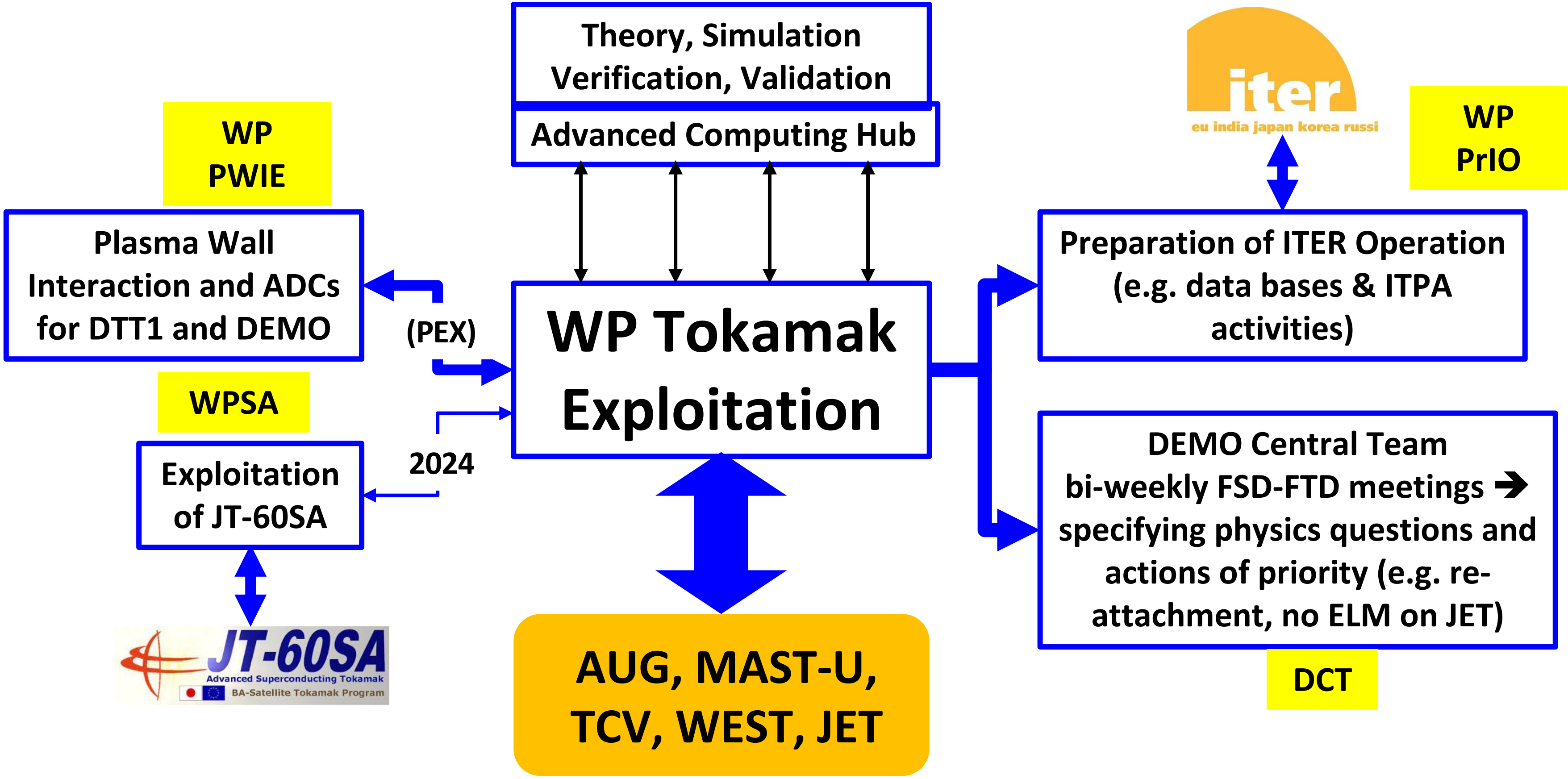
WP TE in FSD with overarching priorities: ITER & DEMO & PEX



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:
  - 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 related to TSVV1

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. 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). In the process of removing it~~	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.13	Recommendation on the seeding impurity mix in view of a future reactor.	Dec. 2024

Proposed to EC cancellation of TE.D.11 as GD attached to WP packages

WP TE is currently structured into 9 Research Topics

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

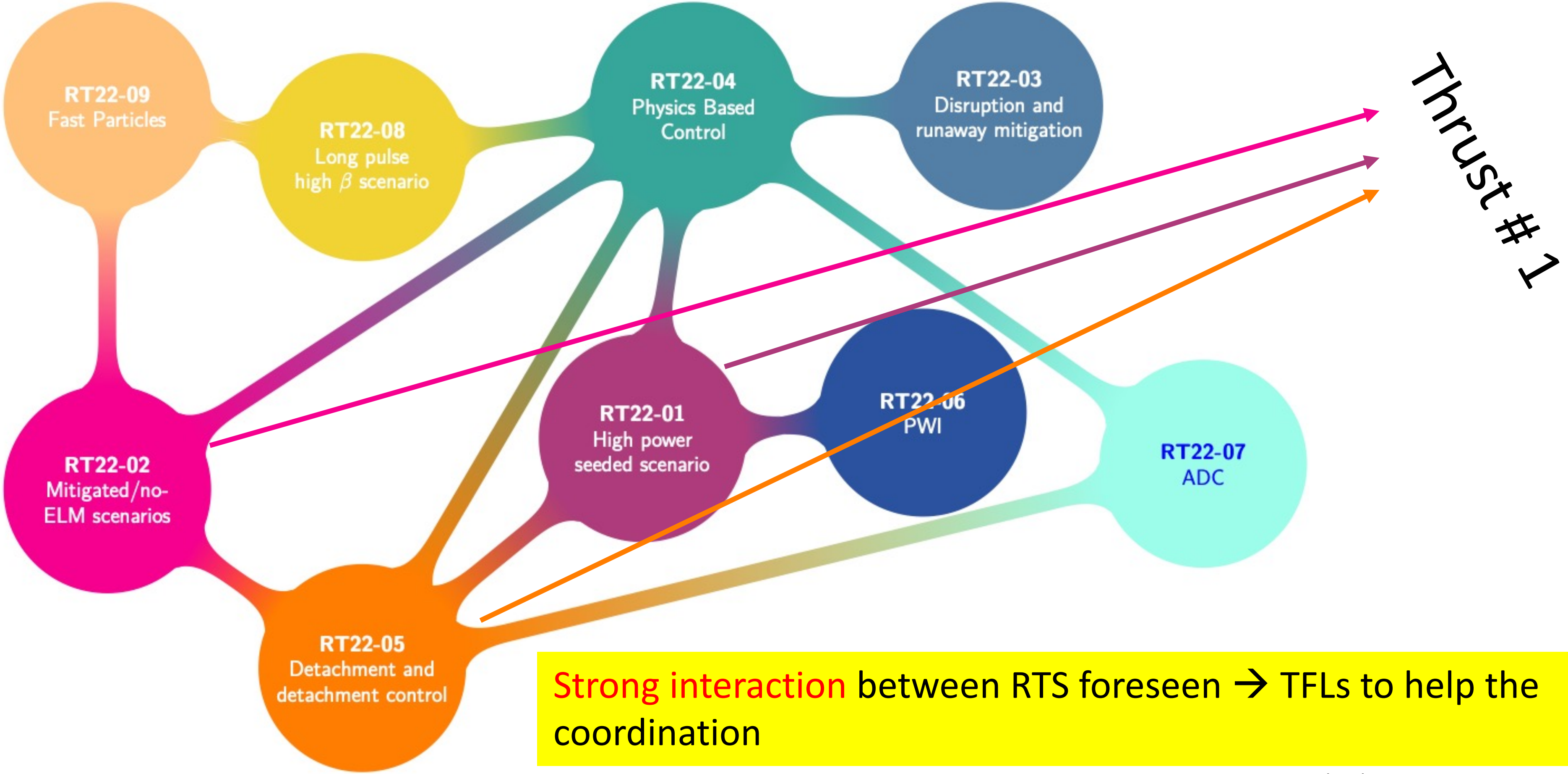
RT06: preparation of efficient PFC operation

RT07: Alternative divertor configuration

PEX

Mission 1 | Mission 2

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

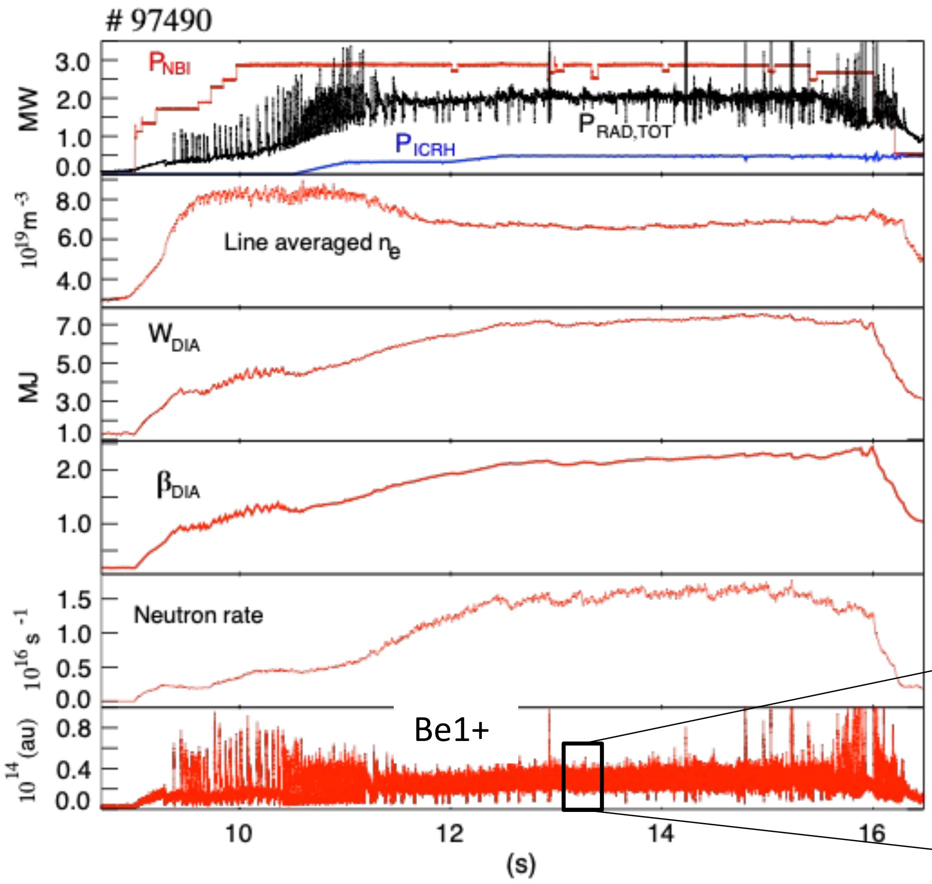
	JET	TCV	MAST-U	WEST
	Sessions	Shots	Shots	Shots
2022	7	50	40	0
2023	28	100	35	15

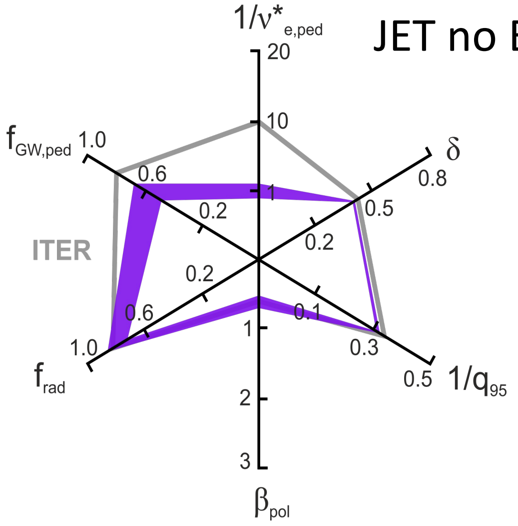
RT22-01 ITER-baseline Core-edge integ.

- In ITER-baseline plasmas, investigate how seeded impurity affect transport and ELMs in ITER-baseline plasmas, essential component of the core-edge integration

- In ITER-baseline plasmas, investigate
  - How is the pedestal transport affected differently between Ne and N at similar concentration ? What is the key component ?
  - Pedestal transport at large SOL opacity for unseeded plasmas
  - Impact of DT vs D (unseeded and Ne-seeded)
  - The physics of the H to L transition in high density seeded plasmas
    - L-mode at 3.2MA/3.45T with C_{Ne} varying from ? To ?

Best case of integrated scenario with Ne-seeding at JET





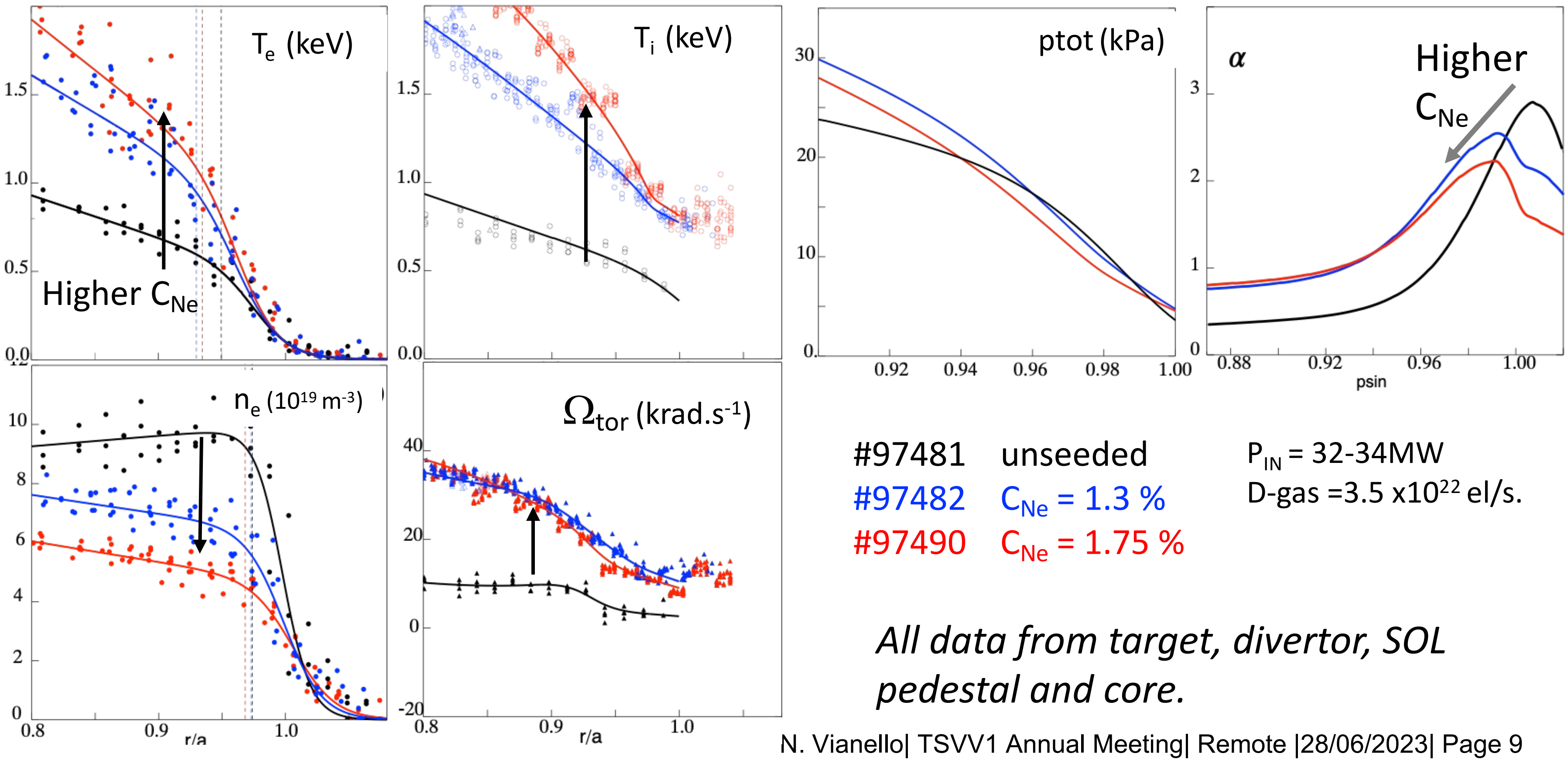
JET no ELM ITER-Baseline

$P_{sep}/P_{LH}<2$

$H_{98(y,2)}=0.9$
$\beta_N=2.2$,
$f_{GW}=0.7$,
$f_{GW,ped}=0.46$
$f_{rad}=0.86$,
$Z_{eff}=2.7$, $C_{Ne}=1.7\%$
$T_i=1.4xT_e$
$\nu^*_{e,sep}= 35$ (12 $Z_{eff}=1$)

Pedestal modification with Ne

As C_{Ne} rises, T_{ped} , ω_{tor} increases, $n_{e,ped}$ falls, p_{tot} and width increases



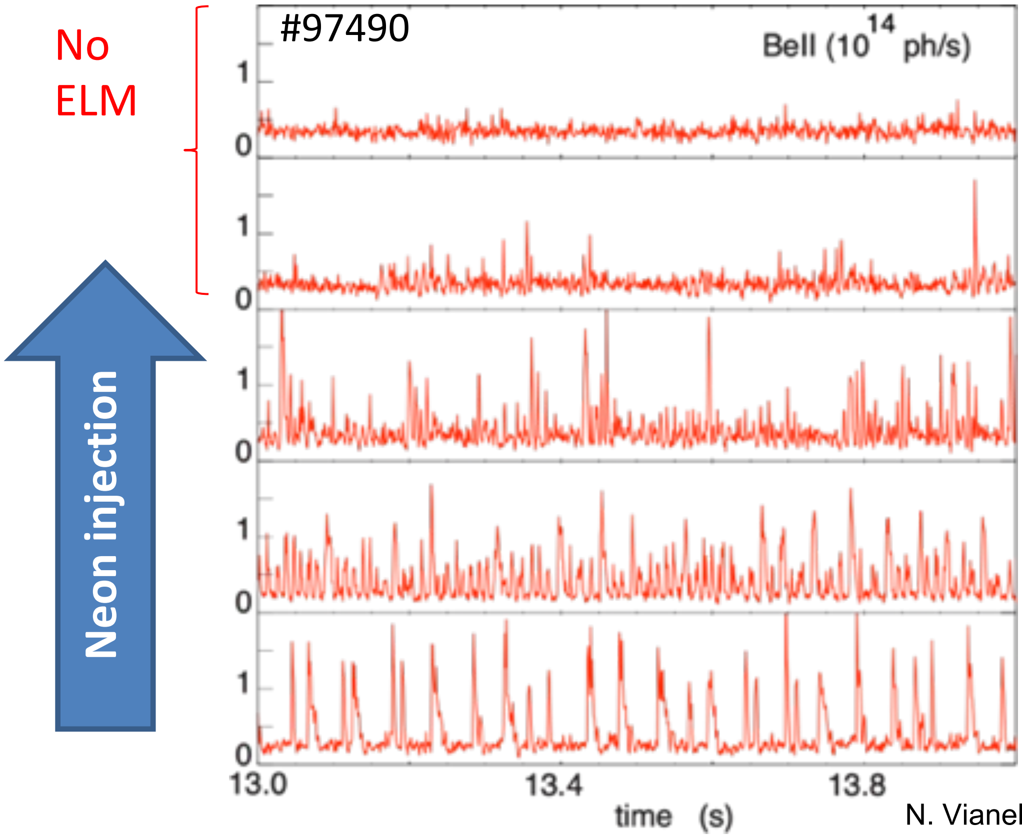
#97481 unseeded
#97482 C_{Ne} = 1.3 %
#97490 C_{Ne} = 1.75 %

P_{IN} = 32-34MW
D-gas =3.5 x10^{22} el/s.

All data from target, divertor, SOL pedestal and core.

ELM variation with increasing C_{Ne}

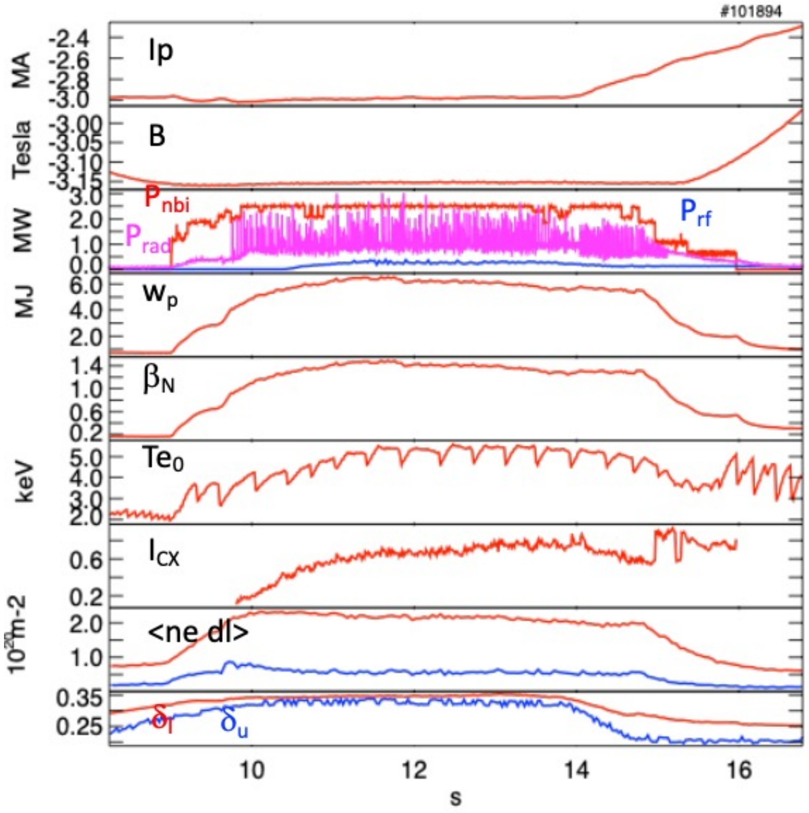
ELM size reduces with increasing C_{Ne}



C_{Ne} (%)	$\Delta W_{MHD}/W_{HD}$ (%) Isolated ELMs	$f_{gw,sep}$	$n_{e,sep}/n_{e,ped}$
1.7	<0.3	0.23	0.5
1.5	1.7	0.30	0.58
1.3	5.7	0.30	0.47
0.7	3.3	0.32	0.4
0.1	6	0.28	0.3

Move to higher current in seeding discharges

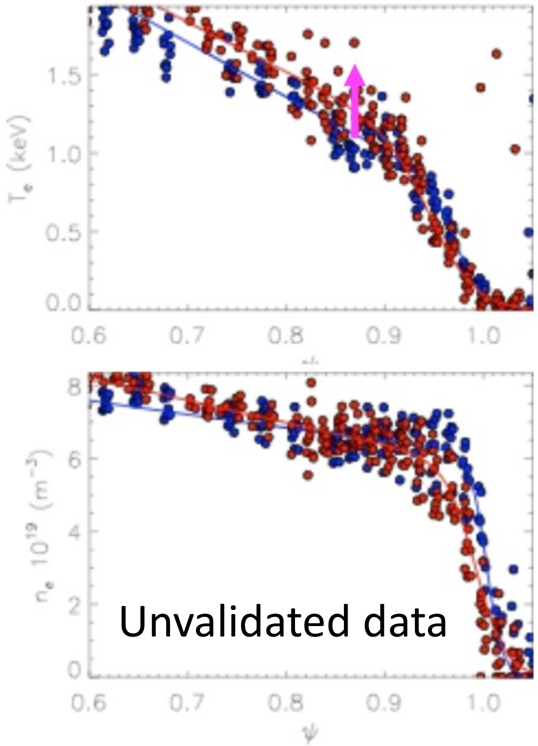
- 3MA/3.15T N seeding discharges obtained, with good stationary conditon



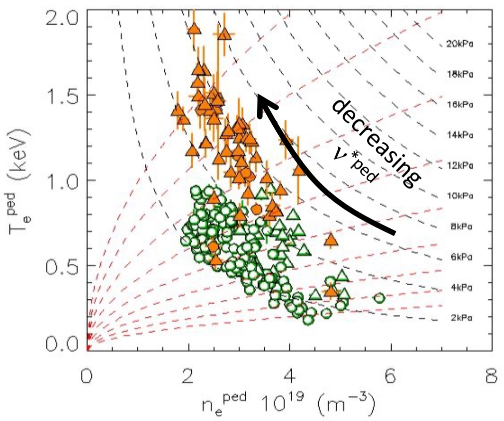
101779 2.5MA / 2.8T

101894 3MA. / 3.15T

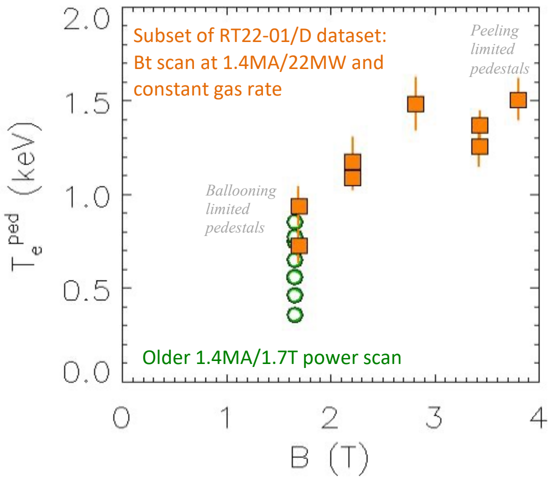
Higher temperature and same density

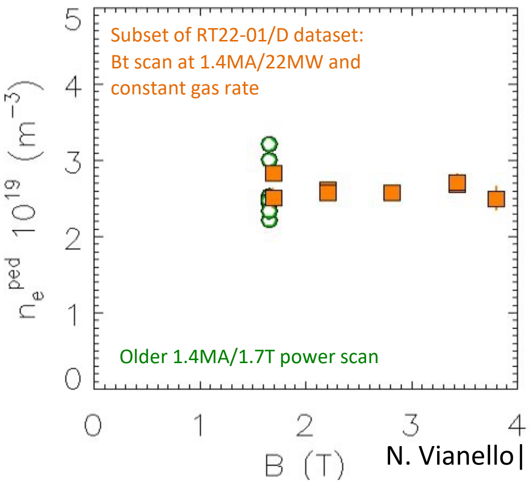


RT22-01/D pedestal modelling plans



- RT22-01/D dataset:
  - Orange data: 1.4MA at high Bt and low ν^{*ped}
- Older dataset:
  - Green data: all 1.4MA JET-ILW data
- ITER-relevant lowest ν^{*ped} reached ($\nu^{*ped}\approx0.1$). However, at non ITER-relevant q_{95}
- At the lowest ν^{*ped}, RT22-01/D has reached ITER-relevant peeling limited pedestal
- A Bt scan has created a link between the earlier balloning limited and the new peeling limited plasmas
- Isotope mass scan planned in DTE3 to investigate if the isotope mass effect on tranport and stability is different between the usual high ν^{*ped} scenario and the new low ν^{*ped} ($\nu^{*ped}\approx0.1$)





MODELLING ACTIVITIES:

- Study and compare pedestal stability between
  - low and high ν^{*ped} datasets
  - Bt scan
- Test predictive pedestal models
- Compare pedestal turbulent transport between:
  - the usual high ν^{*ped} dataset (≈1.0, on which all the JET pedestal GK modelling is based on)
  - the new low ν^{*ped} dataset ($\nu^{*ped}\approx0.1$)
  - Bt scan dataset
- Compare pedestal turbulent transport in the isotope mass scan at low ν^{*ped}

Link to separatrix condition

Pedestal turbulent transport

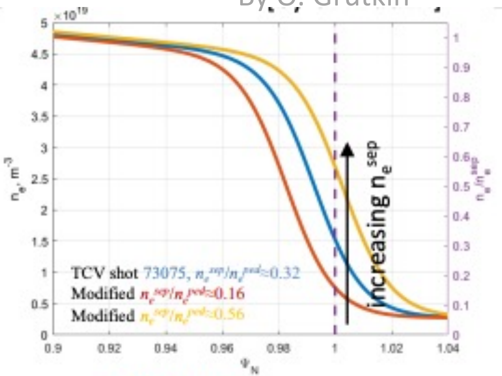
Is there a difference in the microinstabilities and in the turbulent transport between:

- low ν*/peeling limited and high ν */balloning limited pedestals?
- low $n_{e,sep}/n_{e,ped}$ and high $n_{e,sep}/n_{e,ped}$ ped at high ν*? → GENE simulations on going (O. Krutkin)

Separatrix density and SOL

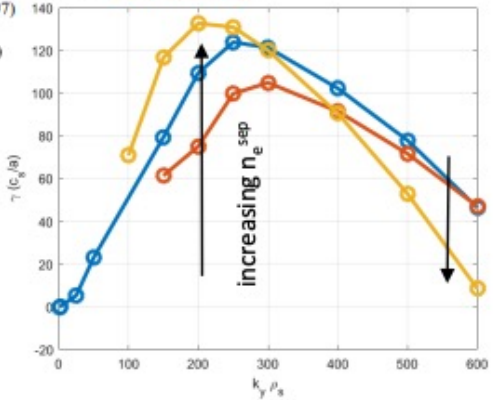
- high ν */balloning limited pedestals:
  - $n_{e,sep}/n_{e,ped}$ increases with increasing gas rate.
- low ν*/peeling limited and
  - $n_{e,sep}/n_{e,ped}$ remains constant with increasing gas rate.
- Can the modelling provide interpretation to these observed differences?

By O. Grutkin

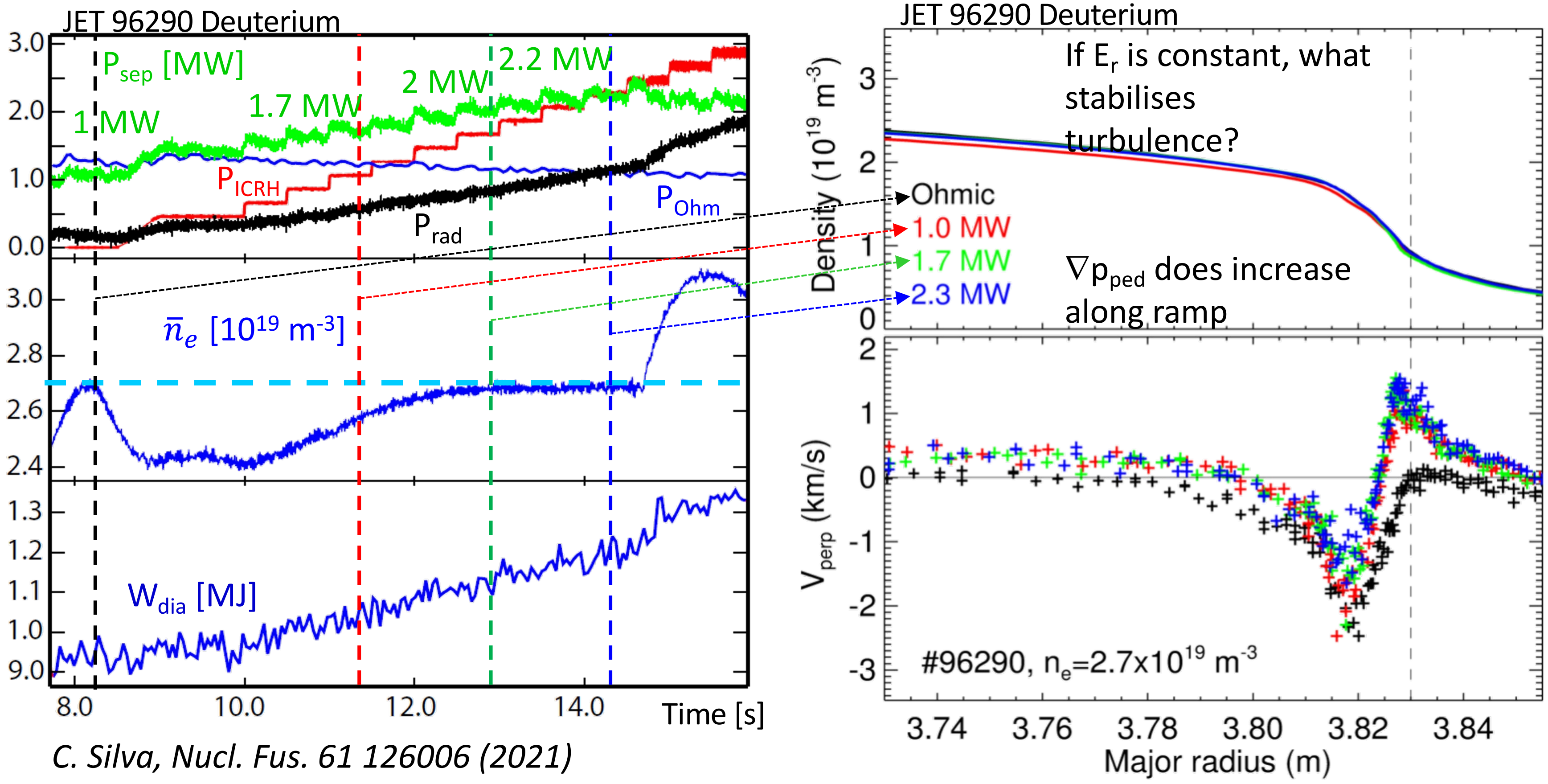


Linear GENE growth rates (preliminary):

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



Doppler reflectometry along power ramp in Deuterium



C. Silva, Nucl. Fus. 61 126006 (2021)

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

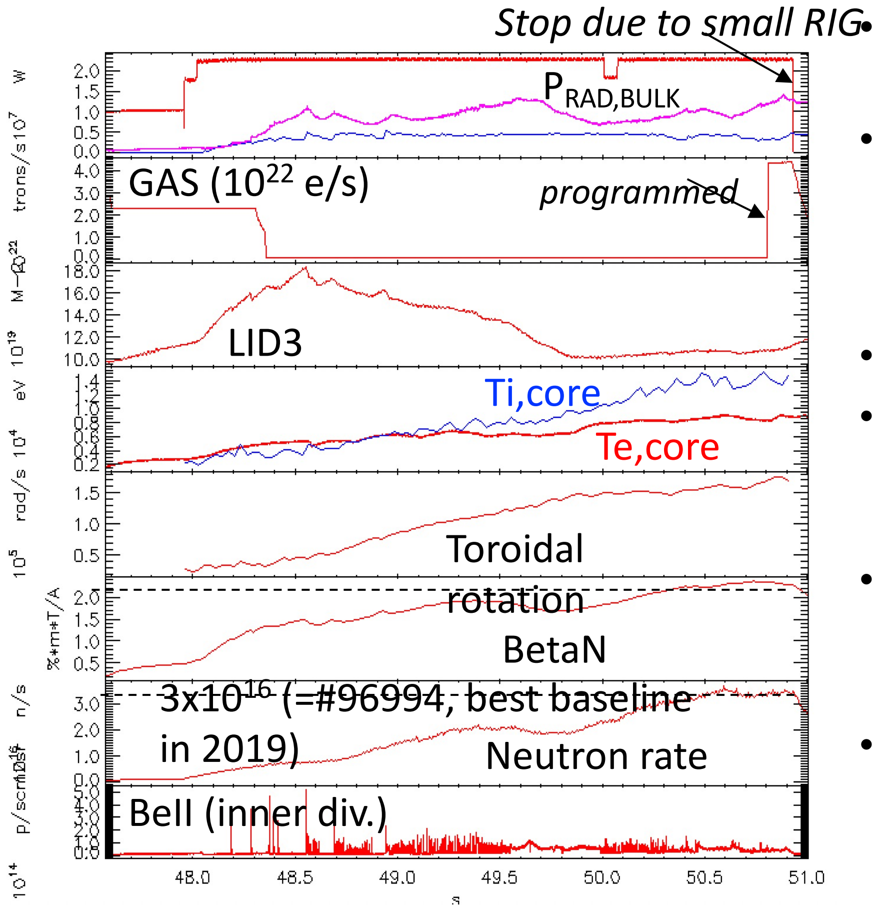
#	
D1	Quantify turbulent and MHD driven transport in the vicinity of the separatrix and implications for predictions for ITER and DEMO
D2	Quantify first wall load in no-ELM scenarios and provide model for SOL transport extrapolation
D3	Extend the parameters space of no-ELM scenarios to large Psep/R and/or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

- RT22-02 has multiple no/small ELM scenarios
  - SE – (Baseline) Small ELMs
  - EDA – enhanced D-alpha
  - **QCE – quasi-continuous exhaust regime**
  - NT – negative triangularity
  - (R)MP – (resonant) magnetic perturbation
- Clearly determining the role of pedestal transport in small—ELM is mandatory for proper extrapolation
- Remember that WPTE program on JET will be the last chance to test geometrical size dependence on large devices and at least QCE will be explored in DT

Low-gas small-ELMs scenario

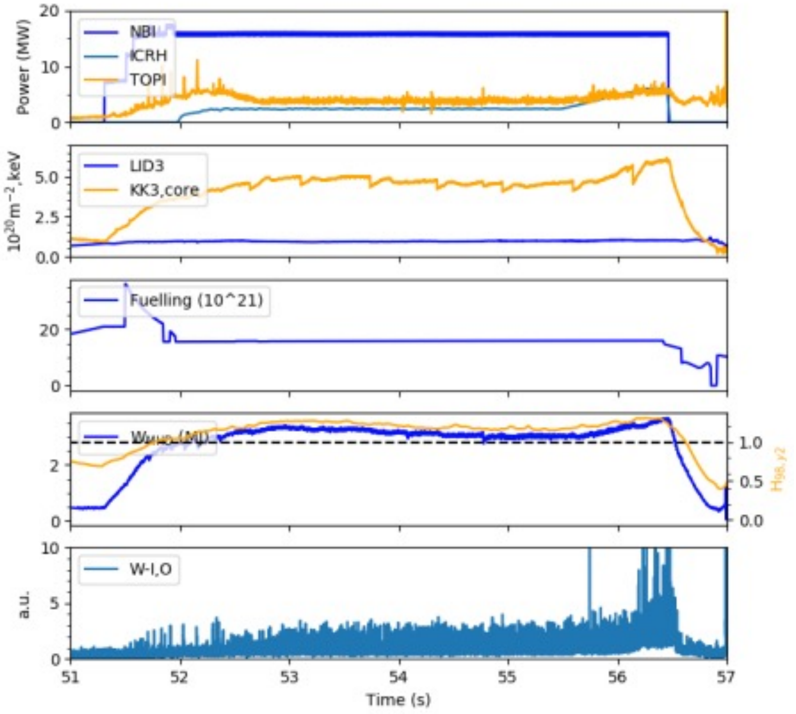


- Scenario: low delta, corner configuration, 3 MA / 2.8 T, q95=3, with no gas
- Reproduced performance of earlier pulses (#94900) →access to small ELMs clearly observed at low density, Ti>> Te (similar to hot ion mode), **not core accumulation.**
- Small ELMs phase duration not limited by radiation
- Clear phase where ELMs fully disappear, but still H-mode, with high Te pedestal + wide pedestal density profile
- Useful information for edge stability in connection with the ELM triggering physics and impurity & turbulent transport analysis
- Modelling activity already started (**M. Dicorato et al**) but not in within RT22-02

QCE on JET

Robustly established at 1.5 MA/
2.8 T

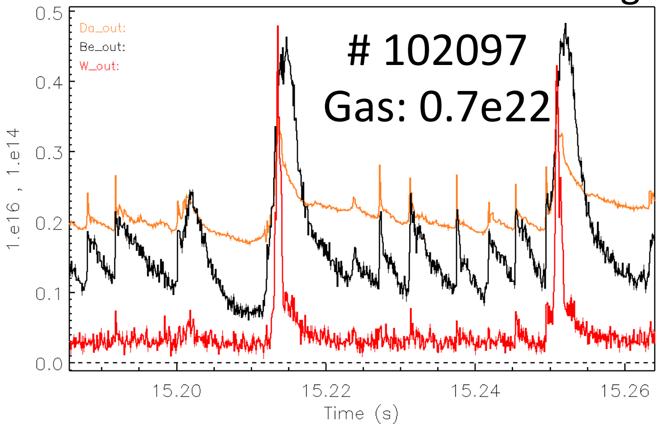
- Final shape in most pulses from ca 52.5 s onwards
- High Pnet, low Prad
- Responds very well to increased RF power
- High normalised confinement
  - (Invalid) SCAL H98,y2 = 1.2
- Sees only noise in W-I signal at slightly higher fuelling



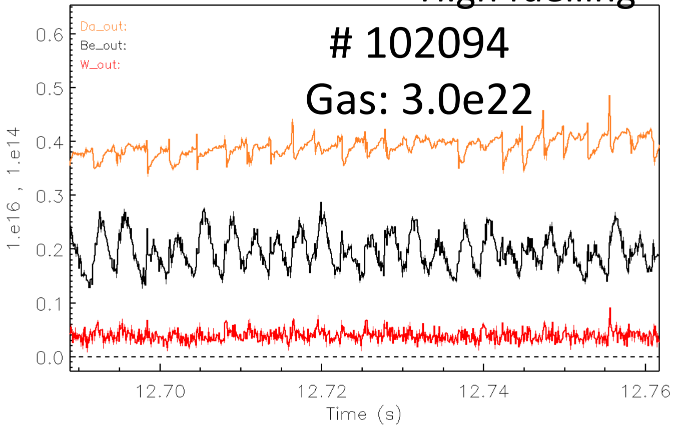
QCE on JET

- ELM size not “just” dependent on q and shaping
- See qualitative difference in typical signals at low vs high fuelling
  - Low fuelling - “typical” ELMs, with inter-ELM events
  - High-fuelling - only fluctuations with no real frequency or peak

Low fuelling



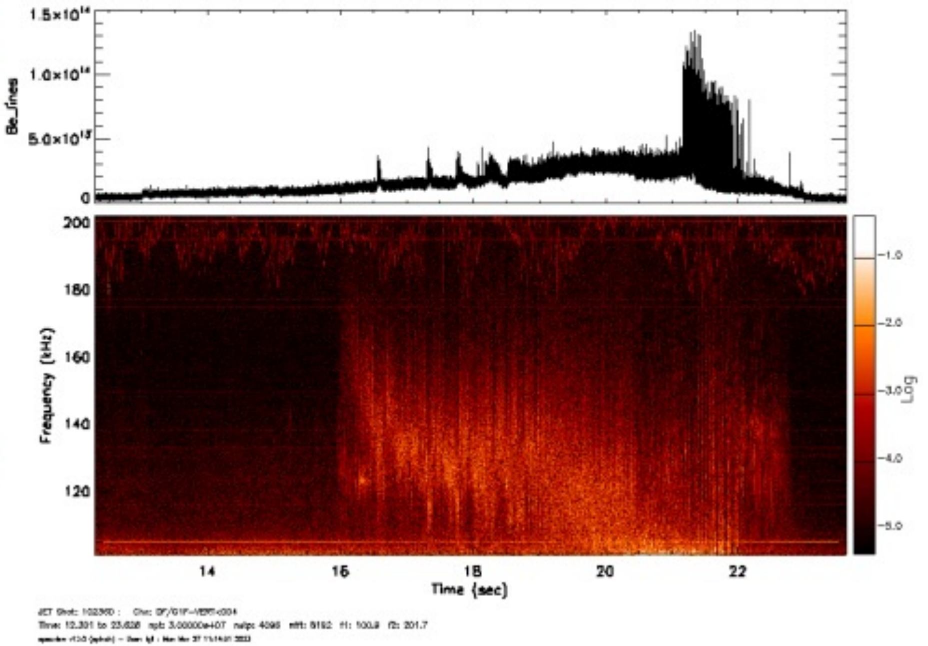
High fuelling



EDA on JET

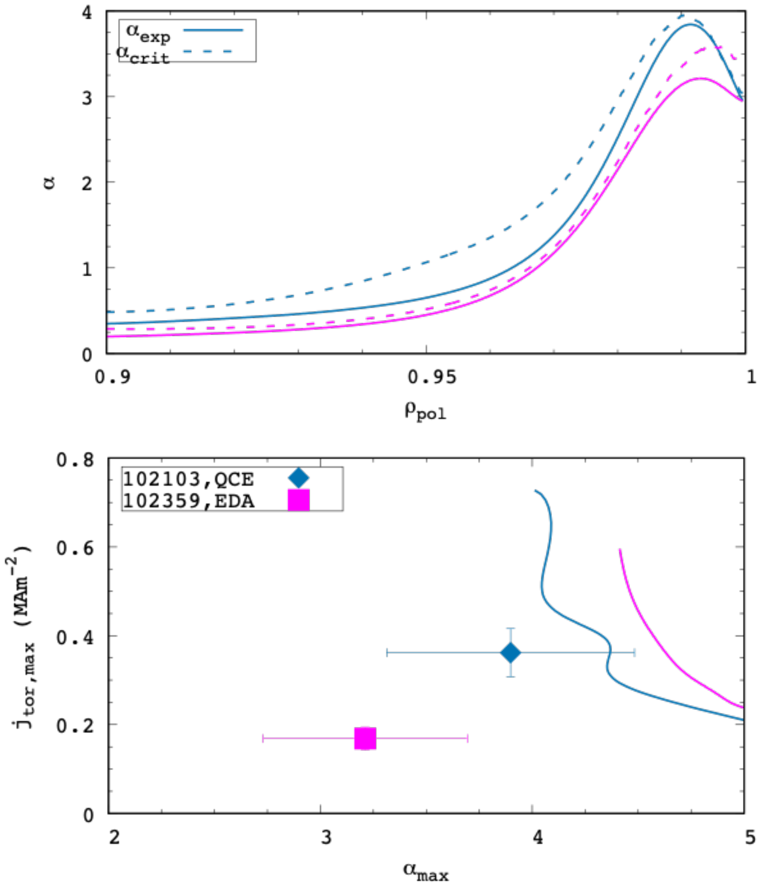
- Established at both 1.5 and 2.0 MA
- All pulses with RF and NBI ramp to assess EDA and ELMy H-mode access
- Quasi-coherent mode (QCM) well visible at both plasma currents
- At highest NBI power, see ELMs coming back
  - Could likely mitigate with more fuelling
  - Γ_D already quite high in some pulses…

JPN 102360



Preliminary interpretive pedestal modelling

- Compare EDA and QCE at same current/field
  - Shapes slightly different
- Profiles made using yet-to-be-validated HRTS data
  - Also assuming Ti=Te
- QCE:
  - Ballooning unstable close to the separatrix
  - Close to PB stability boundary
  - In line with AUG experience of good-performing QCE
- EDA:
  - Ballooning stable at separatrix, but unstable further inside



Strong modelling requests from RT22-02

- Pedestal and near-SOL non-linear transport modelling would be quite beneficial for our topic.
- Linear threshold calculation from e.g. HELENA available and consistent with expectation but there is the strong need for determination of transport coefficients. For QCE present understanding suggest the primary role of modes at pedestal bottom close to the separatrix → GENE-X?
- Embedding the already on-going effort on Small-ELMs into Research Topic structure

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Already allocated resources under WPTE

- RT22-01 2023:
  - M. Hamed: JET
  - A. Mariani: JET
  - I. Predebon: JET
  - O. Krutin: TCV
  - C. Angioni: JET
  - T. Luda di Cortemiglia: JET
  - US Collaboration: C.S. Chang, F. Parra, D. Hatch, E. Belli, J. Dominski

Already allocated resources under WPTE

- RT22-02 2023:
  - 0 no resources allocated but clear need for interpretative modelling

Conclusions

- Ambitious program built for 4 devices in 2022-23 exported as well into DTE3
- A similar Research Topic structures will be likely maintained in 2024
- Despite being formally fully embedded into WPTE program the TSVV validation exercise is still in the early phase
- TSVVs should take advantage of the wide parameter range offered by similar program runs in different devices. Some unique features (e.g. machine size scaling or isotope effects including DT plasmas) are clear opportunities
- The interpretative work with all the advancements obtained within TSVV framework should be now embedded into EF program, overcoming the "in-house" approach