WPTE-RT22-08: “Physics and operational basis for high beta long pulse scenarios”

First results from TCV experiments

RTCs: A. Burckhart[1], R. Dumont[2], C. Piron[3]
TFLs: D. Keeling, M. Baruzzo, E. Joffrin

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WPTE-RT08: Scientific Objectives

D1.Develop scenarios to assess the **flux pumping** mechanism efficiency

D2.Quantify the **compatibility** of high β_N long pulse with **mitigated ELMs** and/or with **exhaust in metallic wall devices**

D3.**Characterize** the **fast and thermal ion transport** together with the ExB, magnetic shear, turbulence conditions in steady-state scenarios at high-q

D4.Develop **projection schemes** of long pulse at high beta as a potential **reactor scenario**

D5.Develop an intrinsically **steady state solution at high βN** (>3) in terms of q/pressure profile and stability. Compare it with other existing solutions **in view of** its application to **JT-60SA and DEMO**

Summary of pre-campaign work

- 18/03/22 WPTE call for proposals, 8 proposals were submitted to RT08

P	Title	Proponents
134	Investigation of rotational stabilization of the RWM at high β_N	A. Lazaros
135	Towards fully non-inductive operation at high beta in a W environment	R. Dumont
136	Develop a high β scenario on JET in support of JT-60SA	L. Garzotti
137	Identifying magnetic flux pumping in the presence of an ideal internal mode in JET	A. Burckhart
138	Develop high q_{min}, high β_N scenarios on MAST-U	B. Patel
139	Ensuring high performance at low rotation shear via pellet injection	M. J. Pueschel
140	**Development and optimization of high-bootstrap, high-beta tokamak scenarios towards steady state**	S. Coda and C. Piron
141	Study q and Bt scaling of heat transport and intrinsic rotation in ohmic discharges on JET	E. Delabie

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Devices that address SOs

Scientific Objectives	JET	TCV	MAST-U	WEST
D1	P137			
D2				P135
D3	P141	P140	P139 P140	P139 P140
D4		P140	P140	P140
D5	P136	P134 P140	P138 P140	P135 P140

Allocated priorities [WPTE-TFM 31/05/2022]:
P1 experimental priority
P2 will be done if time allows after P1 experiments are completed
P3 back-up programme/not possible in 2022
PB piggy-back experiment/pure analysis proposal

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year	JET (sessions)	TCV (pulses)	MAST-U (pulses)	WEST (pulses)
2022	0	50	35*	0
2023	8	50	50	30**

* Experiments shifted to 2023

** [15 in 2023 + 15 in 2024], RTCs meeting 18/11/22

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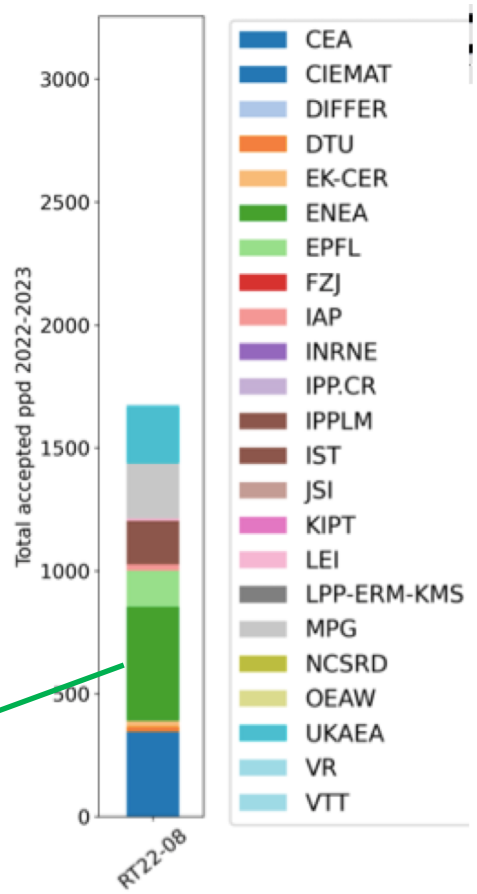
- 06/10/22 RTCs prepared the cross-machine strategy (experiments, analyses and modelling plans) to target the RT objectives
  - C. Piron: 2022/23 WPTE-RT08 strategy talk
- Following the manning selection:

ENEA: C. Piron, P. Buratti, G. Pucella, F. Orsitto, L. Senni
RFX: L. Piron, F. Auriemma, M. Valisa, D. Terranova, L. Pigatto, M. Bonotto, (M. Agostini, M. Ugoletti)*
ISTP: S. Garavaglia, A. Moro, S. Nowak, E. Alessi, C. Sozzi
UNI: G.Sias (**DIEE**), M. Laquaniti (**UNICA**), V. Zotta (**UNIRM**), S. Gabriellini (**UNIRM**)



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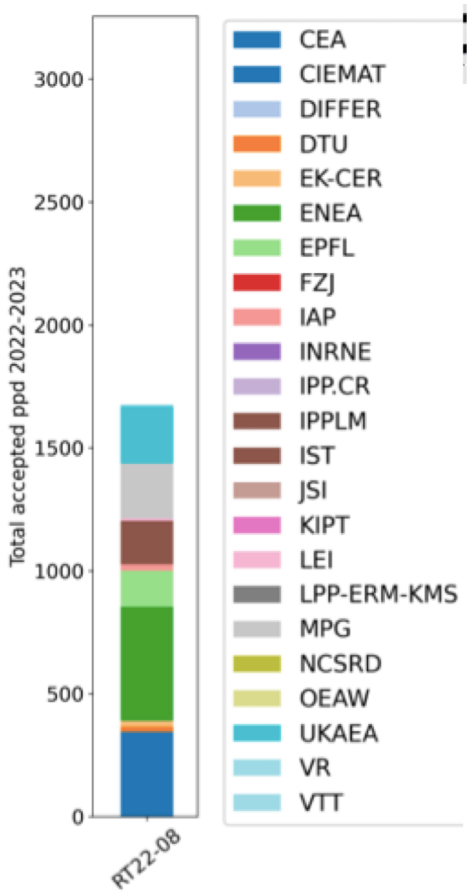
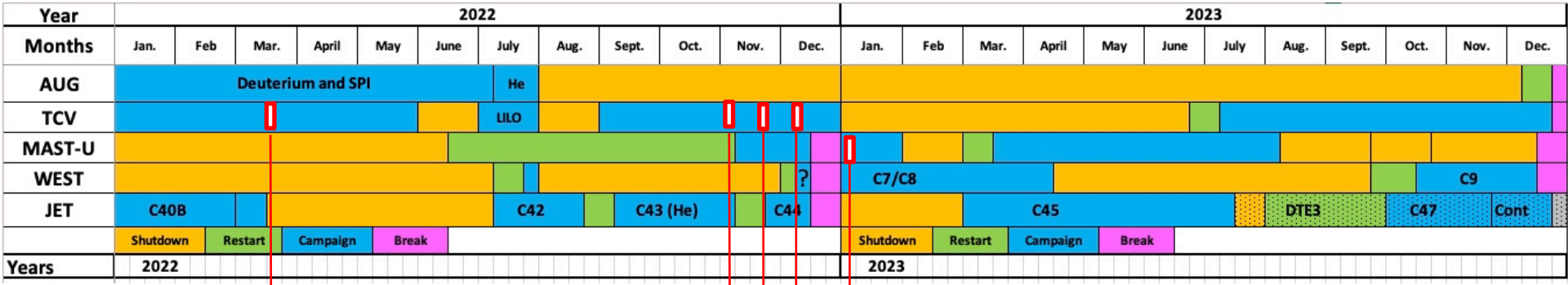
- Following the manning selection:
  - 13/10/22 Cross-machine kick-off meeting
  - 13/10/22 Preparation of session I on TCV
  - 27/10/22 Modelling session in preparation of session II
  - 11/11/22 Preparation of session II on TCV



Timeline (v1.7)

WPTE-RT08 scheduled experimental sessions



W02, 09-13/01

W47, 22-25/11

W47, 22-25/11

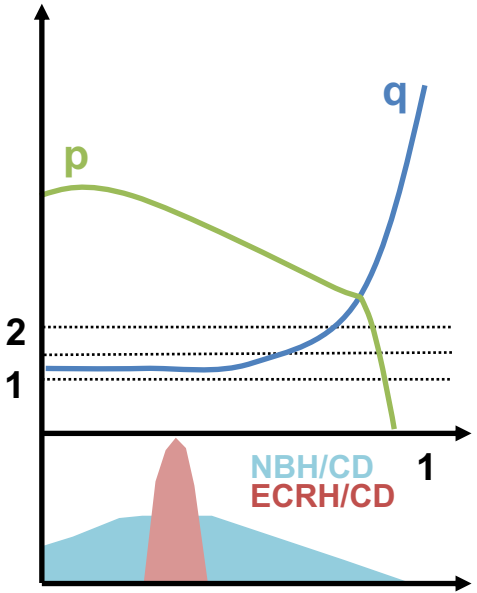
W22, 30/05-03/06

RT12

W44, 01-04/11

RT08

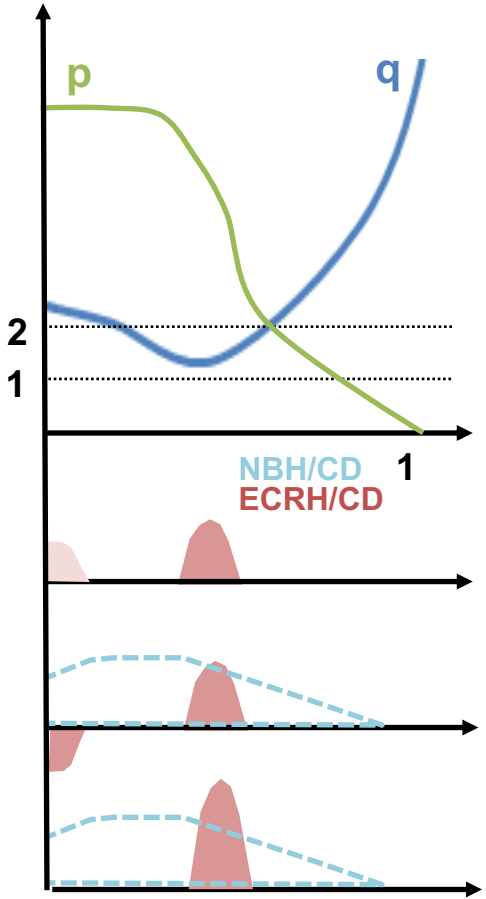
Explored routes towards AT scenarios



ETB

- Ip=[*110,120,140*, 150] kA
- $n_{e,L}$(FIR)≈1.6x10^{19}
- LSN, z_0 ≈ 10cm

off-axis co-ECCD + NBI



ITB

- Ip=[*100*,150,160] kA
- $n_{e,L}$(FIR)≈1.1x10^{19}
- LSN, z_0 ≈ 10cm

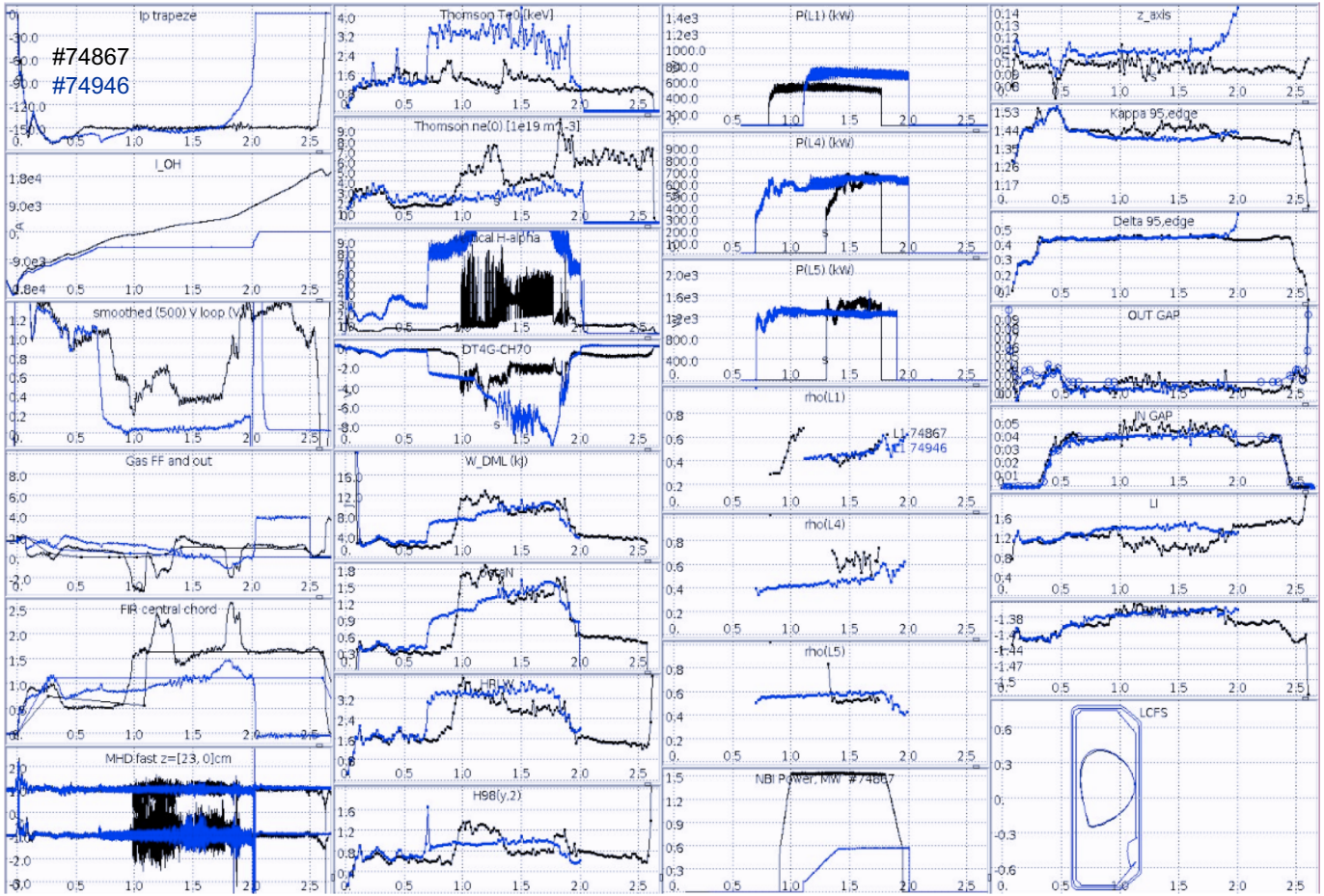
off-axis co-ECCD + on-axis ECH

off-axis co-ECCD + on-axis cnt-ECCD (NBI)

off-axis co-ECCD + on-axis cnt-ECCD (NBI)

Please find here an overview of the 2020/21 WPTE-RT12 results

ETB vs ITB scenario



Main similarities:

- Ip 150kA
- LSN z_0=10cm
- $P_{EC} \cong 2MW$

Main differences:

- n_{el}
- ECRH timing
- P_{NB}

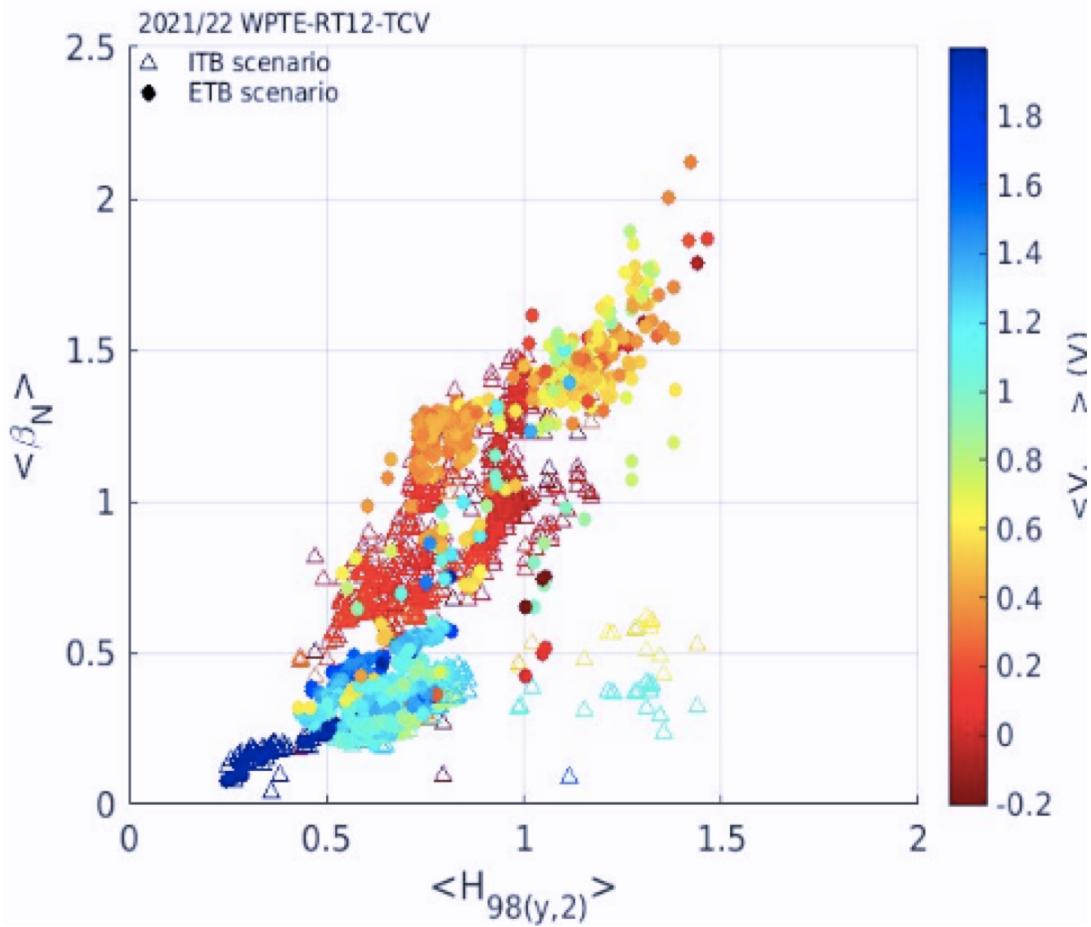
ITB scenario:

→ V_{loop}=0V, $\beta_N \cong 1.5$

ETB scenario:

→ V_{loop}>0V, $\beta_N \cong 2$

ETB vs ITB scenario



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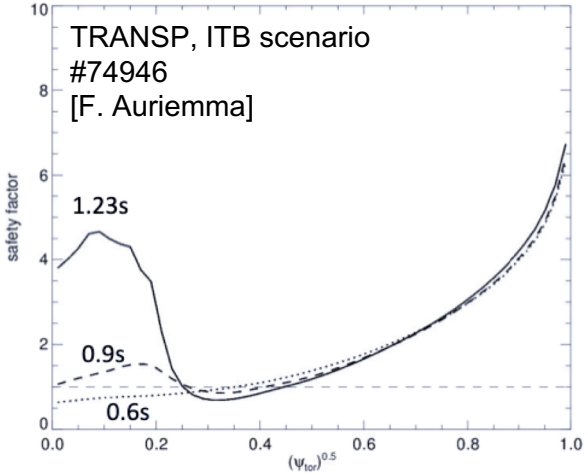
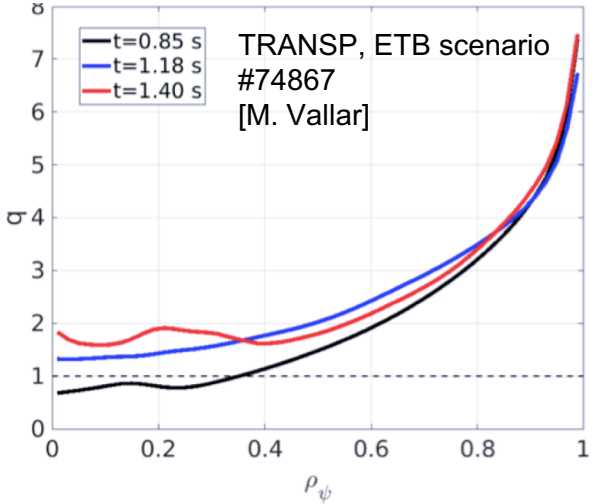
ETB scenario:
→ V_{loop}>0V, $\beta_N \cong 2$

Extensive modelling work

- Interpretative transport simulations of reference pulses have been carried out with ASTRA [I. Voitsekhovitch (UKAEA)] and TRANSP [F. Auriemma (Consorzio RFX), M. Vallar (EPFL)]
  - j, q-profile reconstruction
  - NBI losses
  - Non-inductive current fraction

→ ASTRA vs TRANSP code comparison





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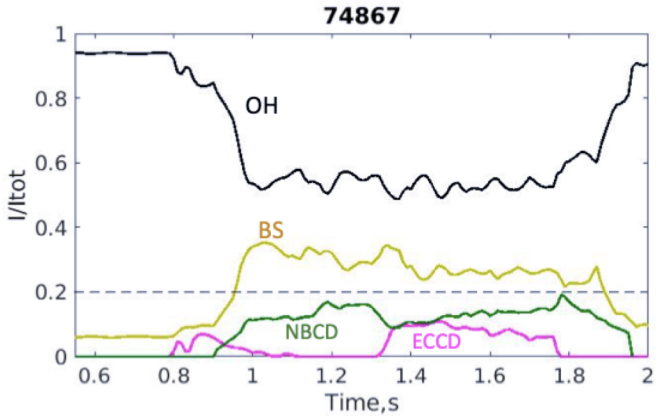
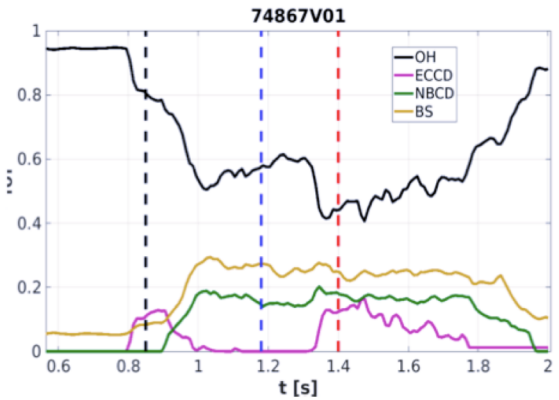
ASTRA
[I. Voitsekhovitch]



TRANSP
[M. Vallar]



Shot plan for session I

Session I W44 2-4 Nov 2022, 20 shots

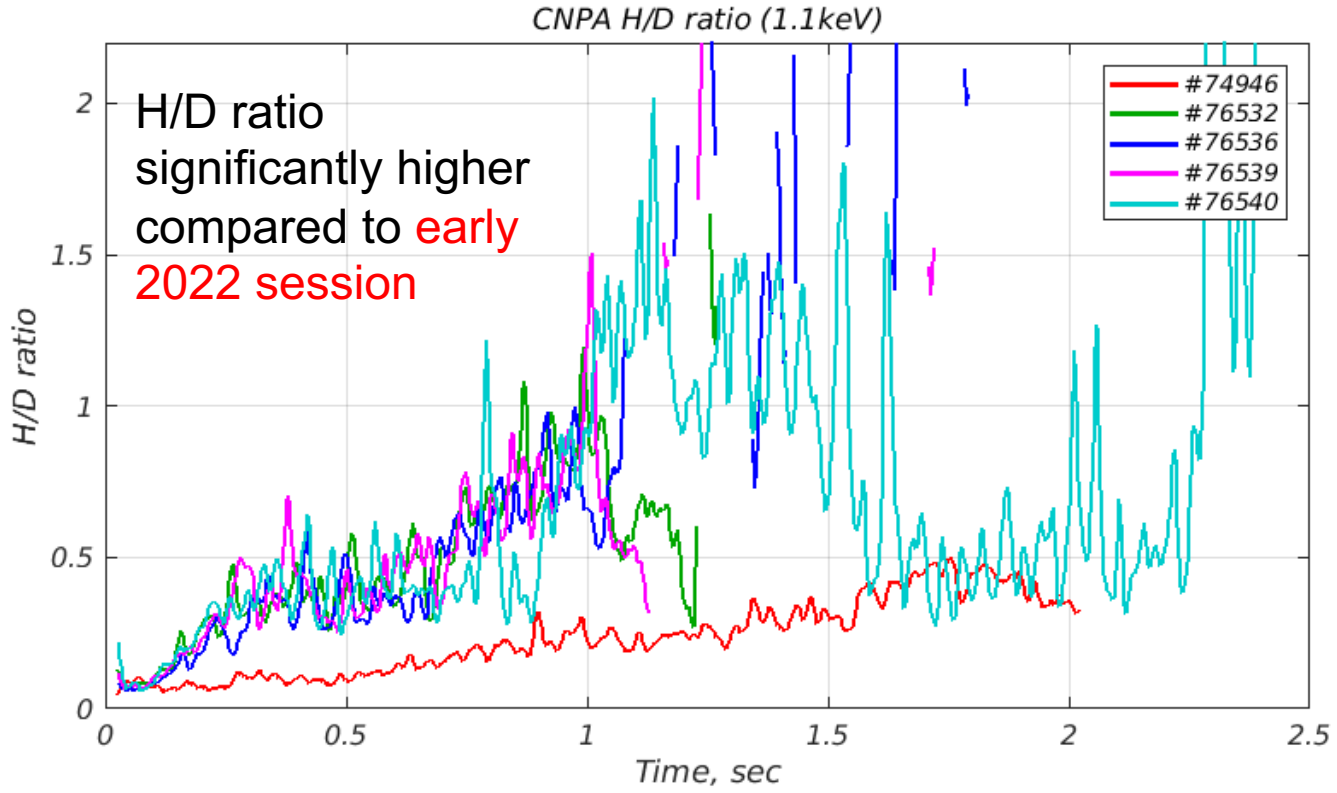
ITB scenario [TOT. #7/14shots]

1. Straight repeat of #74946 aiming at zero IOH slope, full nominal L1 polarization, better core (TS) and edge (TS + THB) ne, Te measurments [#1/2 shots]
2. If needed, adjust gas puff reference according to wall condition (target: $ne<ne_{EC,cut\text{-}off}$ in H-mode) [#1/3 shots]
3. According to the Ip value obtained with zero IOH slope, repeat #74746 at lower Ip (ex. Ip = [110, 130]kA) (modelling request) [#2/4 shots]
4. Increase PNB = [0.75, 1, 1.3]MW in separate shots [#3/5 shots]

ETB scenario [TOT. #8/15shots]

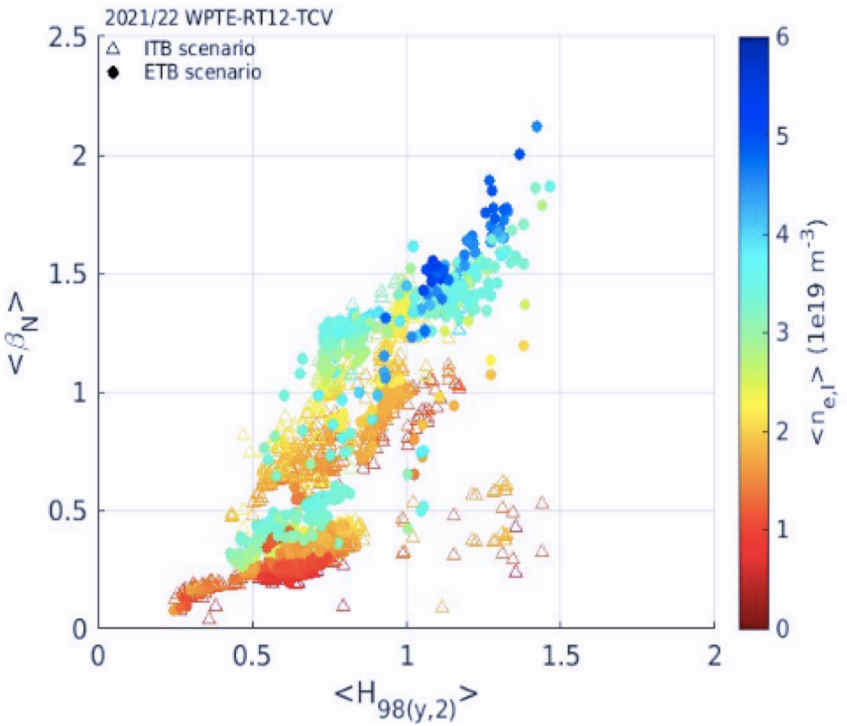
1. Straight repeat of #74867 with full nominal L1 polarization and THB diagnostic for better edge ne, Te measurments [#1/2 shots]
2. If needed, adjust gas puff reference according to wall condition and L/H-mode transition (target: $ne<ne_{EC,cut\text{-}off}$ in H-mode) [#1/3shots]
3. If ELM limit cycle is triggered:
    1. density scan during the ECRH phase to avoid H/L-mode back transition [#2/3 shots]
    2. repeat at lower Ip<140kA (to check whether mode locking has a role in it) [#1/2 shots]
4. If limit cycle is NOT triggered:
    1. scan ECRH/CD deposition towards the inside to probe Vloop response [#2/3 shots]
    2. repeat the shot with the lowest Vloop with clamped IOH [#1/2 shots]

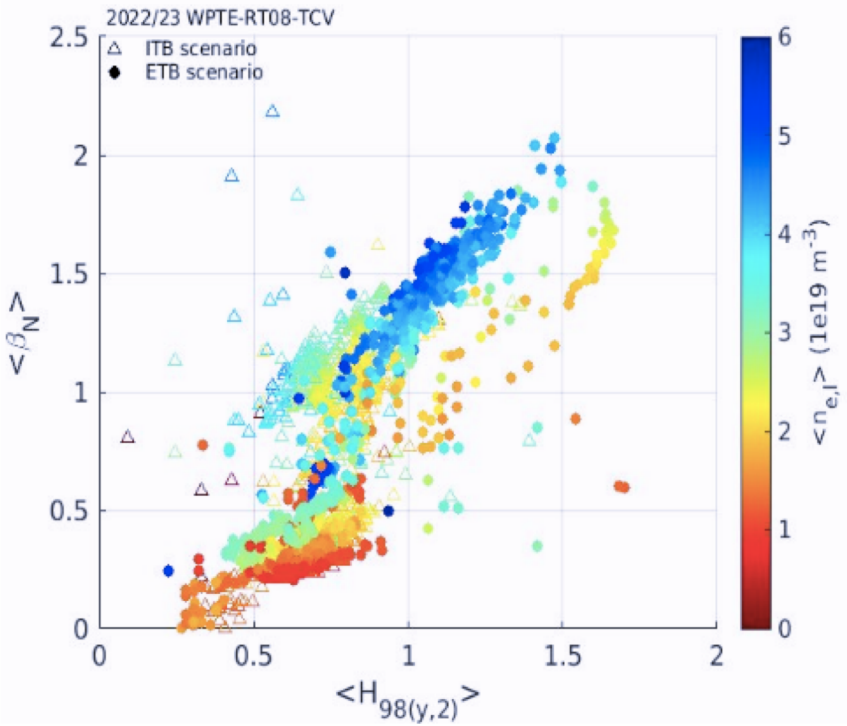
High wall recycling during session I



[Thanks to A. Karpushov (EPFL)]

RT12 vs RT08 performance





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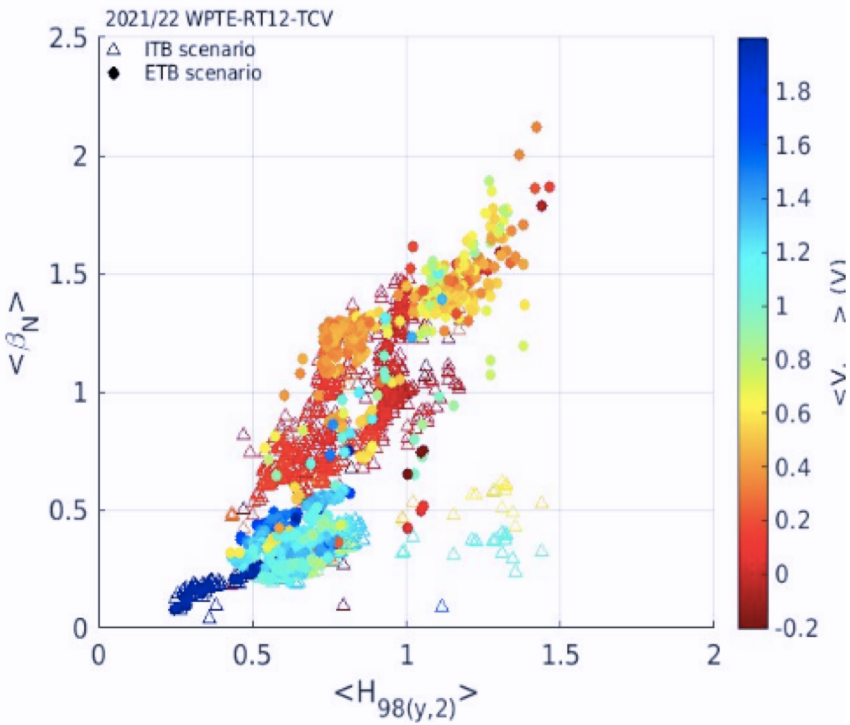
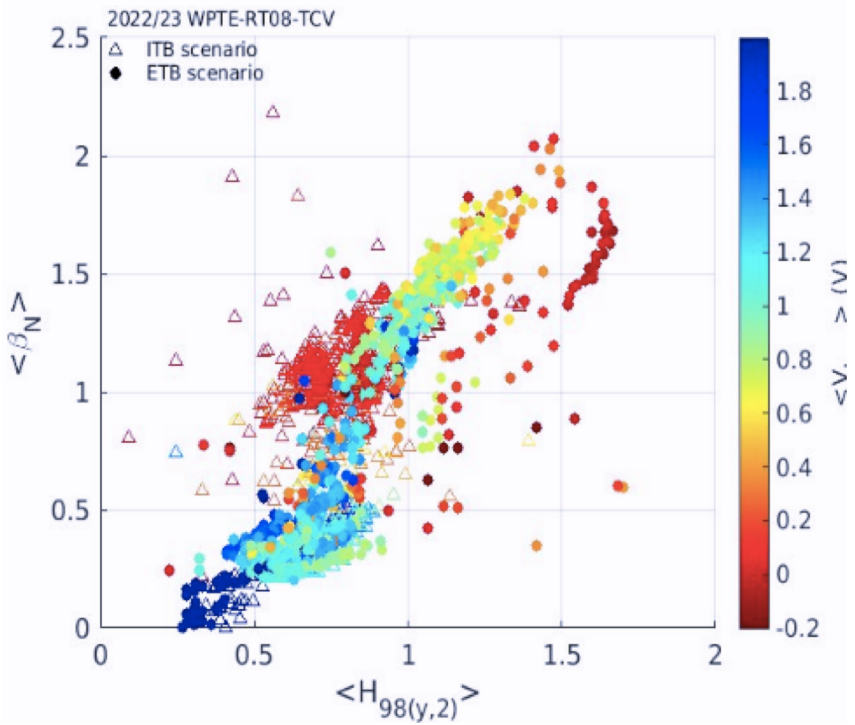


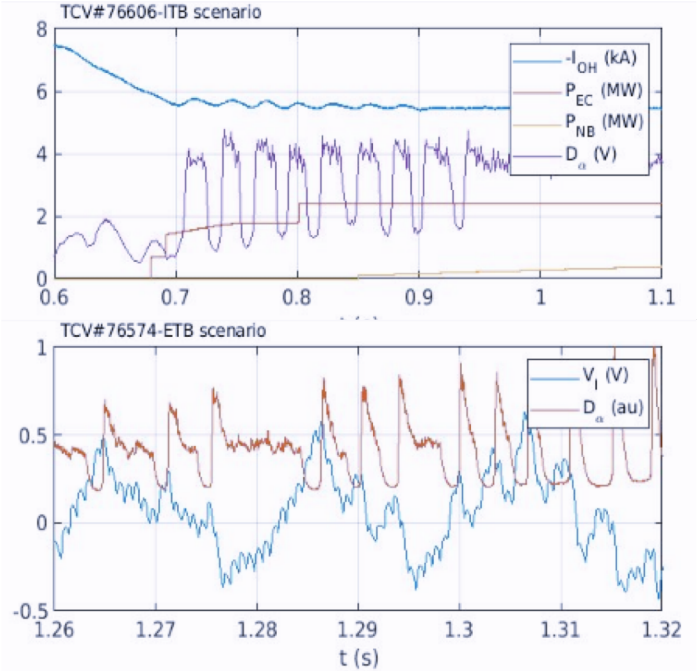


RT22-08: Physics and operational basis for high beta long pulse scenarios

Device: TCV

SCs: A. Burckhart, R. Dumont, C.Piron **TFLs:** M. Baruzzo, E. Joffrin, D. Keeling

Objective	Pulses/Sessions goals	Status	Pulse #
D5	reprise of reference E/ITB scenarios	😐 ☹	76569 (I) 76610 (E)
D5	ITB scen. @ Ip<150kA	☹	76575,7, 602,6,8,9
D3,5	$P_{NB/EC}$ scan ITB scenario	😐	76571,8,602,6, 8,9



Main technical / scientific deficiencies:

- ❑ Density control: completely determined by wall recycling and NBI fuelling
- ❑ Protection window alarms frequently triggered: ECRH power refraction due to high density operation

Main scientific results achieved:

- ❑ Dithering L/H-mode with ECRH only in the ITB scenario
- ❑ Transient H-mode at low V_{loop} in the ETB scenario
- ❑ Good diagnostic coverage (THB in both L and H-mode)

Objectives for the next planed pulses / sessions on this device:

- ❑ Boronization before next session (W47) highly desirable
- ❑ Continue scenario development with a wider density control margin

RT22-08 pulses/sessions executed so far	**20**
Total allocation of the RT22-08	**100**
Contingency request?	**NO**