Le programme du Work Package Tokamak Exploitation (WP TE) dans EUROfusion

Colloque FR FCM | May 19, 2022

E. Tsitrone for WP TE TFL

E. Joffrin, M. Baruzzo, A. Kappatou, D. Keeling, A. Hakola, B. Labit, E. Tsitrone, N. Vianello, M. Wischmeier

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Outline

- The Work Package Tokamak Exploitation (WP TE) : how does it work ?
- Recent (selected) scientific highlights
- What’s next : building the 2022-2023 programme of WP TE

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WP Tokamak Exploitation : coordinating the programme of EU tokamaks

❑ Key objectives

- Prepare ITER exploitation
- Provide physics basis for guiding DEMO design

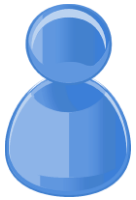
❑ WP TE addresses the missions of the EUROfusion roadmap :

- Mission 1 (Plasma Regimes of Operation)
- Mission 2 (Heat exhaust System)

❑ WP TE lead by a collegium of Task Force Leaders


E. Joffrin / CEA
TFL


M. Wischmeier / IPP
TFL


M. Baruzzo/ ENEA
DTFL


A. Hakola / VTT
DTFL


A. Kappatou / IPP
DTFL


D. Keeling / CCFE
DTFL


B. Labit / EPFL
DTFL


E. Tsitrone / CEA
DTFL

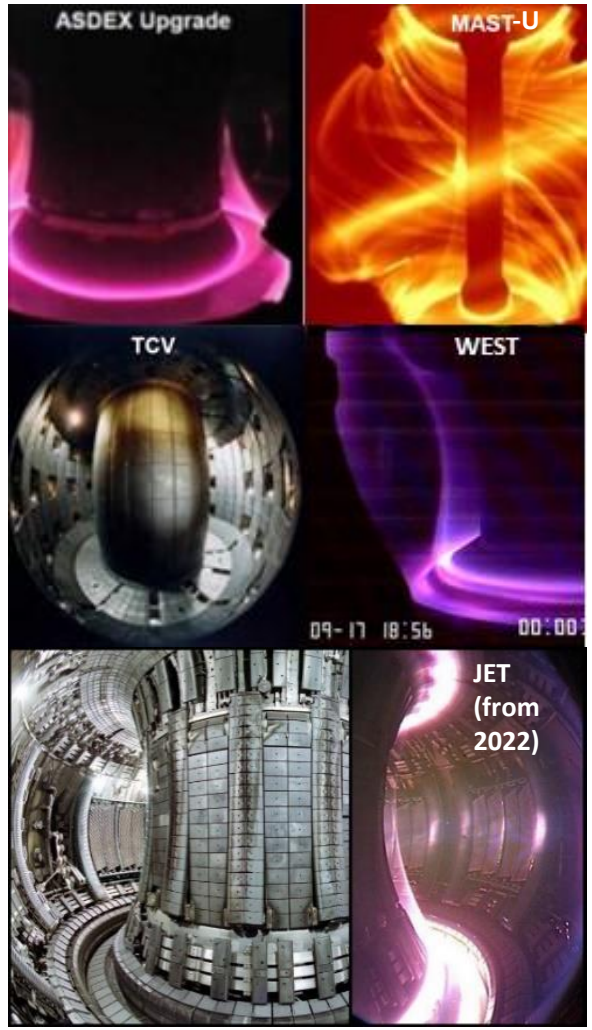

N. Vianello / ENEA
DTFL

❑ More info ?

- WP TE TF meetings : Mondays and Thursdays @ 2 pm CET
- Weekly device meetings broadcasted (AUG, MAST-U, TCV, JET … and soon WEST)

➔ Subscribe to WP TE mailing list + https://wiki.euro-fusion.org/wiki/WPTE_wikipages:_Tokamak_Exploitation_Work_Package

Making best use of synergies between EU devices



WP TE structured into Research Topics (RT)

	Research Topics (2021-2022)	
RT1	ITER Baseline scenarios towards low collisinality and detachment	Mission 1 – ITER Scenario
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	
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RT12	Development of the steady state scenario	
RT10	Fast-ion physics with dominant ICRF heating	Mission 1 – Burning plasma
RT11	Impact of MHD activity on fast ion losses and transport	
RT13	X-point radiation and control	Mission 2 – Exhaust
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	Mission 2 – PWI
RT17	Material migration and fuel retention mechanisms in tokamaks	

❑ Research Topics coordinated by Scientific Coordinators :

- Multi experiments / multi devices ➔ scientific objectives of RT
- Prepare, run, coordinate experiments and subsequent analysis/modelling/publication plan within their international team

How is the WP TE programme build ?

❑ A multi step process

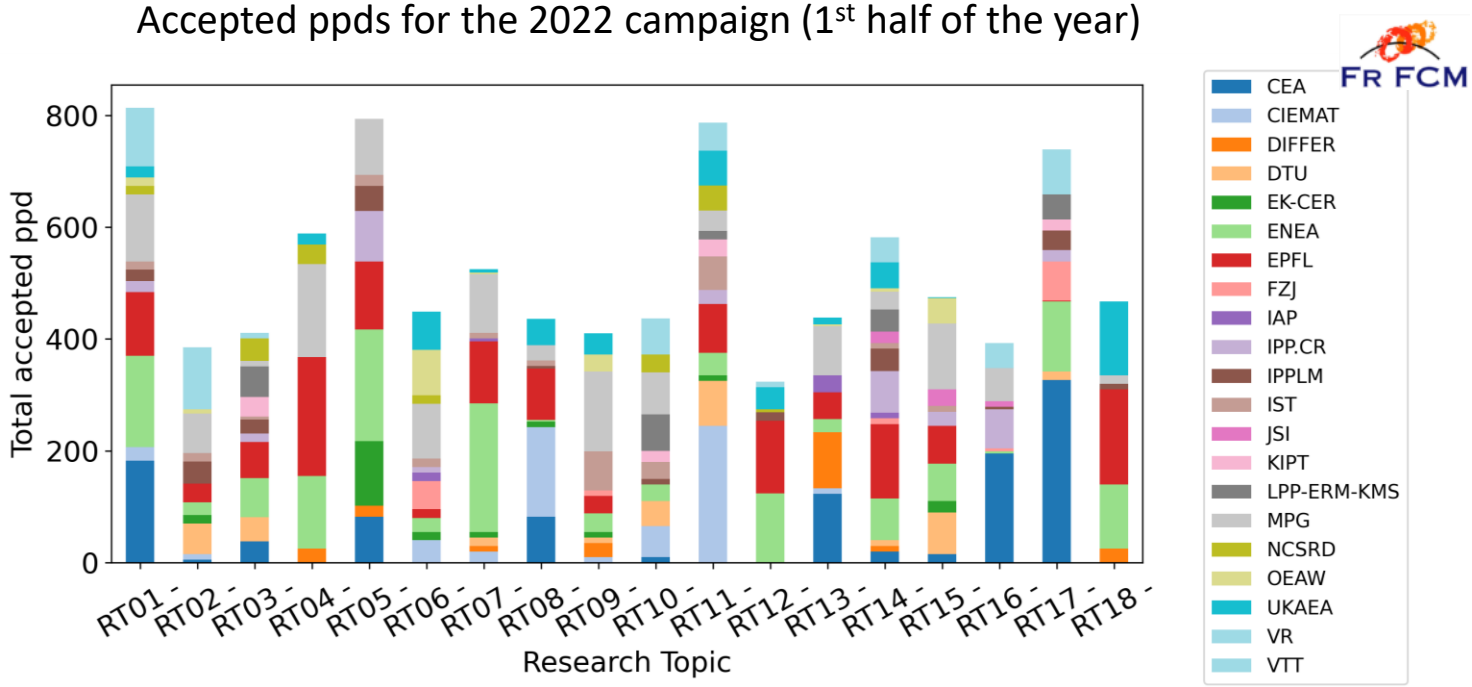
1. Call for experimental and modelling proposals + scientific coordinators
   - with scientific priorities defined by WP TE, multi devices (proposal on WP TE wiki pages)
2. Programme meeting
   - Prioritize / merge / give up proposals
   - Research Topics structure / associated scientific objectives and selection of SC
   - Shot allocation per Research Topic / device, within % of experimental time allocated to WP TE on each device as defined by EUROfusion GA
3. Call for participation
   - Staffing selection, within manpower / mission budget (workplan under IMS)
4. Campaign execution
   - TFL : timeline, contingency requests
5. Campaign analysis and modelling
   - TFL : conference rehearsals, paper clearance on EUROFusion pinboard

❑ The scientific programme of 2022-2023 now under construction

WP TE in numbers …

- **The largest budget within the Fusion Science Department (tokamak operation costs, enhancements, scientific exploitation, missions)**
- **> 100 ppy for scientific exploitation of TE devices in 2022**
- **Involves > 20 Research Units**

Accepted ppds for the 2022 campaign (1st half of the year)



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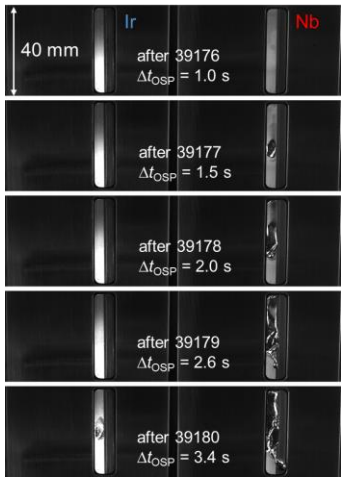
- Recent (selected) scientific highlights
- What's next : building the 2022-2023 programme of WP TE

WP TE devices in 2021-2022

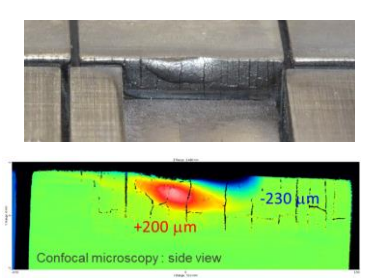
- **A very fruitful campaign in AUG and TCV**
- **First campaign successfully completed in MAST-U**
- **WEST campaign shifted to spring 2022 due to technical issues**

(but full ITER like divertor successfully installed)

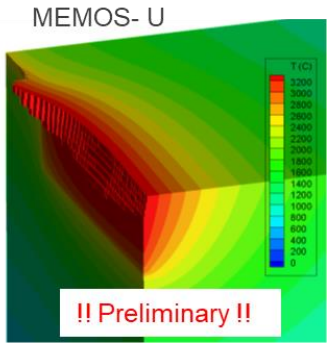


AUG

Melting experiments performed in AUG / WEST
used to benchmark the MEMOS-U code (RT16)



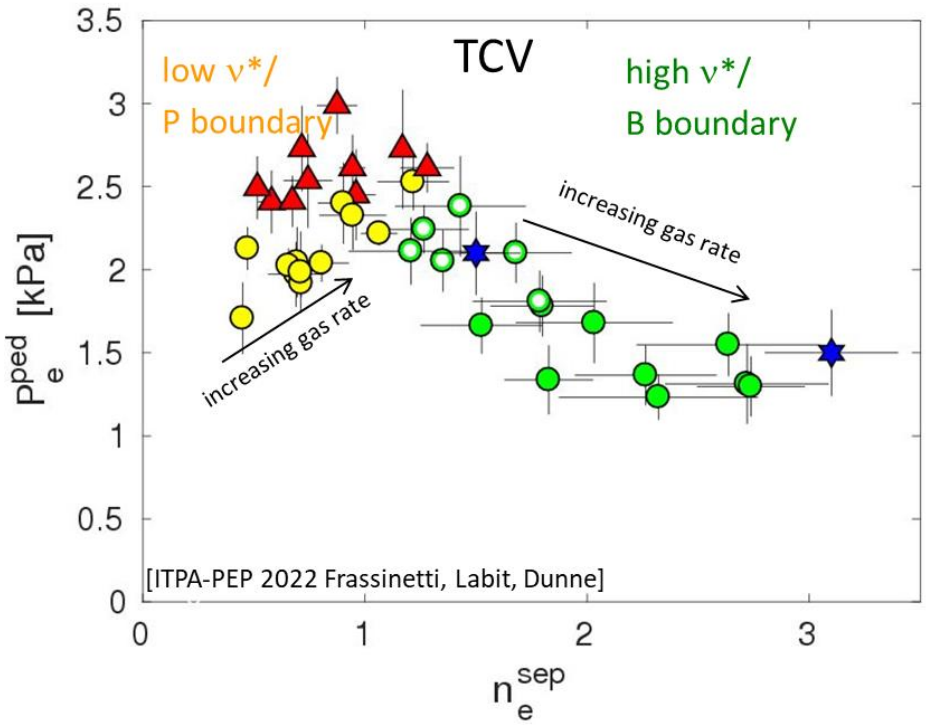
WEST



+ JET DTE2 campaign completed (new record in fusion energy)

Scenario development for ITER and DEMO ongoing

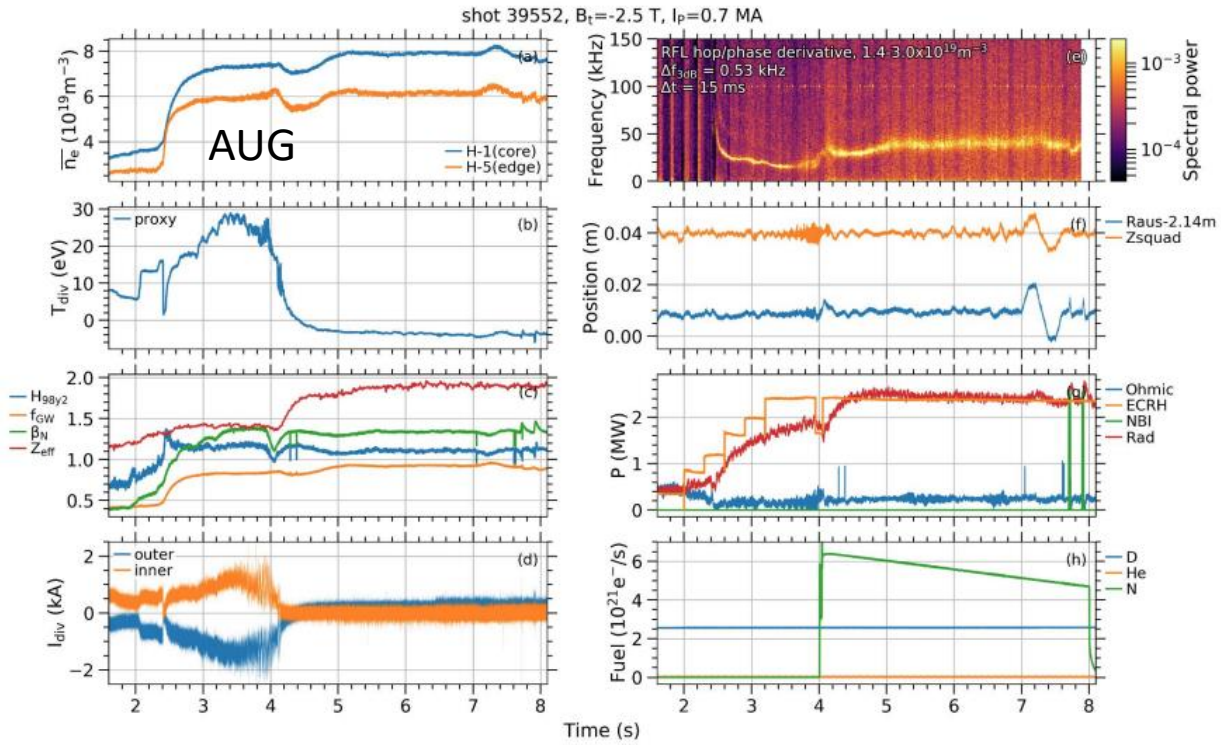
ITER baseline scenario



- low ν* / high-δ / 150kA / NBI+ECRH / gas scan
- low ν* / low-δ / 150kA / NBI+ECRH / gas scan
- high ν* / low-δ / 170kA / NBI / gas scan (with different types of baffles)
- high ν* / low-δ / 170kA / NBI / gas scan (no baffles)

Different behavior evidenced at the peeling / ballooning boundary

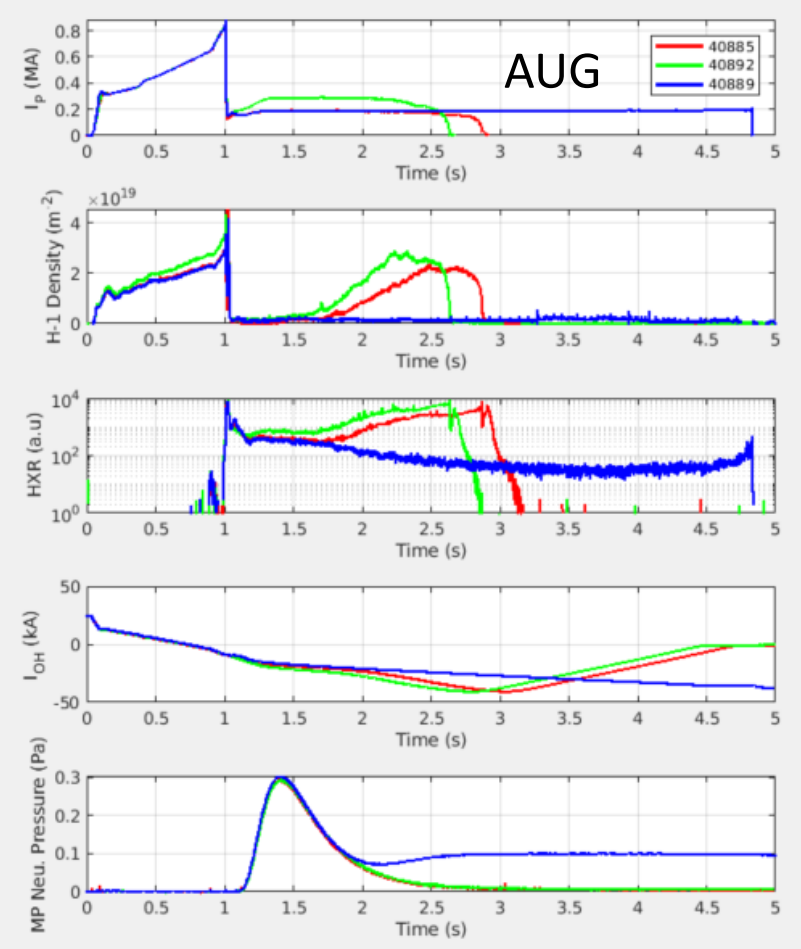
Alternative no ELMs scenario (DEMO)



EDA H-mode compatible with radiative scenario for detachment maintaining confinement ➔ identified as proposed candidate of no ELM regimes to be tested on JET for 22/23

Disruption and runaways mitigation

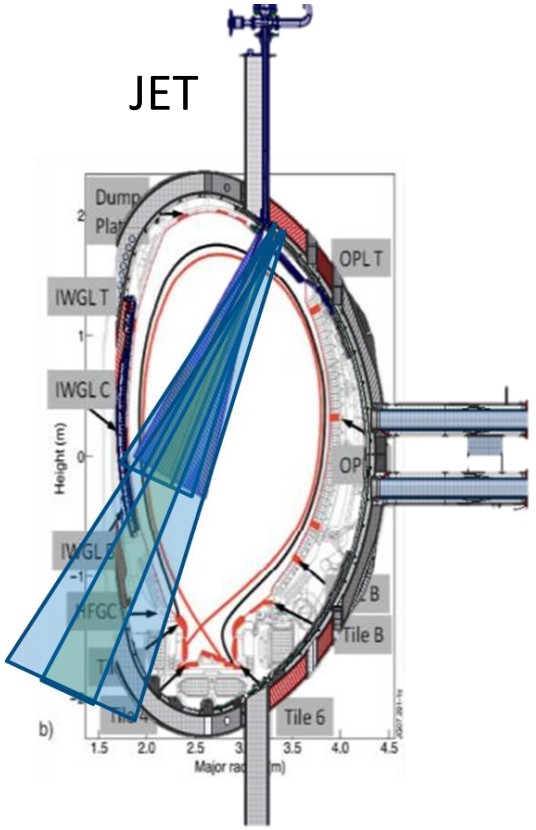
Real time control of runaway beams

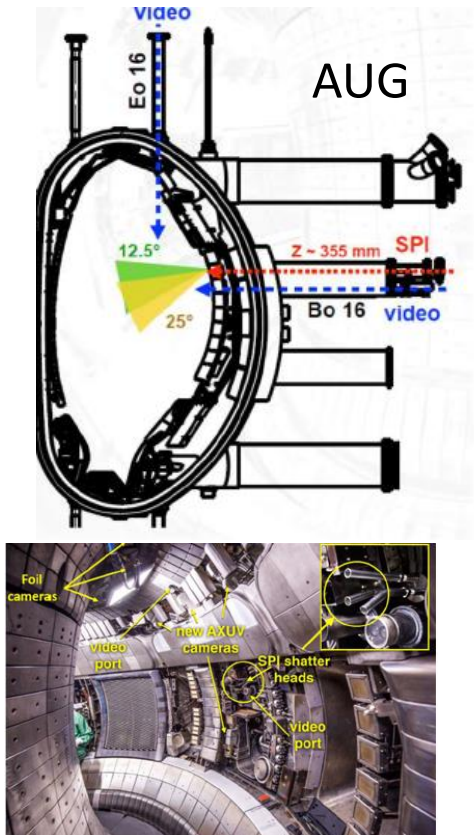


- Runaways controlled over ~4 s (record)
- Benign termination achieved

Shattered pellets injection being tested on AUG and JET

EUROfusion iter CCFE Culham Centre for Fusion Energy Oak Ridge National Laboratory

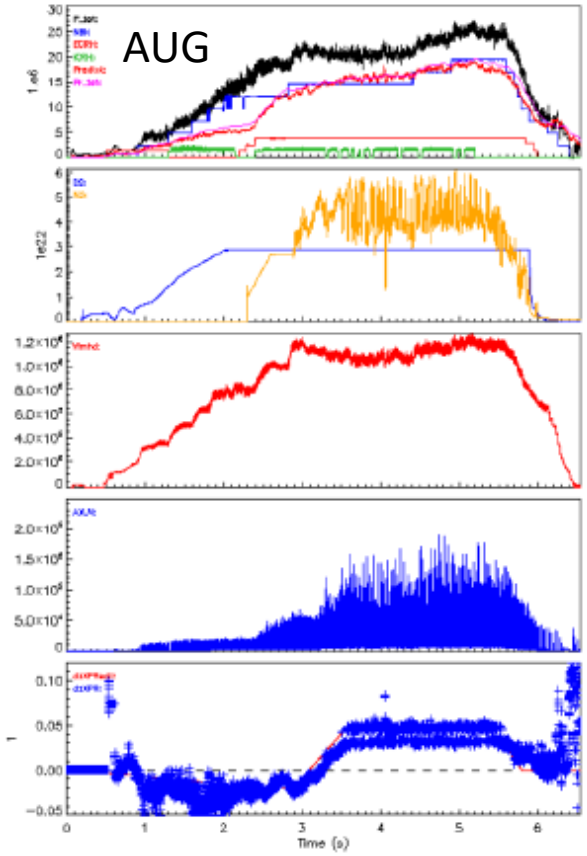




- First SPI experiments performed at AUG
- SPI commissioning planned in JET this summer

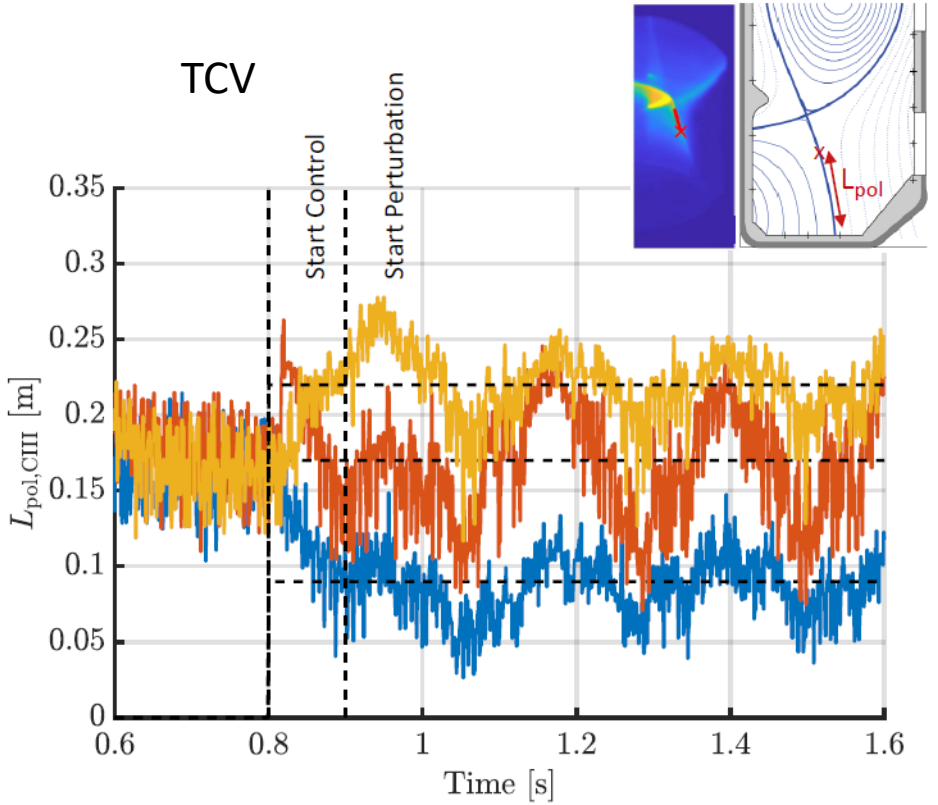
High X point radiation (XPR) confirmed on various devices

Sustained detachment over a full discharge



- Sustained detachment from diverted phase up to ramp down (L-H transition, H mode flat top, heating ramp down)
- Directly going into the XPR ELM-suppression phase
- High power record discharge achieved (sustained XPR, 26 MW of additional power)

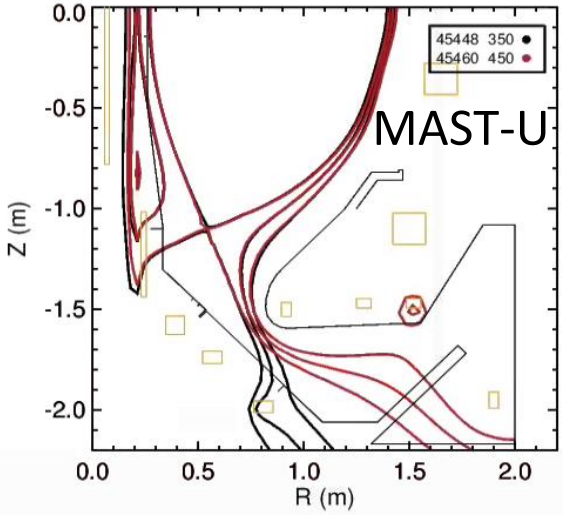
Detachment control of the radiation front

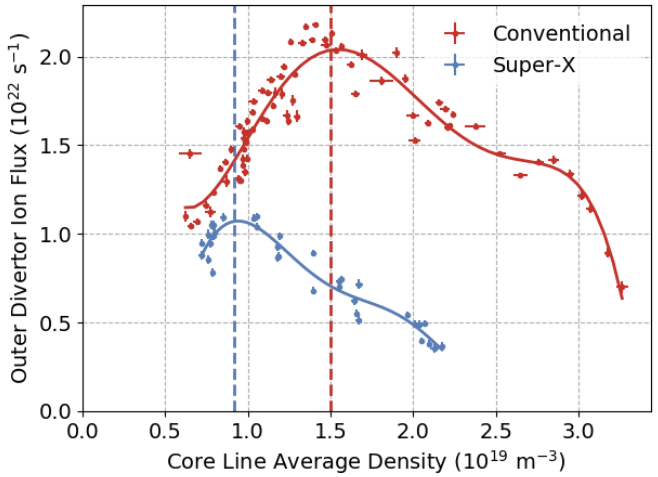


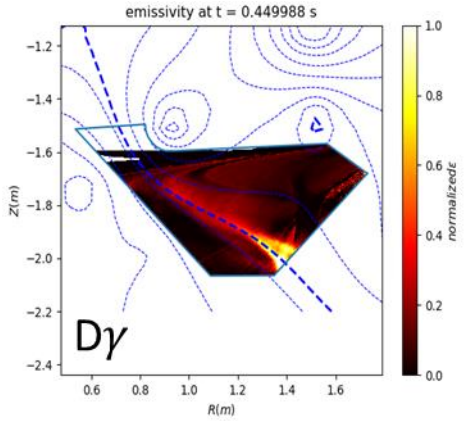
- XPR regime achieved (L mode, H mode)
- XPR tracking using the MANTIS system : control perturbed by ELMs

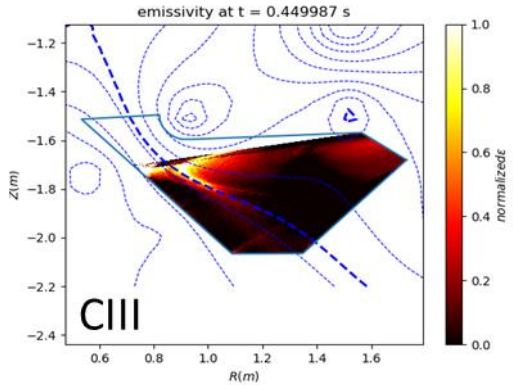
Alternative divertor configuration explored

First results in super X configuration obtained in MAST-U



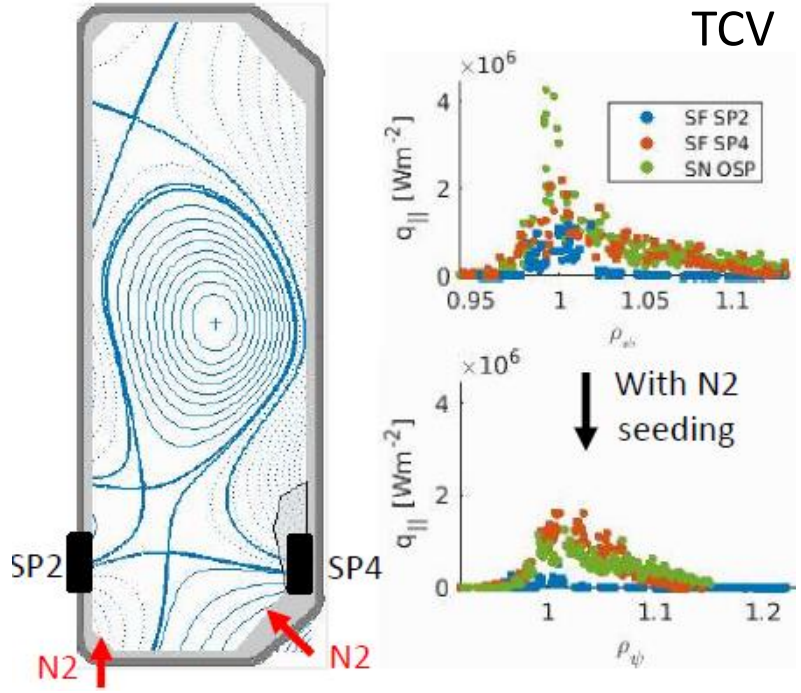






- Detachment as a function of flux expansion (conventional vs super X)
- Detailed spectroscopy analysis ongoing

Snow flake configuration characterized in TCV



- With X point separation for optimal strike point splitting : peak heat flux reduced by ~50%
- First experiments performed with impurity seeding : difficult to reduce further peak heat flux in SF

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The campaigns for the 1st half of 2022 are ongoing

1. • Call for experimental and modelling proposals
2. • Programme meeting
3. • Call for participation
4. • Campaign execution
5. • Campaign analysis and modelling

	Research Topics
RT1	ITER Baseline scenarios towards low collisinality and detachment
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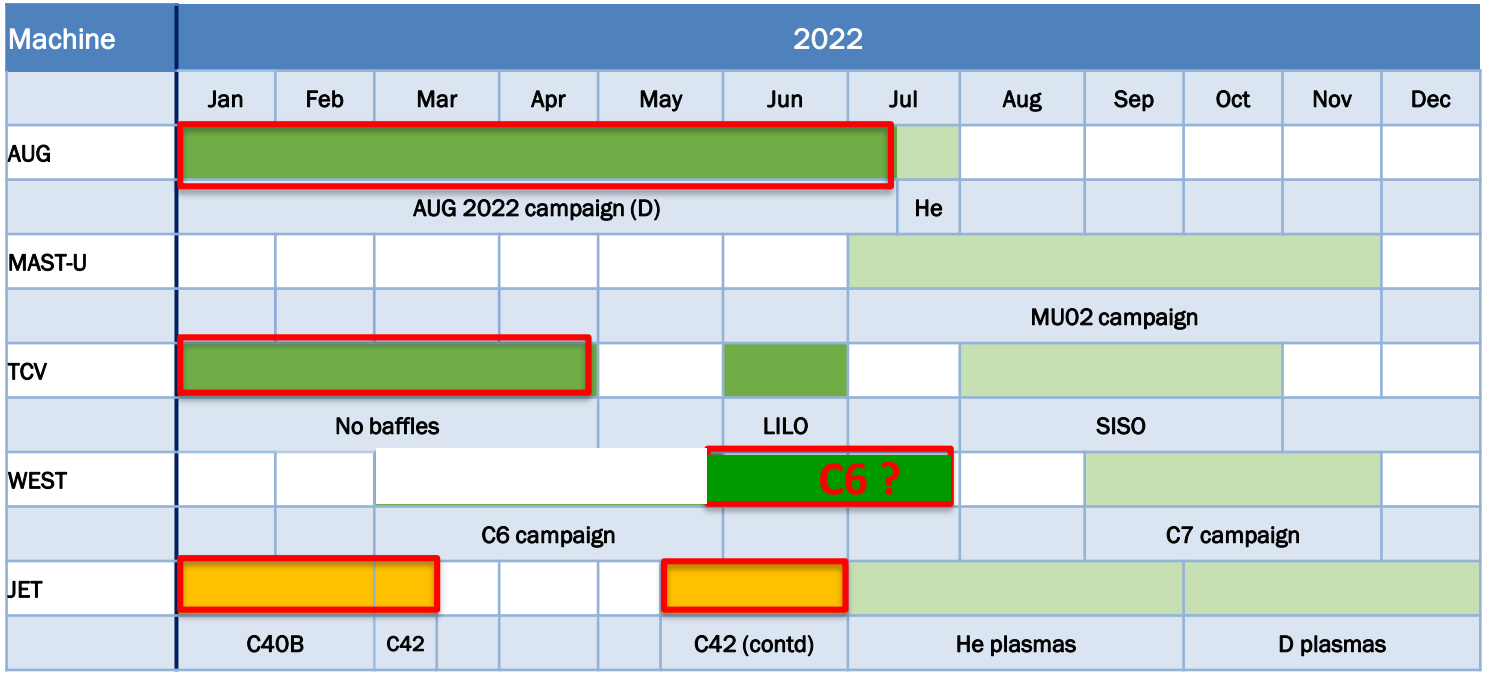

❑ For WEST : shift of the 2021 WP TE programme

- WP TE RT involved in C6 campaign : RT01 (Er field), RT03 (ICRH assisted breakdown) , RT05 (runaways), RT08 (I mode), RT13 (XPR), RT16 (high fluence, pre-damaged PFU, toroidal gaps loads), RT17 (H/D changeover, ammonia formation, W sources)
- Possible to request time for data analysis and modelling to meet the scientific objectives of the WPTE 2021-mid 2022 Campaign until end of 2022

Dedicated helium campaigns to be run on AUG and JET

1. • Call for experimental and modelling proposals
2. • Programme meeting
3. • Call for participation
4. • Campaign execution
5. • Campaign analysis and modelling

Machine	2022											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AUG												
	AUG 2022 campaign (D)						He					
MAST-U												
	MU02 campaign											
TCV												
	No baffles					LILO		SISO				
WEST												
	C6 campaign								C7 campaign			
JET												
	C40B		C42			C42 (contd)		He plasmas		D plasmas		

❑ Opportunity to gain experience for future WEST He campaigns

- Priority : develop robust ELMy H mode in He / PWI in He plasmas with metallic walls in support of ITER non nuclear phase
- ~2 weeks in AUG / ~2 months in JET
- Experimental teams to be announced soon but experiments preparation already starting with SC

RT	Name	AUG - pulses	JET - sessions
RT-He-01	ELMy H-mode operation in He in view of the non-active phase of ITER	15	22
RT-He-02	Qualifying transport in the core and edge of helium plasmas, in preparation of the non-active phase of ITER	12	10
RT-He-03	ELM control in helium H-modes for the non-active phase of ITER	0	6
RT-He-04	Helium plasmas for undestanding detachement physics	2	2
RT-He-05	Assessing plasma wall interactions in He plasmas in view of the non-active phase of ITER	14	18
RT05	Runaway electron generation and mitigation, *including disruption mitigation in He plasmas*	0	2
RT06	ELM mitigation and suppression in ITER/DEMO relevant conditions, *including RMP in He plasmas*	12	0
RT17	Material migration and fuel retention mechanisms in tokamaks, *including fuel retention mechanisms in He plasmas*	0	4
Contingency		0	16
TOTAL		55	80

Programme for 2022-2023 under construction

2021 → 1st half 2022 (18 RT)

	Research Topics 2021-2022 (18 RT)	
RT1	ITER Baseline scenarios towards low collisinality and detachment	ITER Scenario
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RT15	Extrapolation of SOL transport to ITER and DEMO	
RT18	Alternative divertor configurations	
RT16	PFC damage evolution under tokamak conditions	PWI
RT17	Material migration and fuel retention mechanisms in tokamaks	

PEX

2nd half 2022 → 2023 (9 RT)

	Research Topics 2022-2023 (9 RT)
RT22-01	Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER
RT22-03	Strategies for disruption and run-away mitigation in support of the ITER DMS
RT22-04	Physics-based machine generic systems for an integrated control of plasma discharge
RT22-08	Physics and operational basis for high beta long pulse scenarios
RT22-02	Physics understanding of alternatives to Type-I ELM regime
RT22-09	Physics understanding of energetics particles confinement and their interplay with thermal plasma
RT22-05	Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation
RT22-07	Physics understanding of alternative divertor configurations as risk mitigation for DEMO
RT22-06	Preparation of efficient Plasma Facing Components (PFC) operation for ITER, DEMO and HELIAS

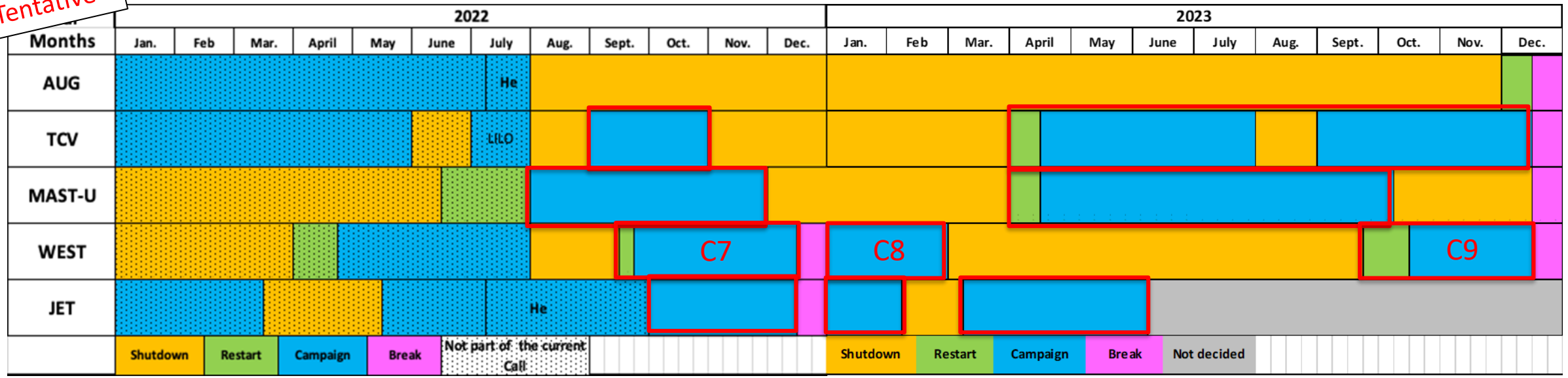
A more integrated approach proposed for 2022-2023

Programme meeting and call for participation coming soon

1. • Call for experimental and modelling proposals
2. • Programme meeting
3. • Call for participation
4. • Campaign execution
5. • Campaign analysis and modelling

- Covers 2nd half 2022+2023 for JET, MAST-U, TCV and WEST (NB : AUG in shutdown for PEX upgrade)
- Call for experimental / modelling proposals + SC for 2022-2023 ➔ now under assessment
- Programme meeting : May 30 and 31
- Call for participation to be launched early June, team selection early july ➔ experiment preparation to start asap

Tentative



A large number of proposals submitted for WEST

More than 1000 discharges proposed for WEST (oversubscribed), embeded in a number of multi-machine proposals, participation from IPP.CR, IPP, CCFE, EPFL, ENEA

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Ti/Te, RF heated H mode in full W, flows and turbulence in favourable vs unfavourable configs

Runaway mitigation

Ramp up in W, heat flux real time control (RTC), ICRH coupling resistance RTC

Fully non inductive operation in full W

RI mode, I mode, QCE

Modelling with ETS

W sources in detached plasmas, real time control of XPR, detachment access, plasma molecular interactions, investigation of DN

High fluence campaign, fuel retention, long term material migration, pre damaged PFU exposure, melting experiment, heat loads in gaps, fuel removal and conditioning, ICRH impact on impurity production, dielectric coatings to reduce high Z impurity contamination, digital twin for machine protection, W emissivity

Stay tuned for the coming call for participation to the 2022-2023 WP TE programme !

Thank you for your attention

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