PSD Project Board # 06

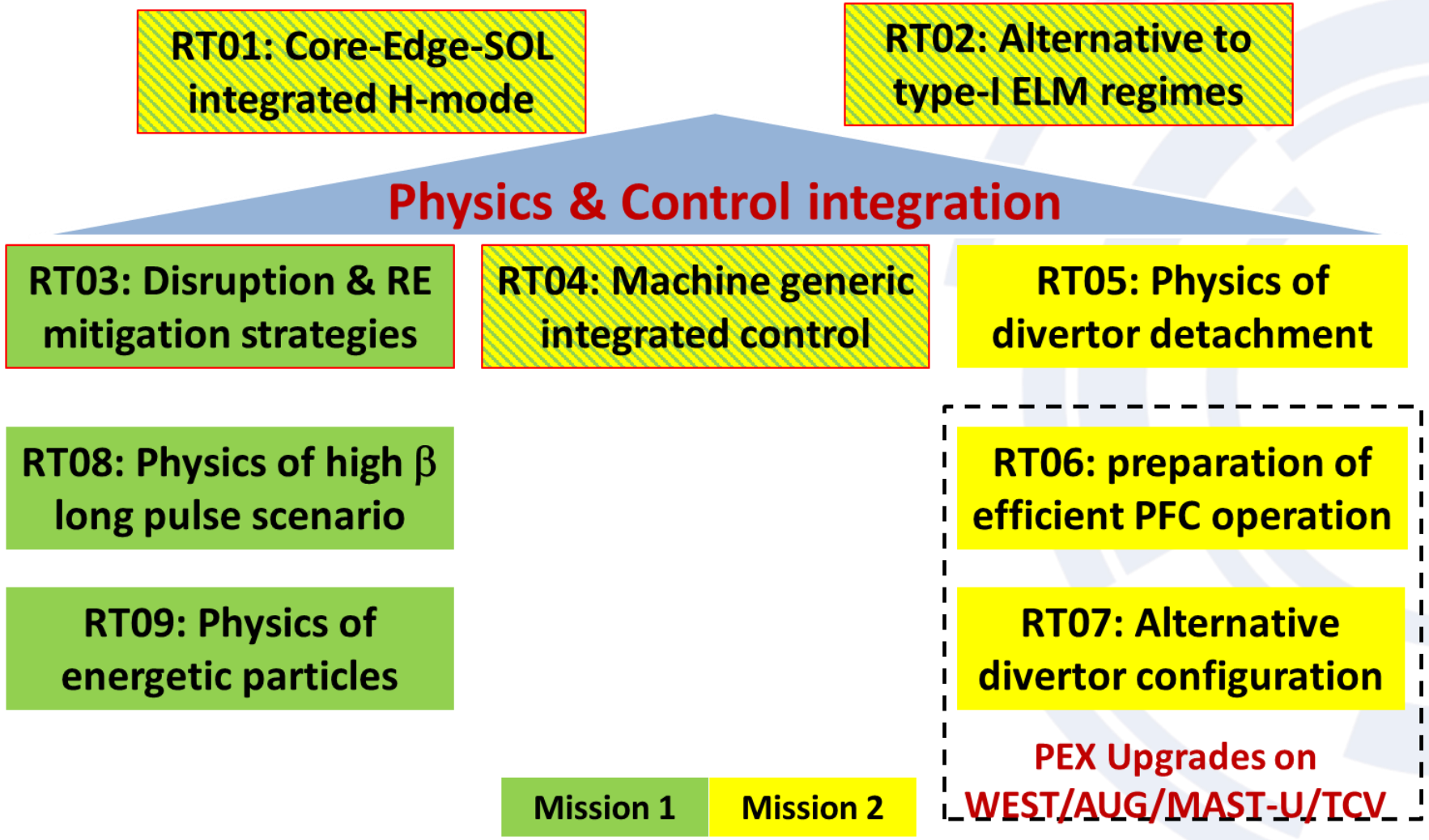
WPTE: Status summary of 2024 and changes/status for 2025 compared to AWP

N. Vianello and E. Tsitrone for TE TFL

E. Tsitrone, N. Vianello, M. Baruzzo, A. Hakola, V. Igochine, D. Keeling, B. Labit

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Research Structure kept in continuity during 2024-2025

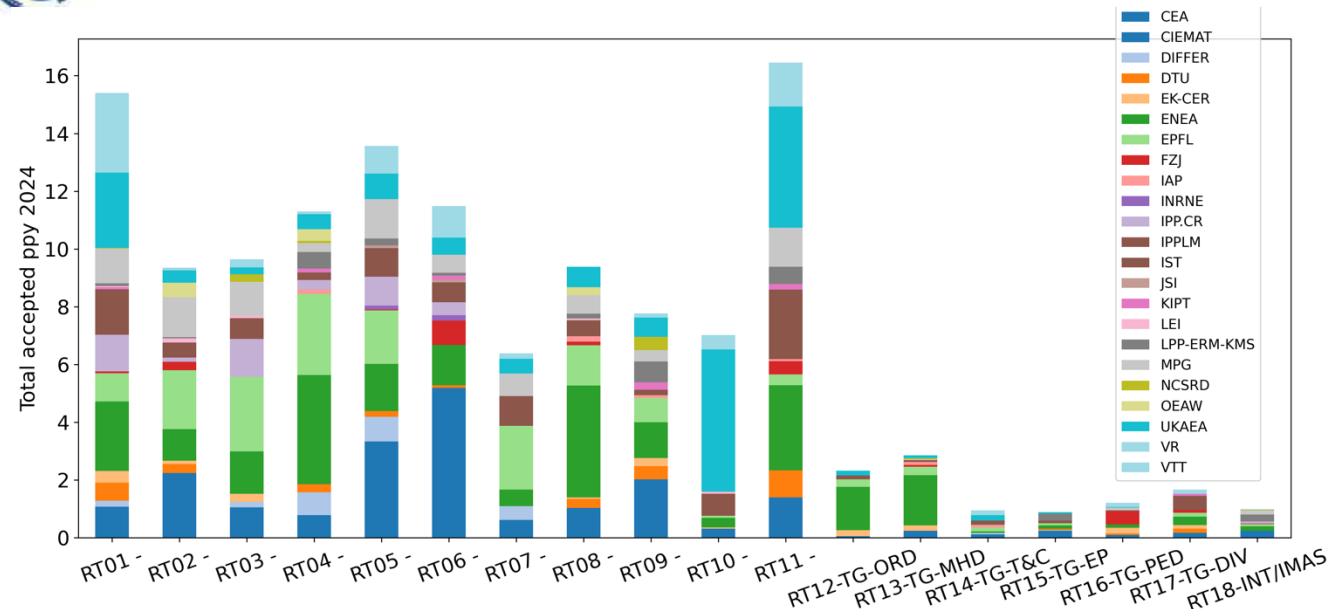


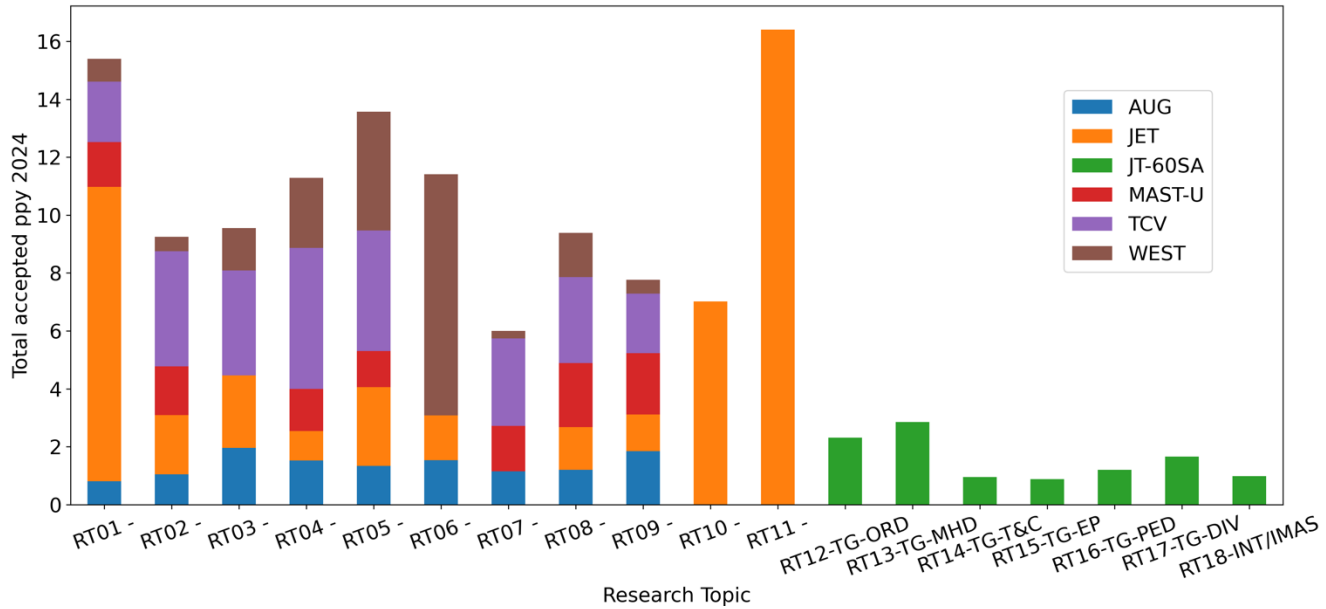
2024 WPTE programme at a glance

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
AUG												
TCV		NINO							SILO		LILO	
MAST-U										MU04		
WEST		C9								C10		

- In 2024 operation mainly on TCV and WEST: MAST-U and AUG resume experiments from late Oct till end of the year
- **ITER new baseline R&D requests** incorporated into the programme in 2024 (boronisation, plasma start up on full W …)
- **On site meetings** re-initiated (JET analysis weeks, Tervaniemi, TE+PWIE, GPM …) : mission budget fully used (as planned)

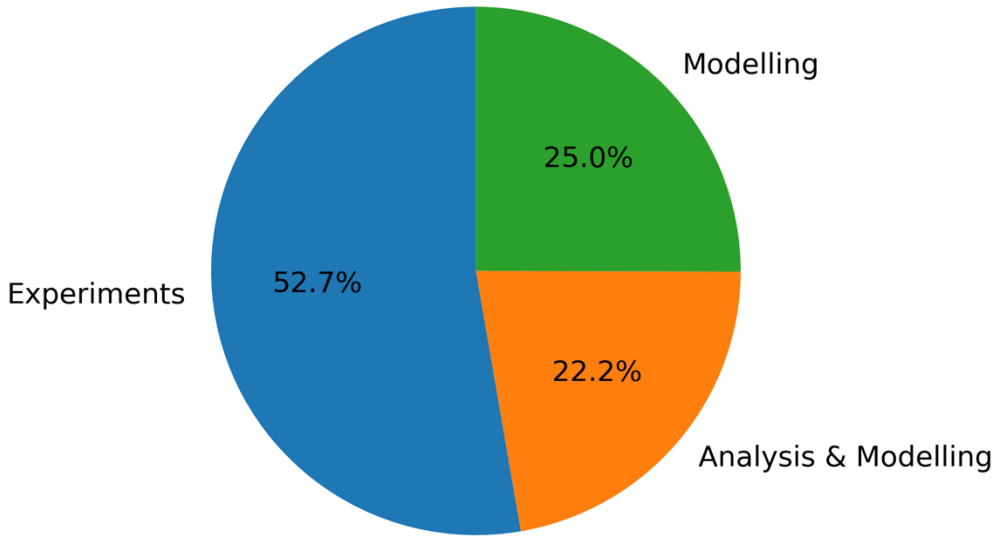
WPTE resource distribution in 2024





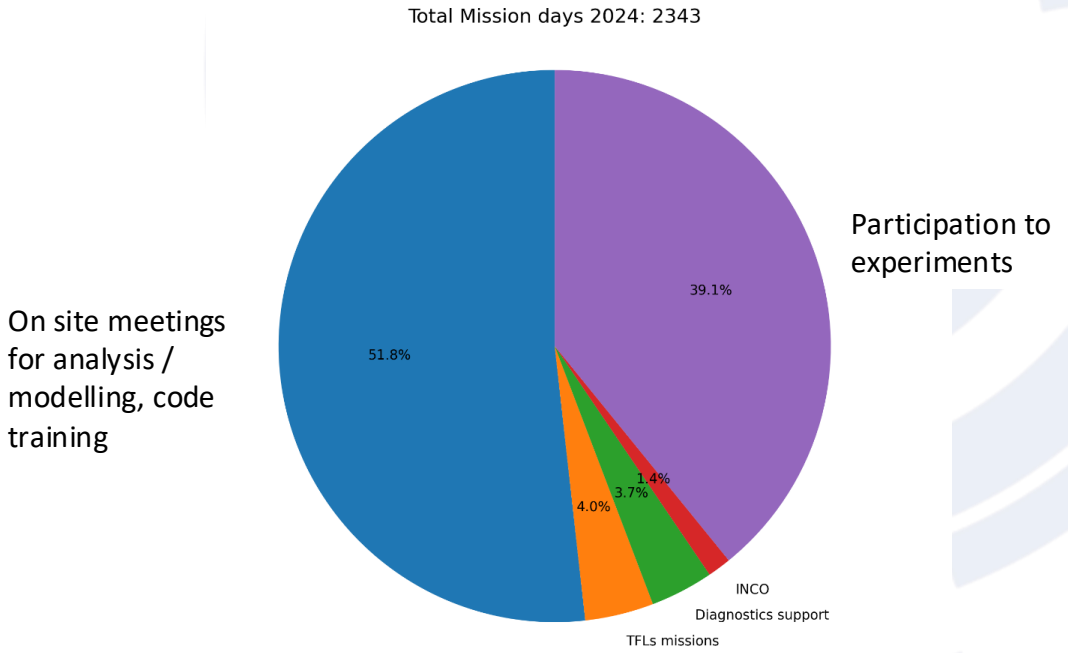
- WPTE : cross-device program with strong contribution by all the EUROfusion beneficiaries (> 600 participants from > 20 labs)
- JET data validation/modelling/scientific exploitation essential in WPTE strategy (significant backlog for data validation)

Increased effort on modelling and mission budget



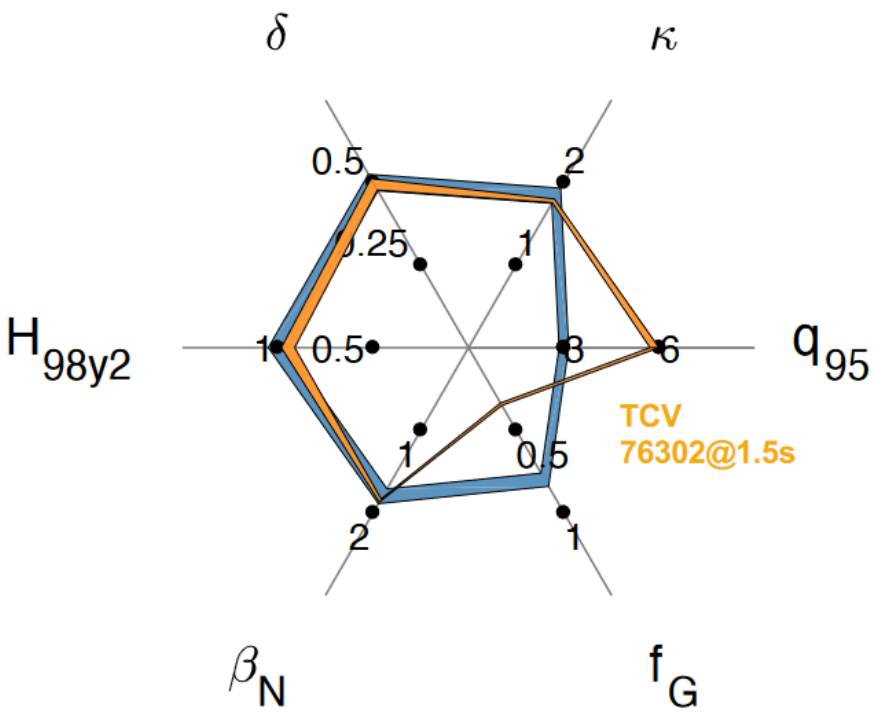
- From 2024 strong increase of effort on modelling (interpretative + extrapolation to ITER/DEMO) started (PCR : additional > 15 ppy granted)

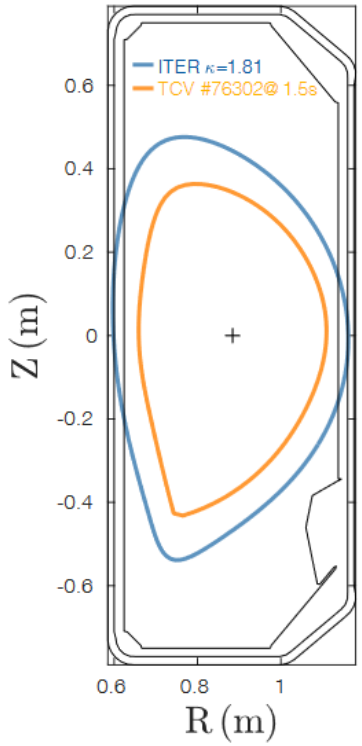
- Significant support to on site participation to TE experiments
- On site meetings for analysis and modelling, code training ➔ team building
- Mission support ➔ key to build a pan-European Scientific team fostering collaboration among European beneficiaries



Physics highlight from 2024 Campaigns

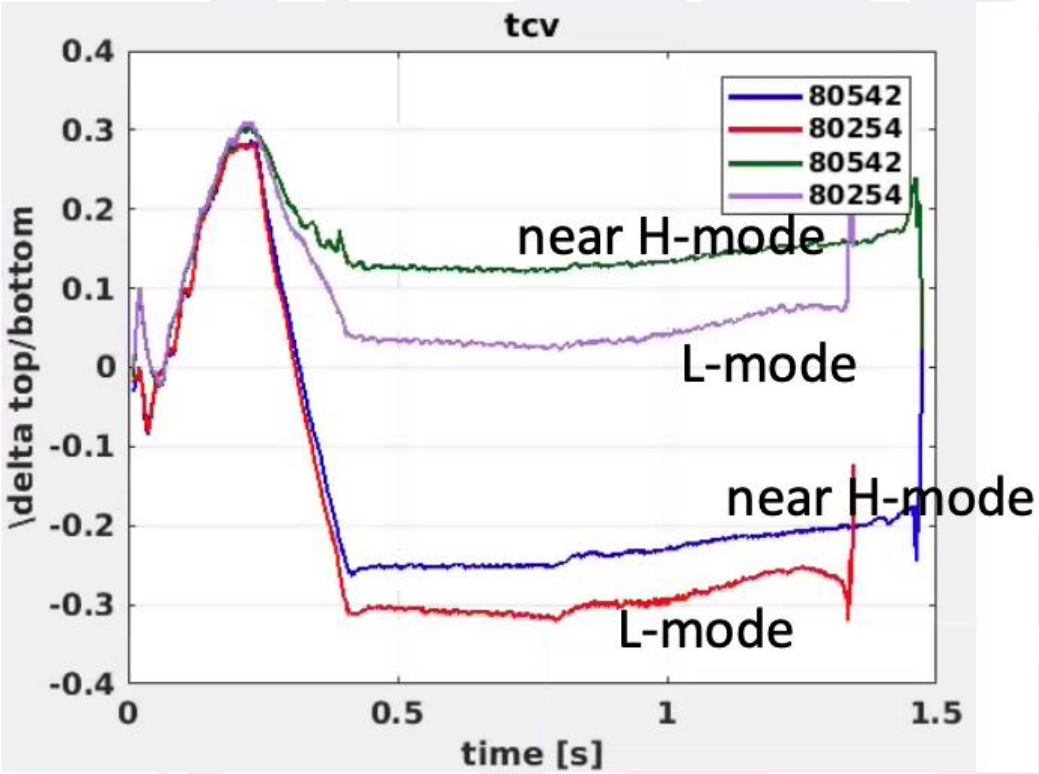
RT01-TCV





- Shaping capabilities of TCV used to reproduce ITER shape: matched at larger q_{95}
- Achieved slighly better confinement than the required ITER target
  - Performance limited by NTM (triggered by an ELM)
- Ramp-down optimization with RAPTOR implemented and optimization ongoing

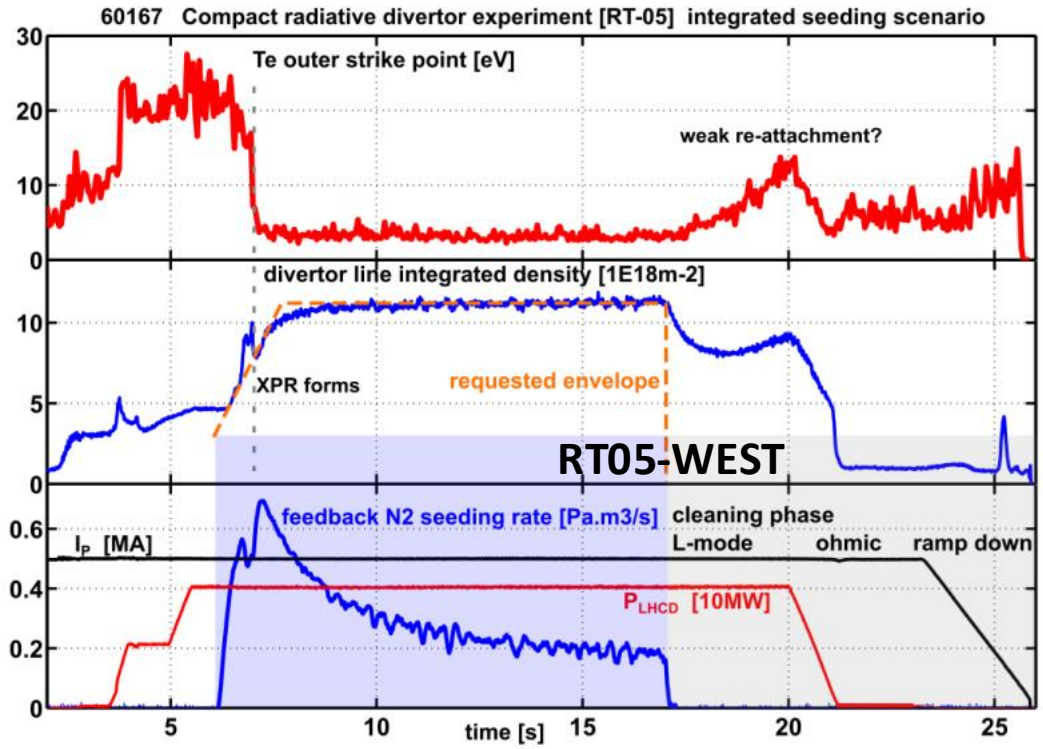
RT02-TCV



- H-mode access at different values of upper **δ** established in TCV for AUG new shape development for 2025

Physics highlight from 2024 campaigns

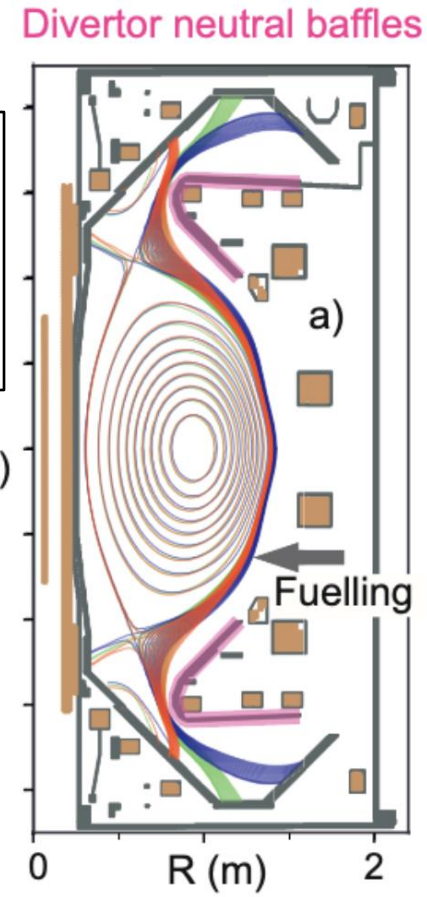
RT05-WEST



Robust strategy
- Stable XPR for 10-15s
- Soft landing for impurity legacy (slow time scale ~5s)
- Transferred to RT-06 in 2024 for high-fluence campaign with seeding

RT05-MAST-U

MAST-U - 3 divertor configurations
- **Conventional Divertor (CD)**
- **Elongated Divertor (ED)**
- **Super-X Divertor (SXD)**



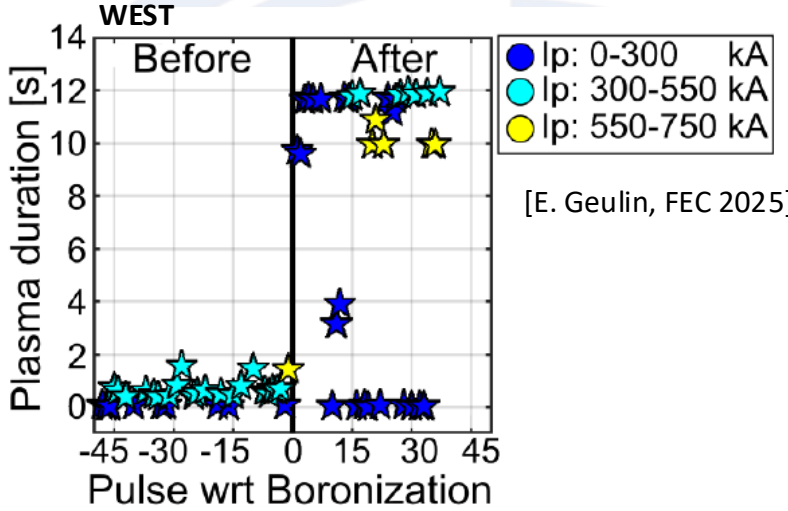
- ADCs are investigated as potential risk mitigation strategy for power exhaust
- Strong improvements combining baffling, poloidal leg length and total flux expansion
- ADCs can provide various benefits: Easier access to detachment (37% (measured)), Lower target heat fluxes (up to x20)
- Maximum power dissipation in divertor can increase with ADCs
- Wider detachment window (up to x3.5) and more stable detachment front (up to x5 less sensitive), thus easier to control and more resilient against reattachment
- Better divertor-core decoupling

Boronisation and W limiter start up studies initiated in 2024 : a multi machine approach to ITER urgent R&D issues (RT06/RT04)

Similar restart plan for both AUG/WEST in late 2024

- **Test (briefly) start up without boronisation**
  - WEST : new bulk W inner bumper tiles / AUG : new upper divertor, first restart after long shutdown and B cleaning
  - ➔ In both machines, start up w/o boronisation very slow and challenging (RE generation in AUG)

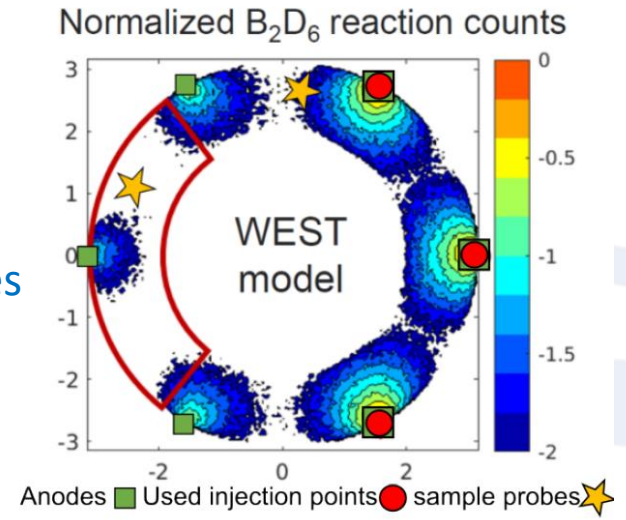
[J. Hobirk, FEC 2025]



[E. Geulin, FEC 2025]

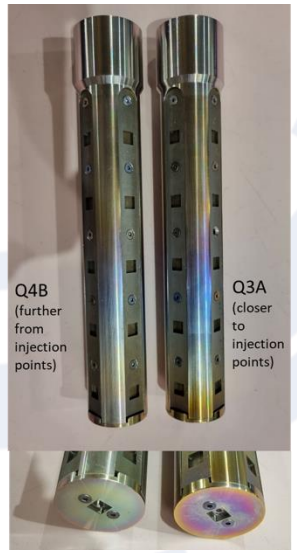
- **Perform non toroidally uniform boronisation**
  - ITER likely to have non uniform set up for boronisation in SRO : need to assess impact
  - Most non uniform configuration selected for both machines based on modelling performed by IO (WEST : 3 of 6 diborane injection points / AUG : 2 of 4 GDB anodes)
  - ➔After non uniform boronisation : start up much easier in both machines (WEST operated for ~1 month w/o issue)

[J. Hobirk, FEC 2025]



[Courtesy T. Wauters (IO), E. Geulin, FEC 2025]

First set of samples exposed in WEST



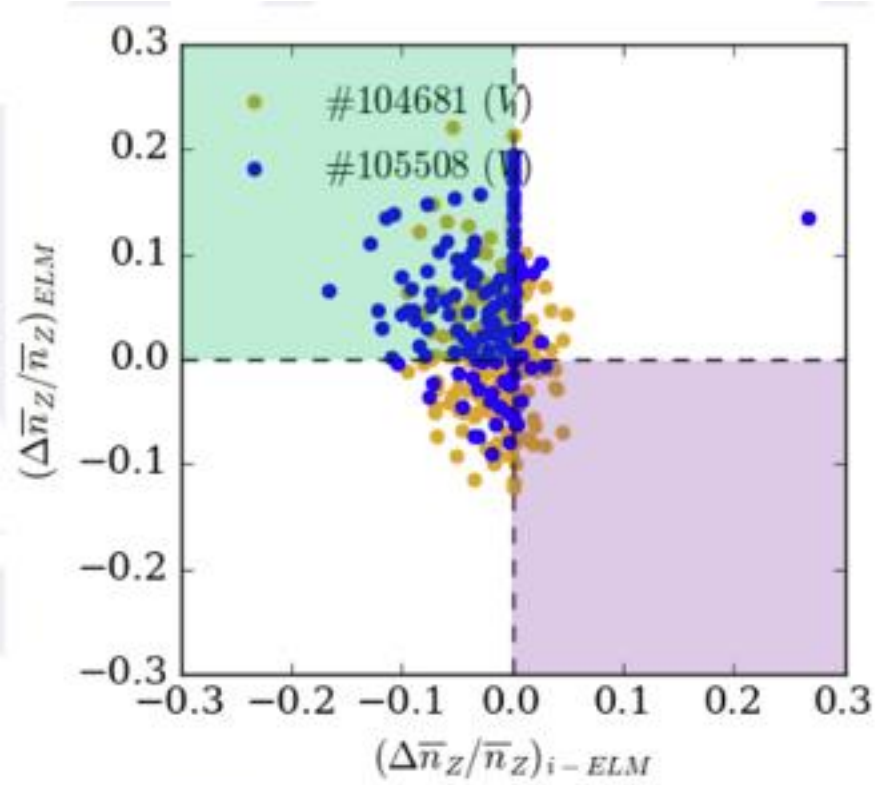
[Courtesy M. Diez]

- **Perform uniform boronisation for comparison**
  - ➔ First set of boronisation exposed samples now available from AUG and WEST (analysis starting with WP PWIE)

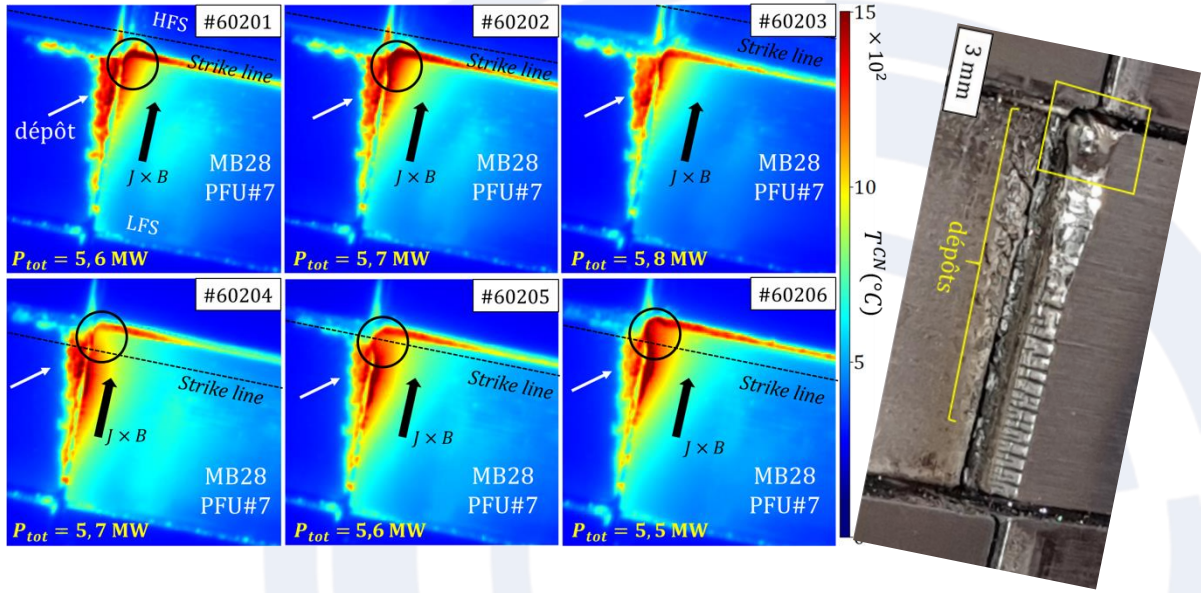
[V. Rohde, PFMC 2025
A. Gallo PFMC 2025]

Physics highlight from 2024 campaigns

RT01-JET: W screening investigation



- NC computation via FACIT Code (D. Fajardo PPCF 2023) suggesst that other mechanisms beyond NC screening might be relevant including: turbulent impurity transport, strong SOL W screening, interaction with other high-Z impurities not accounted for in FACTI



RT06-WEST

- Melt flow across toroidal gap experiment
- Complementary experiments in AUG (transient) and WEST (steady state loads) to validate melt layer motion code used for ITER (MEMENTO)
- Both AUG/WEST experiments confirms gap bridging

Evolution of SSRL according to 2024 L3 report (now updated since last PB)

Level	Emerging	Exploratory	Judgemental	Mature-needs underpinning	Mature-needs support	Established

RT	*Title*	*D1*	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*
RT01	Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER		x		x			
RT02	Physics understanding of alternatives to Type-I ELM regime			x	x		x	
RT03	Strategies for disruption and run-away mitigation						x	
RT04	Physics-based machine generic systems for an integrated control of plasma discharge	x	x		x			
RT05	Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation			x				
RT06	Preparation of efficient Plasma Facing Components (PFC) operation for ITER, DEMO and HELIAS		x					
RT07	Physics understanding of alternative divertor configurations as risk mitigation for DEMO			x				
RT08	Physics and operational basis for high beta long pulse scenarios	x		x	x	x		
RT09	Physics understanding of energetics particles confinement and their interplay with thermal plasma		x	x	x			

- “x” indicates progresses in SSRL according to 2024 L3 report

Status of grant deliverables

"Title" in Sygma	Title in CWP	Initial due Date	Expected deliverable date	Status	Comments/Reason for delay
TE.D.08	Balance between gross and net erosion of W under different operational conditions in full-metallic toroidal devices	Dec 2023	Dec 2024	Completed	Good data set in L mode and H mode. Modelling for H mode + W prompt redep still ongoing
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	Dec 2025	Deferred to 2025	Proper GK analysis concerning impurity effects on pedestal not yet available
TE.D.14	The radiation asymmetry during disruption mitigation and SPI disruption dynamics using improved power balance, radiation diagnostics capability and fast cameras characterized and documented.	Dec 2024	Dec 2024	Completed	JET and AUG data published. JOREK modelling
TE.D.12	The physics basis for the decision for an alternative divertor configuration for DEMO.	Dec. 2024	Dec 2025	Delayed	Upper divertor of ASDEX Upgrade delayed and considered important
TE.D.13	Recommendation on the seeding impurity mix in view of a future reactor.	Dec. 2024	Dec 2025	Delayed	Data exists – but analysis progress by end of year unclear

No change since last PB, report now provided for TE.D.08 and TE.D.14 as planned

WPTE 2025 program definition

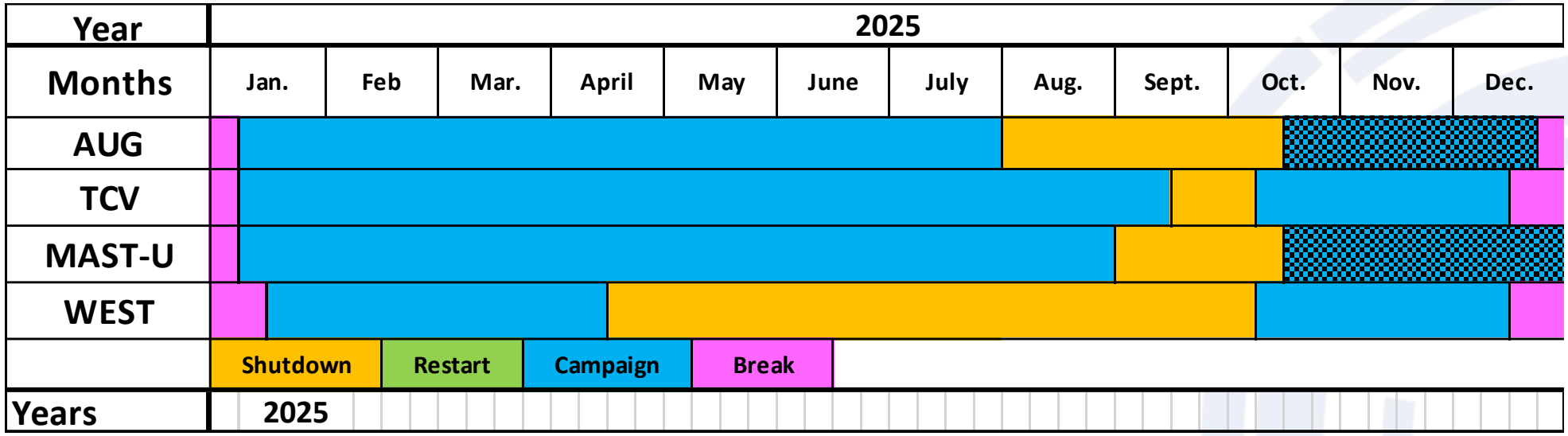
High Level Objectives

- Address urgent issues related to ITER full W using TE metallic devices (AUG, WEST + JET) : far SOL loads, W transport in pedestal, start up on W limiters, RE on W first wall, boronisation …
- Exploit the PEX upgrade of AUG towards qualifications of ADCs at high P/R
- Modelling effort for extrapolation of results from TE devices to ITER / DEMO (e.g. ADC for DEMO, impurity mix for ITER …)
- Prepare JT-60SA scientific exploitation (OP2 programme)

Organisation for 2025

- Keep the same Research Structure and RTC team
- Scientific objectives of the RT slightly amended to reflect priorities for ITER / JT-60SA (boronisation under RT06, extension of SF to multiple X point configuration under RT07, explicit links to JT-60SA in RT08/RT09 …)

Planned device availability for 2025



- Busy year for WP TE with 4 devices running in early 2025
- New features : upper divertor AUG, MAST-U cryopump, ECRH expected on WEST

	TE fraction	Shot budget
AUG	50 %	584
MAST-U	~35 %	346
TCV	40 %	1320
WEST	40 %	384

Main priorities for 2025 in present TE devices

AUG: PEX exploitation (extended H-mode operational space for ADC), SPI, W transport in H-mode and transients, High-β hybrid scenario, W PWI for ITER (boronisation, RE damage in W wall …), small-ELM

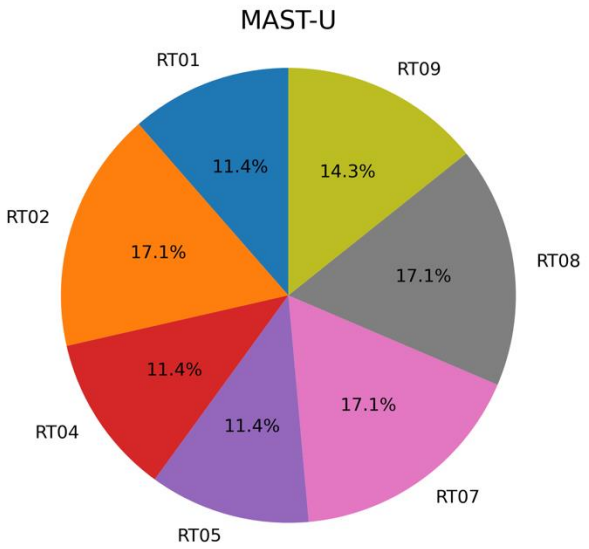
WEST: High fluence campaign, W sources and transport in long-pulse operation, W PWI for ITER (boronisation, RE damage in W wall …)

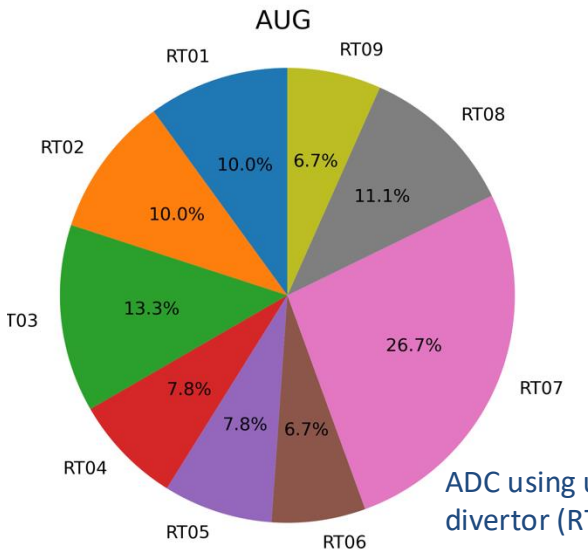
MAST-U: ADC exploration and qualification, no-ELMs, high-β, detachment studies, fast particle

TCV: ADC exploration and qualification, high-β, detachment studies, Pedestal physics (peeling/ballooning), Small-ELM/no-ELM scenarios (NT/QCE), fast particle

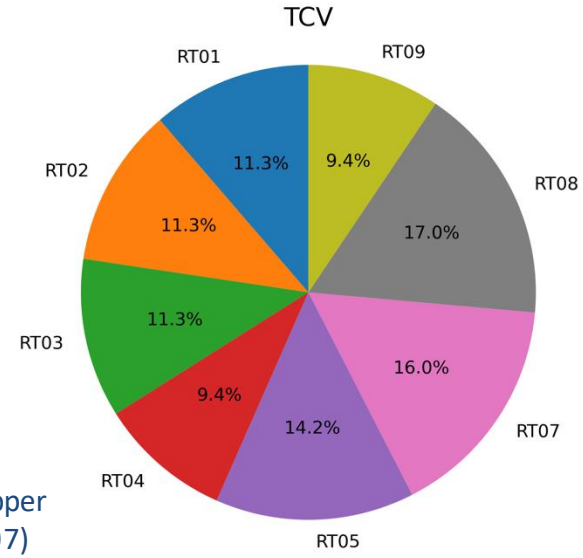
JET: Support exploitation of collected data and interpretative and predictive modelling

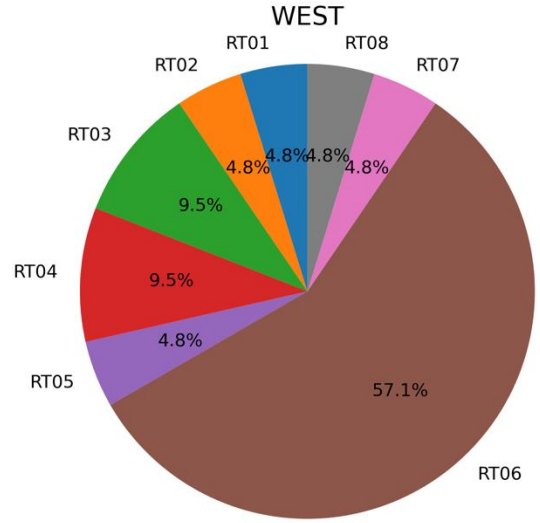
Priorities reflected in shot allocation for 2025





ADC using upper divertor (RT07)

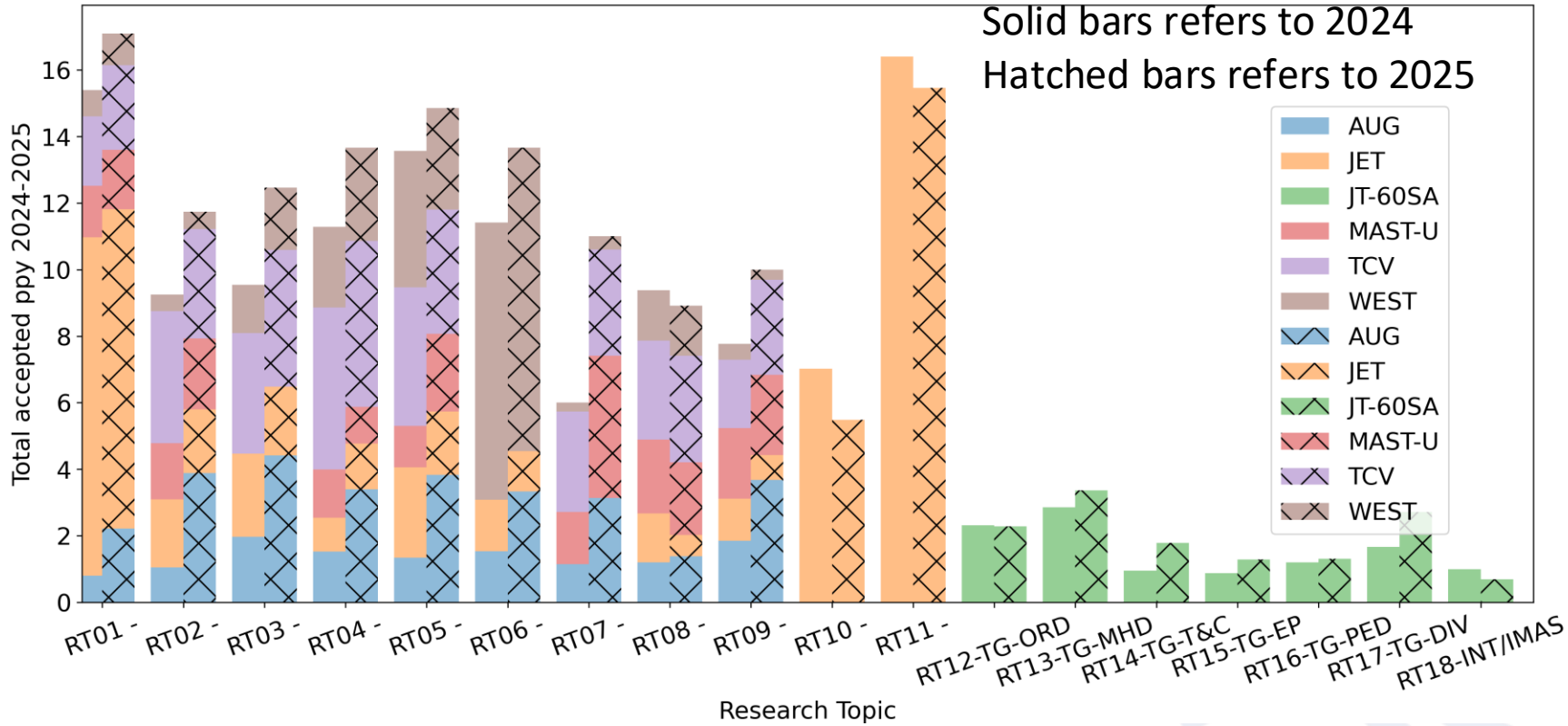




High Fluence campaign (RT06)

	AUG	MAST-U	TCV	WEST
RT01	30	24	120	15
RT02	45	48	120	15
RT03	60	0	120	30
RT04	50	32	60	15
RT05	35	32	150	15
RT06	30	0	0	180
RT07	120	48	170	15
RT08	50	48	200	15
RT09	30	40	100	0

Resource comparison 2024-2025

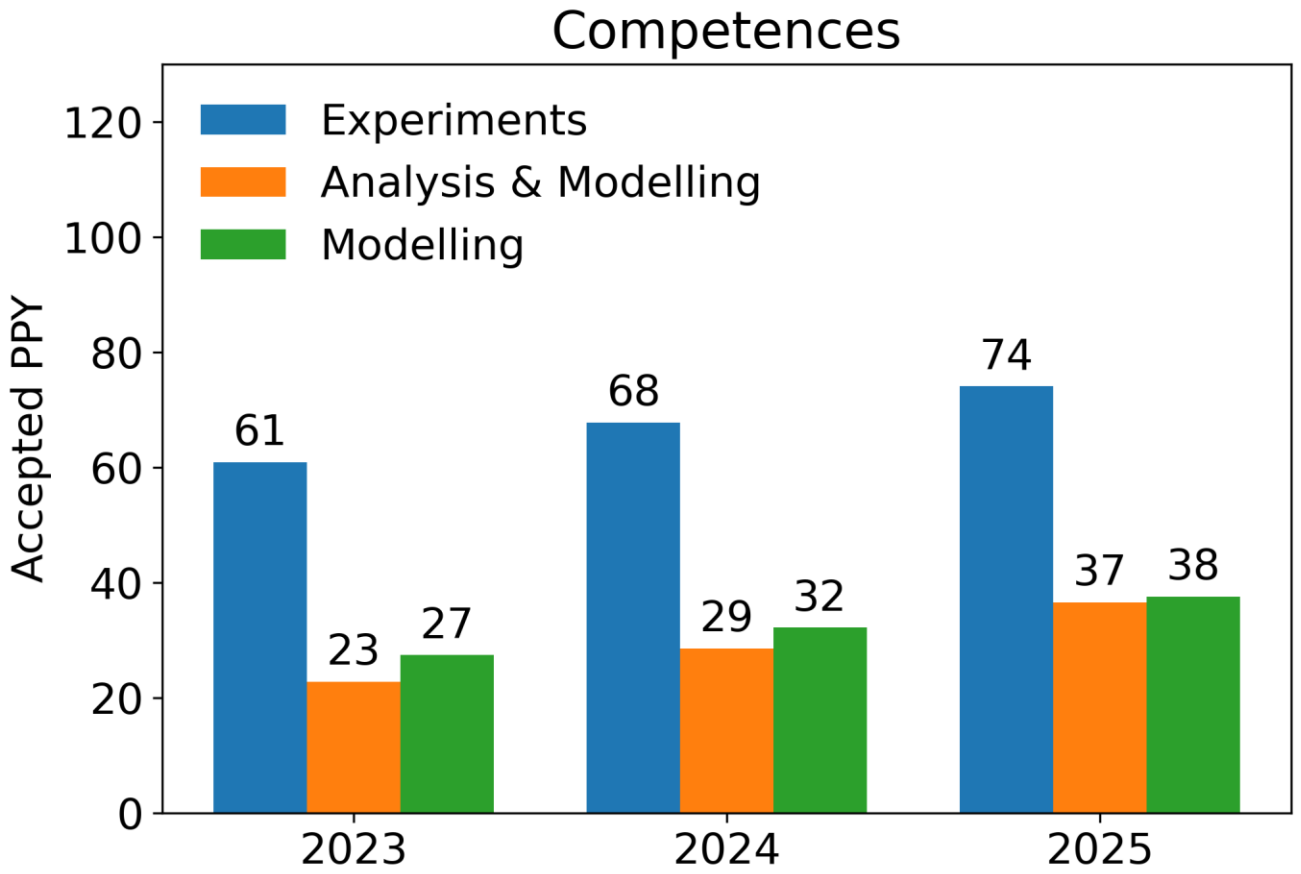


- Higher overall TE budget in 2025 (4 TE devices exploitation / preparation for JT-60SA / modelling needs)
- Higher resources for AUG scientific exploitation in 2025, as AUG now fully back on line with large operational time
- Staged increased resources for JT-60SA (OP1 analysis, transition to W, preparation for OP2)

Also note : additional mission budget planned to be transferred from campaign participation to ensure experiment participation and A&M in view of preparation of high-level conference participation (IAEA in particular)

Competences distribution

- Consistent increase of resources from 2024 to 2025 in all the Competencies
- Throughout the years WPTE has continued to increase the effort towards interpretative modelling to provide full scientific exploitation of TE experiments from experiment execution to physics understanding and future device extrapolation



Enhancements projects launched in 2024 to be continued

Device	Project
AUG	FIRE&GO - Fast Ion Research Enhancements and Gamma-ray Observations [at ASDEX]
	Ultra-fast-swept profile reflectometer on AUG
	Direct Digital Synthesis for the O-mode Profile Reflectometer at ASDEX Upgrade
	Real-time spectroscopy at ASDEX Upgrade
	Real-time control system for ELM buffering at ASDEX Upgrade
COMPASS-U	Tungsten impurity monitoring and control at the COMPASS-U tokamak
	Characterisation of advanced confinement modes at COMPASS-U
	PFCs and diagnostics for power exhaust studies at COMPASS-U
MAST-U	Neutron Detectors suite for 14 MeV neutron triton burnup and 2.5 MeV neutron spectroscopy measurements at MAST Upgrade
	ONCOMING-Optimized taNgentially spaCe resOlved geM ImagiNG [at MAST-U]
TCV	New 100-Hz Laser for the TCV Thomson Scattering System
	Runaway Electron Mitigation Coil for TCV
	Upgrade of the TCV LHPI antenna
	Implementation of the 4th dual-frequency gyrotron for TCV
	Collective Thomson Scattering (CTS) diagnostic for TCV
	Runaway electron mitigation and velocity analysis by magnetic-ripple manipulation [at TCV]
	Upgrade of the TCV ECRH high voltage power supply
WEST	A retarding field analyzer for ion temperature measurements in the SOL of WEST
	Boronization Probes for WEST
	LIBS4FUSION: in-vessel fuel Inventory and deposited layers composition in a full tungsten device
	Fast Ion Loss Detector in WEST
	IRBO IR Bolometry for WEST
	High DEfinition Visible Endoscope for WEST

Delays announced on some projects but should still be completed in 2027 at the latest

AI projects continuing in 2025

#	Project Title	PI	Beneficiary
ENEA-03	AI-assisted Causality Detection and Modelling of Plasma Instabilities for Tokamak Disruption Prediction and Control	R. Rossi	ENEA
ENEA-04	Development of Physics Informed Neural Networks (PINNs) for Modelling and Prediction of Data in the Form of Time Series	M. Gelfusa	ENEA
IST-01	Deep Learning for Spectrogram Analysis of Reflectometry Data	J. Vicente	IST

International collaborations

- Agreement with US on no ELM scenario finalized, collaborative work started
- Collaboration with KSTAR under preparation : high level objectives agreed, more detailed programme under consolidation

Grant Deliverables 2025

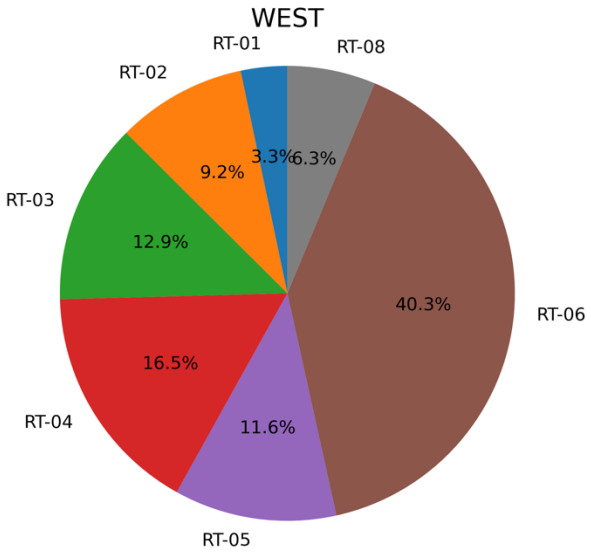
"Title" in Sygma	Title in CWP	Initial due Date	Expected deliverable date
TE.D.09	Establishment and comparison of N and Ne-seeded partially-detached divertor in high-power operations in view of ITER radiative scenario.	Dec 2023	Dec 2025
TE.D.12	The physics basis for the decision for an alternative divertor configuration for DEMO.	Dec. 2024	Dec 2025
TE.D.13	Recommendation on the seeding impurity mix in view of a future reactor.	Dec. 2024	Dec 2025

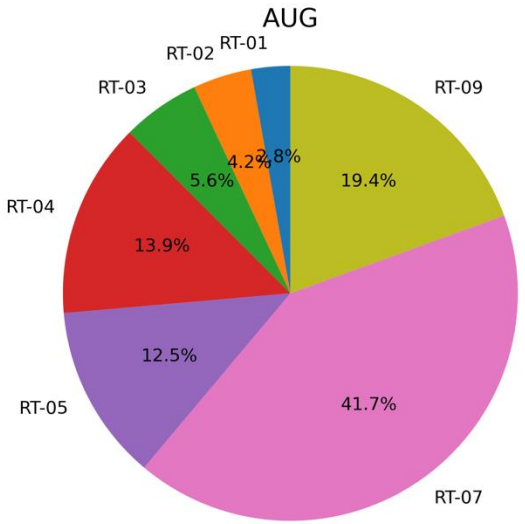
Conclusions

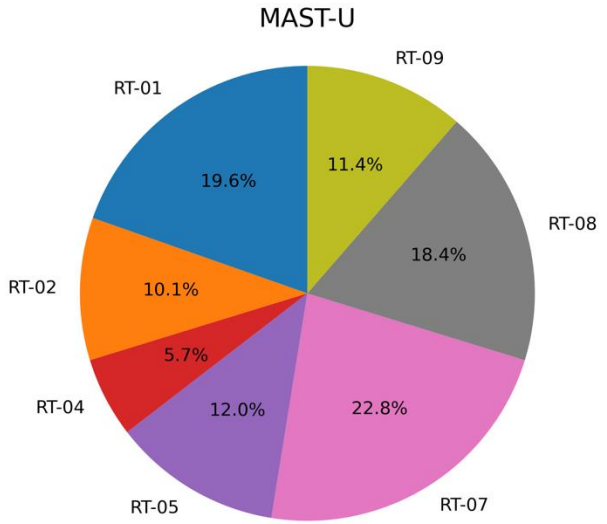
- WPTE program has run reliably over 2021-2024 and on track to continue in 2025
  - All FP9 TE Grant deliverables near completion (10/13 GD completed, 3 last GD on track for 2025)
  - WP TE devices have run reliably and have compensated on following campaigns in case of delay (cf AUG and WEST)
  - Large number of TE multi machine publications in major fusion conferences (see for instance IAEA FEC 2025 : > 15 TE supported oral contributions + 2 machine overviews (JET, JT-60SA) proposed)
- WPTE program demonstrated the capabilities to deliver consistently the objectives and properly use the available resources over FP9
- It provides the framework for establishing a strong pan-European scientific team, allowing consistent multi machine scientific exploitation and enabling access to EU tokamaks for all European beneficiaries

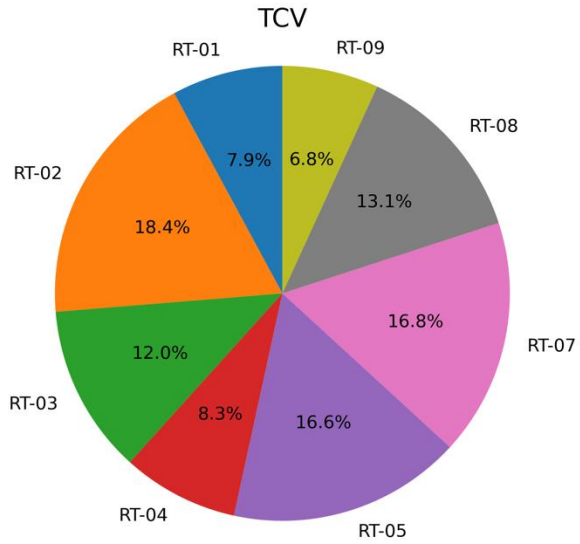
Backup

Stats of performed shots in 2024 on different devices









Research

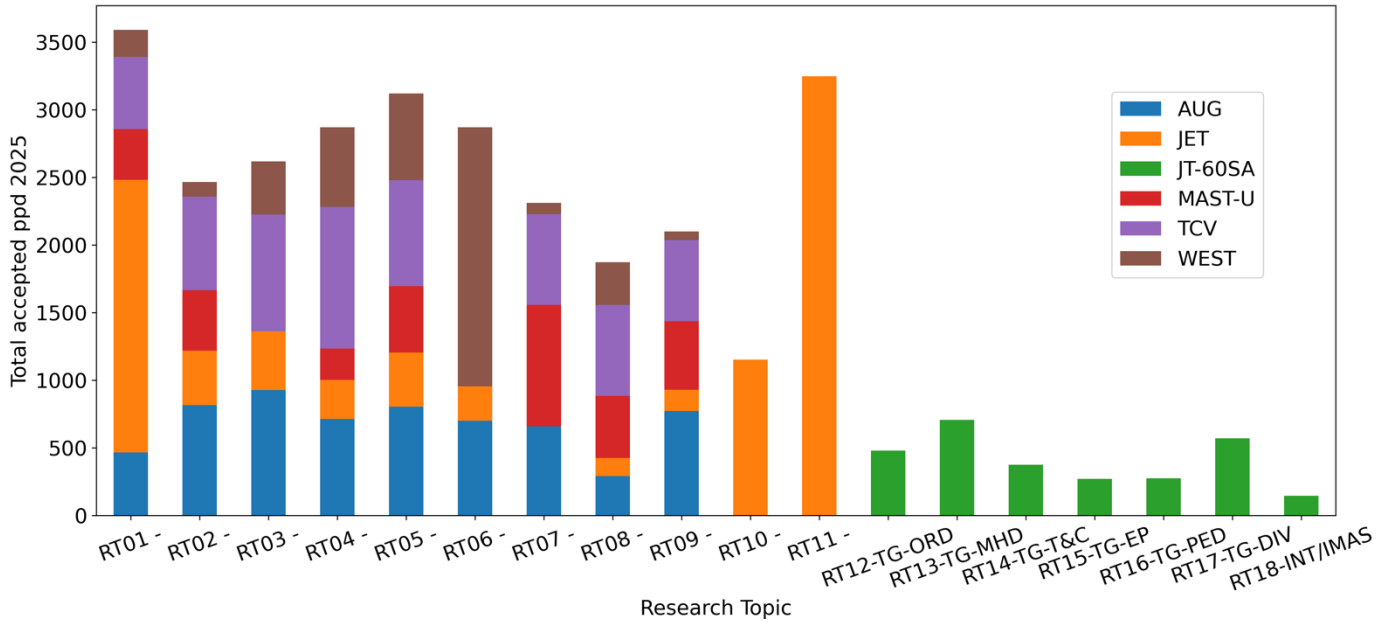
Topic	AUG	TCV	WEST	MAST-U
RT-01	2	105	10	31
RT-02	3	245	28	16
RT-03	4	160	39	0
RT-04	10	110	50	9
RT-05	9	221	35	19
RT-06	0	0	122	0
RT-07	30	224	0	36
RT-08	0	175	19	29
RT-09	14	91	0	18
Total	72	1331	303	158

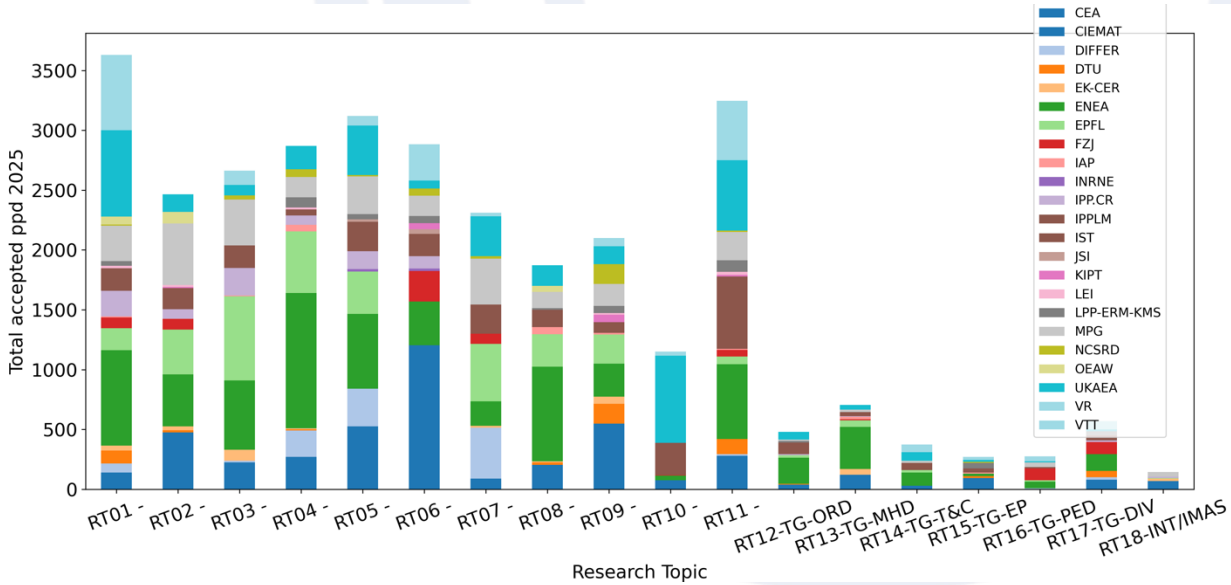
Integration of JT-60SA into WPTE started in 2024

- Jeronimo Garcia on top of his duties as ET Team Leader is also acting as Deputy Task Force Leader for WPTE, ensuring smooth integration between JT-60SA ET activities and EF
- The Different JT-60SA Topical Groups are embedded into TE program as additional JT-60SA specific Research Topics, with European Topical Group Leaders/Designated Contact Person acting as Research Topic Coordinators

	Research topic	Title	WPTE specific Names	TGL/CP
JT-60SA specific	TG-ORD	Operation Regime Development	RT12	J. Garcia
	TG- MHD	MHD Stability and Control	RT13	G. Pucella
	TG-TC	Transport and Confinement	RT14	L. Garzotti
	TG-EP	High Energy Particle Behaviour	RT15	Y. Kazakov
	TG-PED	Pedestal and Edge Physics	RT16	Y. Liang
	TG-DSP	Divertor, Scrape-Off Layer & Plasma-Material Interaction	RT17	G. Falchetto
	IMAS	Integrated Data Validation and data access with IMAS	RT18	F. Imbeaux

Resource allocation





2025 Call Cycle

Call for proposal 2025

- September 202**: Deadline 11th of October**
- Review meeting in September (23rd and 26th)

Call for participation 2025

- 28 October 2024-27 November 2024
- **GPM in person 18/19 November in Garching**

2025 Campaign

	Shot requests			
RT	**AUG**	**TCV**	**MAST-U**	**WEST**
RT01	212	157	44	138
RT02	207	375	169	50
RT03	291	326	20	165
RT04	171	401	66	153
RT05	212	138	135	229
RT06	105	0	0	681
RT07	262	322	296	52
RT08	242	196	238	75
RT09	174	325	76	60
Total	**1876**	**2240**	**1044**	**1603**
Available	**584**	**1320**	**346**	**384**

Staffing selection to be completed before Xmas 2024

Integration of JT-60SA in 2025

	Research topic	Title	IMS tag
Mission 1	RT-01	Core-Edge-SOL integrated H-mode scenario compatible with exhaust constraints in support of ITER	RT01
	RT-02	Physics understanding of alternatives to Type-I ELM regime	RT02
	RT-03	Strategies for disruption and run-away mitigation	RT03
	RT-04	Physics-based machine generic systems for an integrated control of plasma discharge	RT04
	RT-08	Physics and operational basis for high beta long pulse scenarios	RT08
	RT-09	Physics understanding of energetics particles confinement and their interplay with thermal plasma	RT09
Mission 2	RT-05	Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation	RT05
	RT-06	Preparation of efficient Plasma Facing Components (PFC) operation for ITER, DEMO and HELIAS	RT06
	RT-07	Physics understanding of alternative divertor configurations as risk mitigation for DEMO	RT07
JET specific	RT-10	JET data validation	RT10
	RT-11	Analysis and modelling of DTE2 related experiments on JET	RT11
JT-60SA specific	TG-ORD	Operation Regime Development	RT12
	TG- MHD	MHD Stability and Control	RT13
	TG-TC	Transport and Confinement	RT14
	TG-EP	High Energy Particle Behaviour	RT15
	TG-PED	Pedestal and Edge Physics	RT16
	TG-DSP	Divertor, Scrape-Off Layer & Plasma-Material Interaction	RT17
	IMAS	Integrated Data Validation and data access with IMAS	RT18

- **Modification of Scientific objectives for TE EU Devices in the Call for proposals** :
  - RT08 and RT09 modification of Scientific Objectives in view of JT-60SA as a step-ladder approach towards ITER/DEMO (e.g. high β scenario with high f_g or FI population with large E/T_e or super-alfvenic population)
- **Single Call for participation launched** with proposal assessed by a combination of TE TFLs and JT-60SA TG leaders

International collaborations

- TE rationale :
  - Select topics which cannot be addressed with the capabilities of EU facilities
  - Extra attention to critical manpower resources

KSTAR : can complement EU full W devices in some specific areas

Proposed High level objectives for KSTAR exploitation with W divertor

1) Establishment of physics and operational understanding of long discharges in W environment at relevant plasma current and collisionality complements RT01 for high Ip/ low collisionalities extended to long pulse

2) Investigation of stable operation of long pulses in detached divertor conditions Extend RT05 detachment studies in H-mode to long pulse operation

3) Demonstration of integrated RMP control of long pulse H-mode high beta-N plasmas extend capabilities of present EU devices to long-pulse RMP (RT02) and prepare future exploitation of JT-60SA (RT08)

4) Exploration of disruption & runaway electron mitigation and avoidance in long pulses extend present SPI investigation to double SPI (RT03)

5) Implementation of wall monitoring and Plasma Facing Components characterization

EU-US collaboration on small-ELMs

- Initiative from DoE and EUROfusion (EU-US Energy Council, March 2023)
- Multi-year plan for EUROfusion and US DOE collaborative activities:
  - New experiments
  - Data analysis from tokamaks in EU and US
  - Theory & Modelling of plasma regimes without ELMs.
- Timeline
  - Currently structured as 2(yr)+2(yr) (starting this year 2024)
  - Project Agreement (PA) to be signed off by DOE and EUROfusion
  - Draft PA agreed by DoE —> Final version expected by mid-November
- 6 subgroups lead by 2 experts
  - QH-mode: Darin Ernst, USA & **Eleonora Viezzer**, EU
  - I-mode: Amanda Hubbard, USA & **Davide Silvagni**, EU
  - EDA/QCE H-mode: Nils Leuthold, USA & **Michael Faitsch**, EU
  - Negative Triangularity: Oak Nelson, USA & **Olivier Sauter**, EU
  - XPR with no-ELM: F. Scotti, USA & **M. Bernert, EU**
  - Theory and Simulation: Fatima Ebrahimi, USA & **Andres Cathey**, EU
  - Overall coordination: Xi Chen, USA & **Benoit Labit**, EU

Provisional budget for 2025 : main objectives

Initial provisional budget for 2025 build in 2023, now revised in the light of 2024

Staffing

- Increase of staffing for campaign participation on TE devices : intensive exploitation of AUG
- Pursue the effort on modelling (PCR already granted in 2024 for 2025)
- Maintain the effort on JET data validation + analysis and interpretative modelling for completing publications foreseen in major conferences in 2025 (IAEA in particular)
- Maintain effort on JT-60SA at the same level as in 2024 for IC analysis (to be further discussed with JG)

Missions

- Campaign participation consistent with staffing
- Keep on site meetings, as very beneficial for accelerating data analysis / modelling
- Keep INCO at same level as in 2024 as EUROfusion strenghtening international collaboration