Results from the last DD and DT JET campaigns in the framework of the EUROfusion Tokamak Exploitation activity

M. Wischmeier and N. Vianello
on behalf of the EUROfusion Tokamak Exploitation Team*

Consorzio RFX, ISTP-CNR

*Joffrin, E. H. et al. Overview of the EUROfusion Tokamak Exploitation programme in support of ITER and DEMO. Nucl. Fusion (2024) doi:10.1088/1741-4326/ad2be4.

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JET

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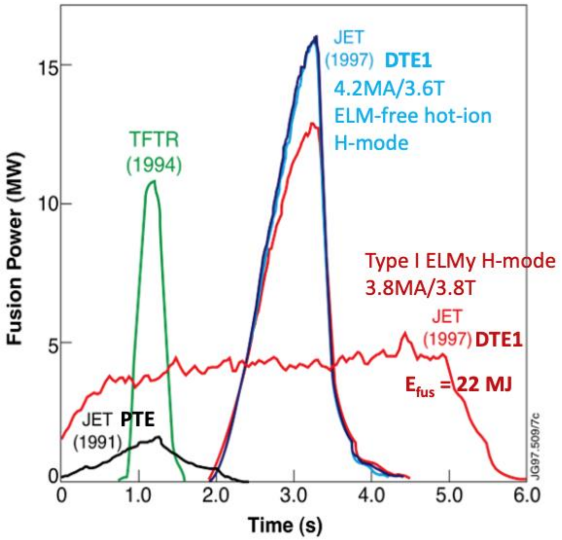
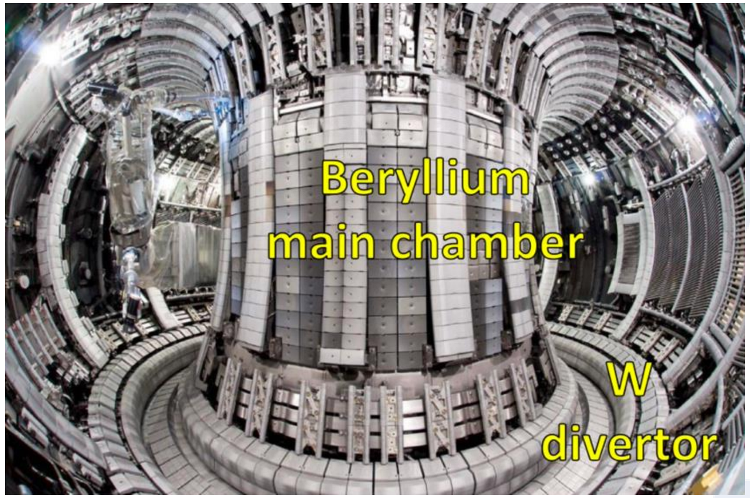
The long history of JET contribution to Fusion Science

*Nuclear Fusion Special Issue Vol 63, **11**, 2023 and C. Maggi et al, NF 2024*

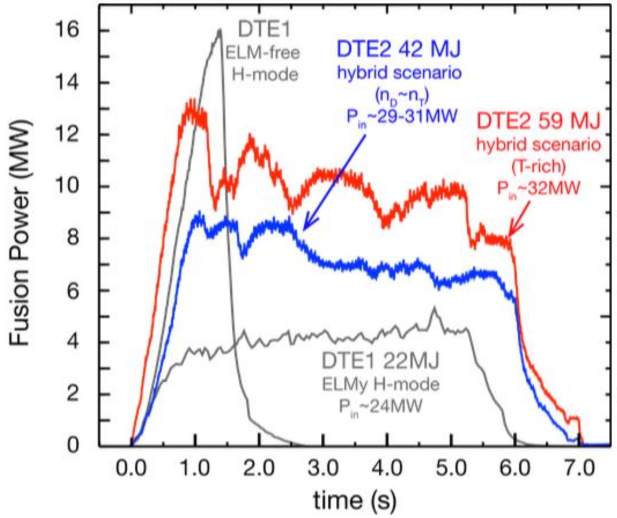


DTE1 Key Scientific Outcomes

- Transient record
- Weak α-particle effects
- **T retention in C machines**



R/a = 2.96/1.25 m
NBI = 34 MW
ICRH = 5 MW
$B_t < 4T$



DTE2

- **Sustained Fusion power > 10 MW for 5s**
- **Fusion Energy up to 59 MJ in T-rich plasmas**

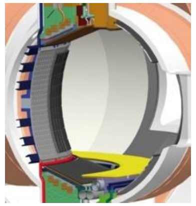
1983	1991	1997	2003	2009/11	2020/21	2022/23	2023	18 December 2023
JET First Plasma	Preliminary Tritium Experiment	DTE1	Trace Tritium Experiment	Be/W metal wall.	Full Tritium and DTE2	C45 D campaign	DTE3 and cleaning campaign	Last day of JET operation

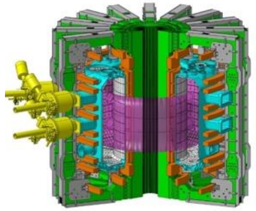
JET operation in the new EUROfusion Tokamak Exploitation Programme

JET

AUG

WEST





TCV

MAST-U

- In 2022-2023 JET program embedded on the wider framework of EUROfusion Tokamak Exploitation Workpackage with a unified progam aiming to
  - Expand parameter space explored
  - Pursue a step-ladder approach
  - Explore D-T operation to extend physics parameter space

1983	1991	1997	2003	2009/11	2020/21	2022/23	2023	18 December 2023
JET First Plasma	Preliminary Tritium Experiment	DTE1	Trace Tritium Experiment	Be/W metal wall.	Full Tritium and DTE2	**C45 D campaign**	DTE3 and cleaning campaign	Last day of JET operation

High level objectives of 2022-2023 JET program

JET

OPERATION														DECOMMISSIONIG		
2022		2023												2024-		
n	d	j	f	m	a	m	j	j	a	s	o	n	d			
Deuterium						Deuterium				DTE3	Cleaning	Deuterium			LIBS	

With D beams

- **Explore scenarios for next step device in both D and D-T** (Core-edge integrated seeded scenarios, no-ELM/small-ELMs, highly radiative scenarios).
- Promote **understanding on key physics gaps** (W screening, peeling limited pedestal, FI, …)
- Secure **safe and reliable operation** for next step device (SPI, Real Time Control, Heating schemes, fuel retention)
- Complete efforts started in DTE2

1983
JET First Plasma

1991
Preliminary Tritium Experiment

1997
DTE1

2003
Trace Tritium Experiment

2009/11
Be/W metal wall.

2020/21
Full Tritium and DTE2

2022/23
C45 D campaign

2023
DTE3 and cleaning campaign

18 December 2023
Last day of JET operation

High level objectives of 2022-2023 JET program

JET

OPERATION														DECOMMISSIONIG
2022		2023												2024-
n	d	j	f	m	a	m	j	j	a	s	o	n	d	
Deuterium						Deuterium				DTE3	Cleaning	Deuterium		LIBS

With D beams

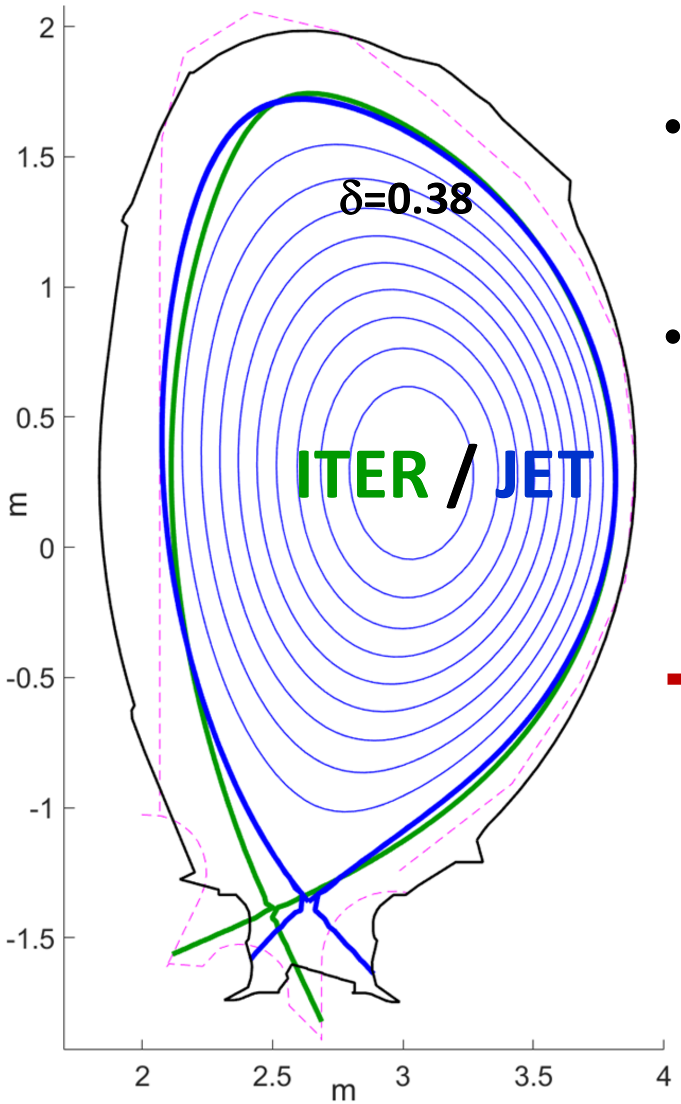
- **Explore scenarios for next step device in both D and D-T (**Core-edge integrated seeded scenarios, no-ELM/small-ELMs, highly radiative scenarios).

Scenarios promoted for physics understanding and exploring parameter space in terms of density and radiation fraction where high fusion power could not be attained in JET class devices

- **1983** JET First Plasma
- **1991** Preliminary Tritium Experiment
- **1997** DTE1
- **2003** Trace Tritium Experiment
- **2009/11** Be/W metal wall.
- **2020/21** Full Tritium and DTE2
- **2022/23** **C45 D campaign**
- **2023** DTE3 and cleaning campaign
- **18 December 2023** Last day of JET operation

SCENARIOS FOR NEXT STEP DEVICES

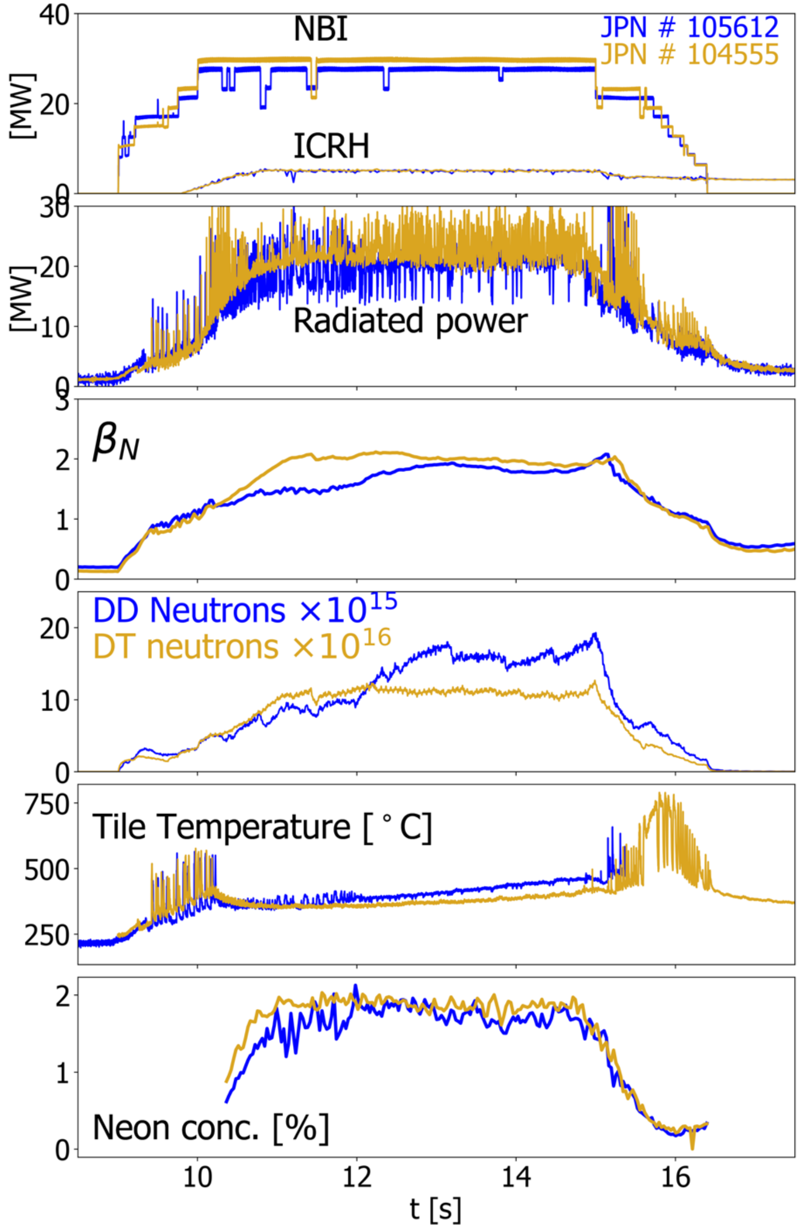
High performance scenario compatible with exhaust solution



- ITER-like plasma high δ shape with SP on vertical tiles
- Partially-detached with clear ELM mitigation with Ne seeding and high radiation fraction
- Confinement: H_{98y2}>0.8 with observed improvements with extrinsic impurities

➔ **Exploration expanded to larger plasma current to**

- To achieve more opaque SOL and lower ν^{*ped}
- To infer detachment operational at narrower λ_q

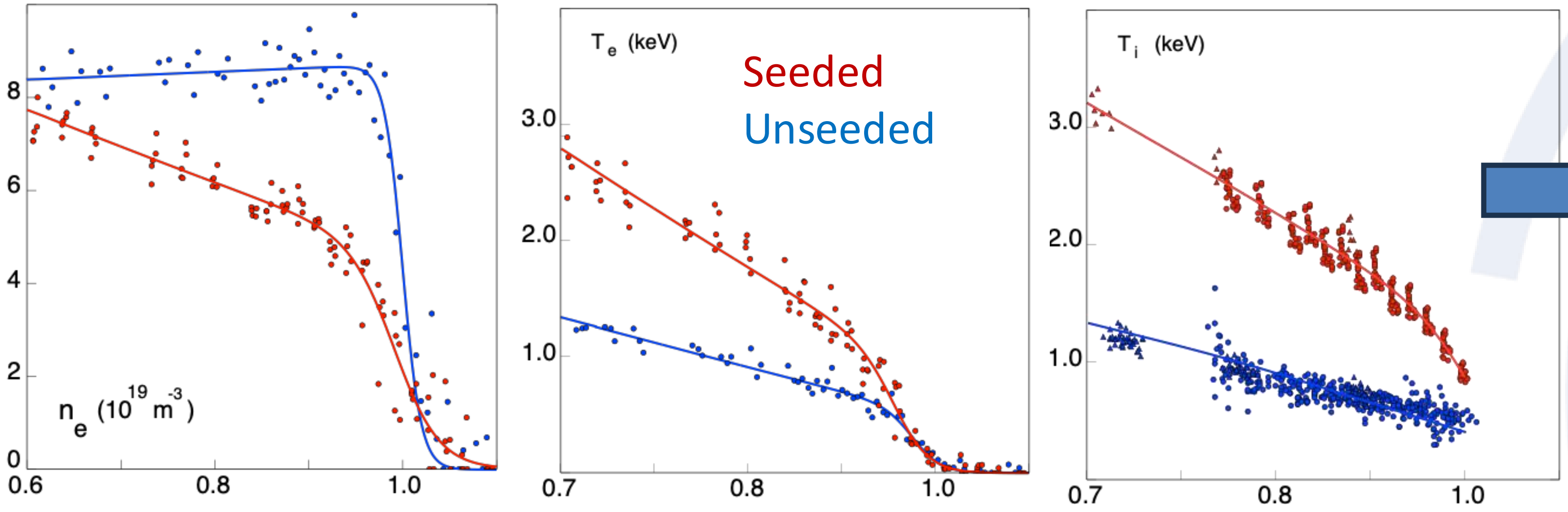


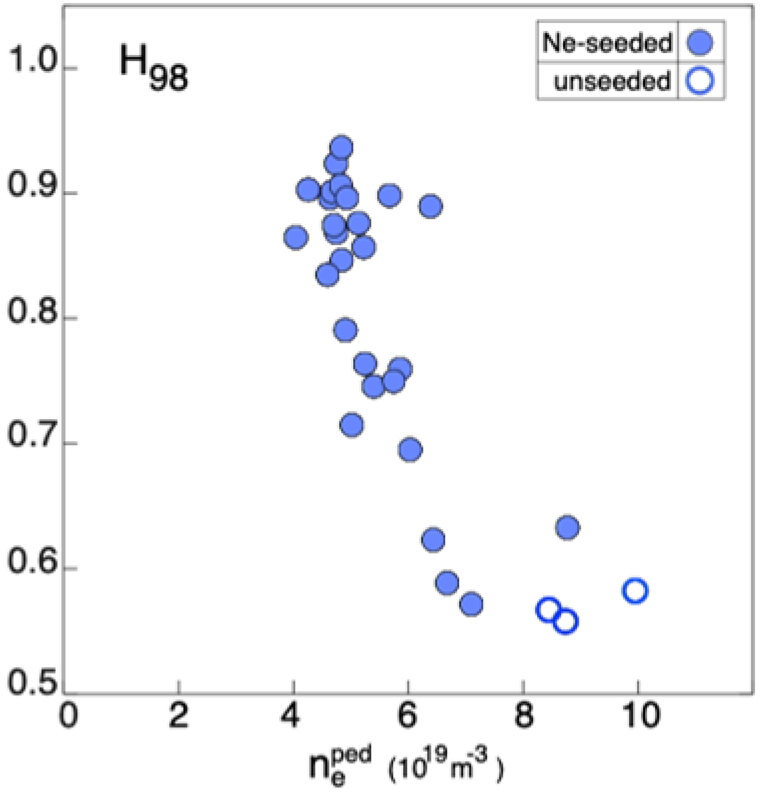
See C. Giroud, regular oral Wednesday 15/10 @ 16.10

High performance scenario compatible with exhaust solution

JET

Operational space at 2.5MA/2.7T increased, with wide range of gas/seeded levels achieving good performances with clear increase of pedestal pressure and increase rotation





- Ne seeding beneficial for confinement at high Ne concentration (C_{Ne}> 1.3%) → primarily (but not only) because of improve pedestal performances

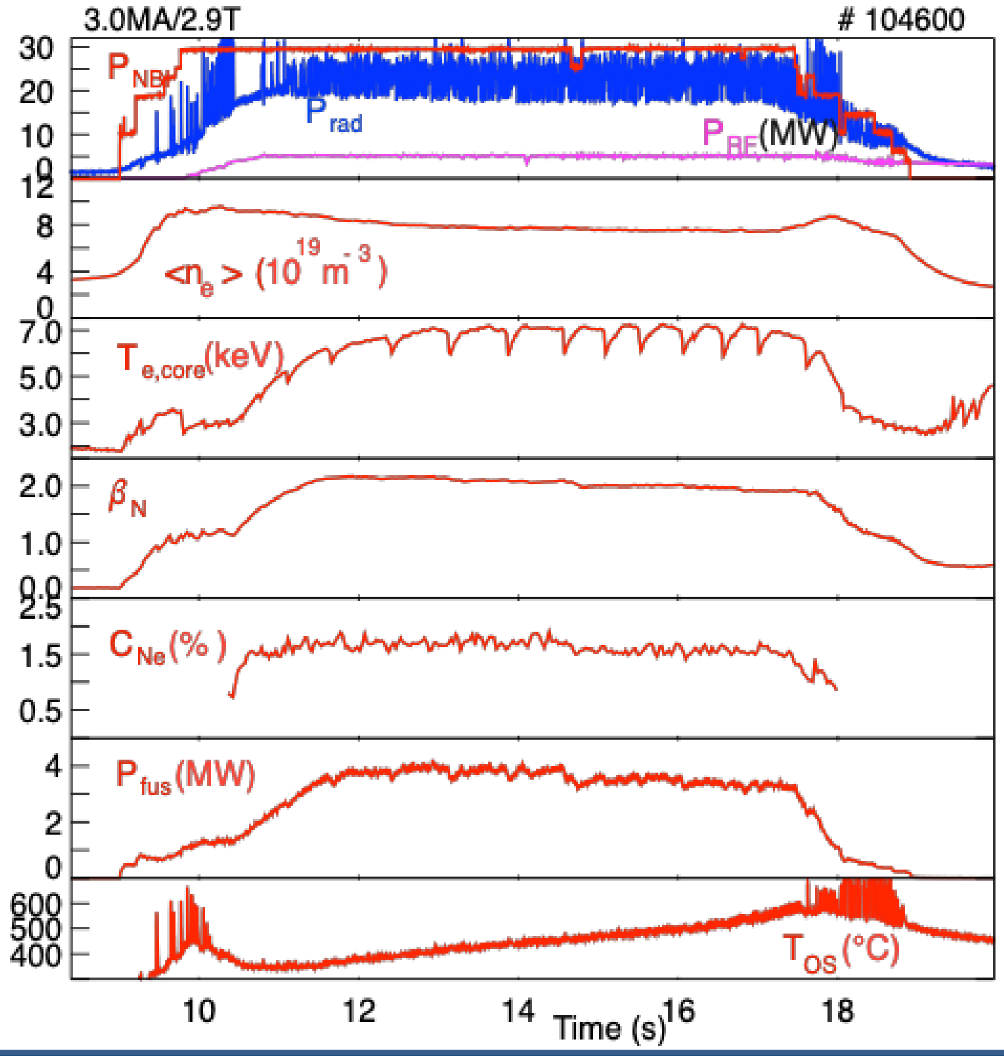
High plasma current (3.0MA & 3.2MA) type I ELMy H-mode challenging even at max P_{IN}=37MW

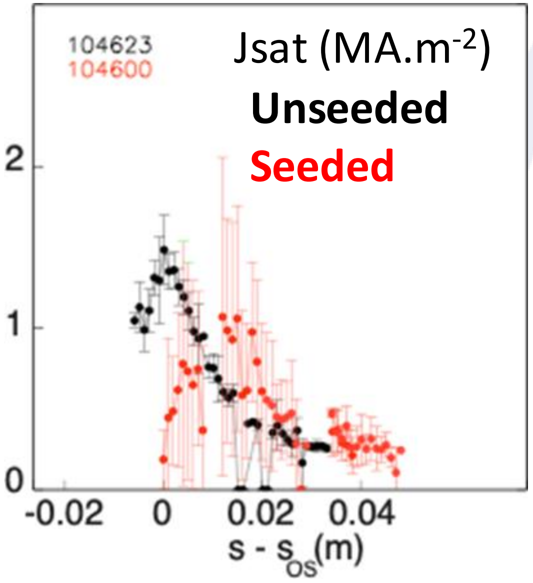
See C. Giroud, regular oral Wednesday 15/10 @ 16.10

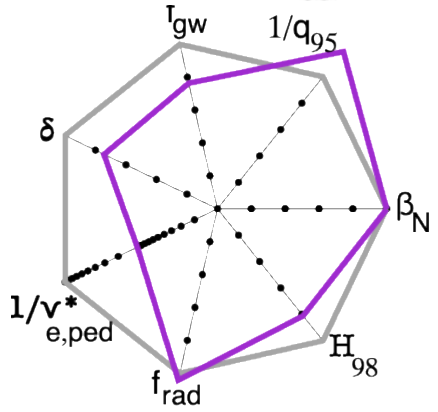
High performance scenario compatible with exhaust solution

JET

DT isotope effects open the operational space → 3MA, high δ D-T partially detached seeded plasmas achieved long pulse H_{98y}=0.85 with P_{IN}=35MW, small/no ELMs: P_{fus} = 4MW, and w/o W accumulation







Extended dataset of seeded ITER baseline scenario available for model validation

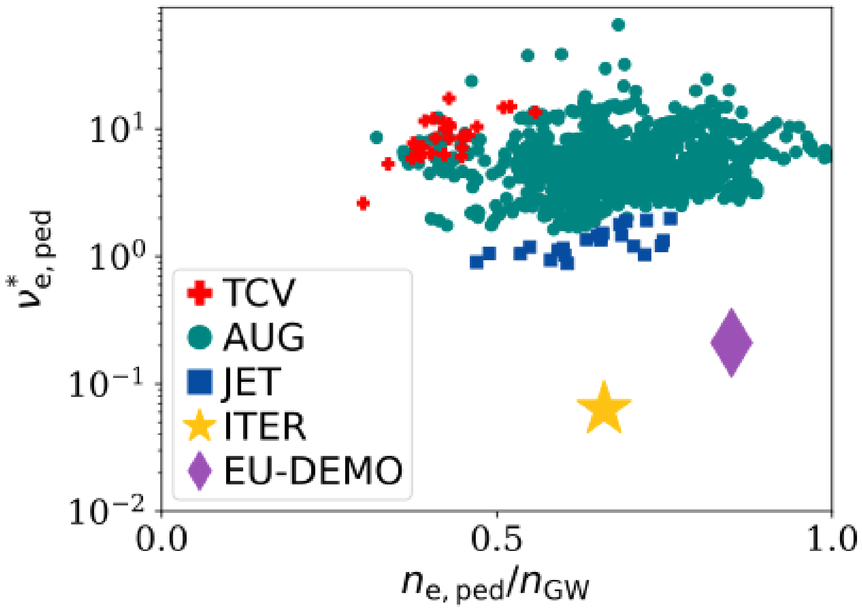
See C. Giroud, regular oral Wednesday 15/10 @ 16.10
See H. Kumpulainen, regular oral Friday 17/10 @ 17.10
See D. Fajardo, regular oral 17/10 @ 16.10

The quest of no-ELM Scenario: The Quasi Continuous Exhaust (QCE)

JET

- QCE is a natural Type-I ELM-free regime
- Key ingredients are
  - **Strong shaping** $S_d = \kappa^{2.2}(1+\delta)^{0.9}$ to stabilize global peeling-ballooning modes
  - **High separatrix density →** to drive separatrix ballooning modes preventing too steep gradient

Faitch, M et al, NME 2025



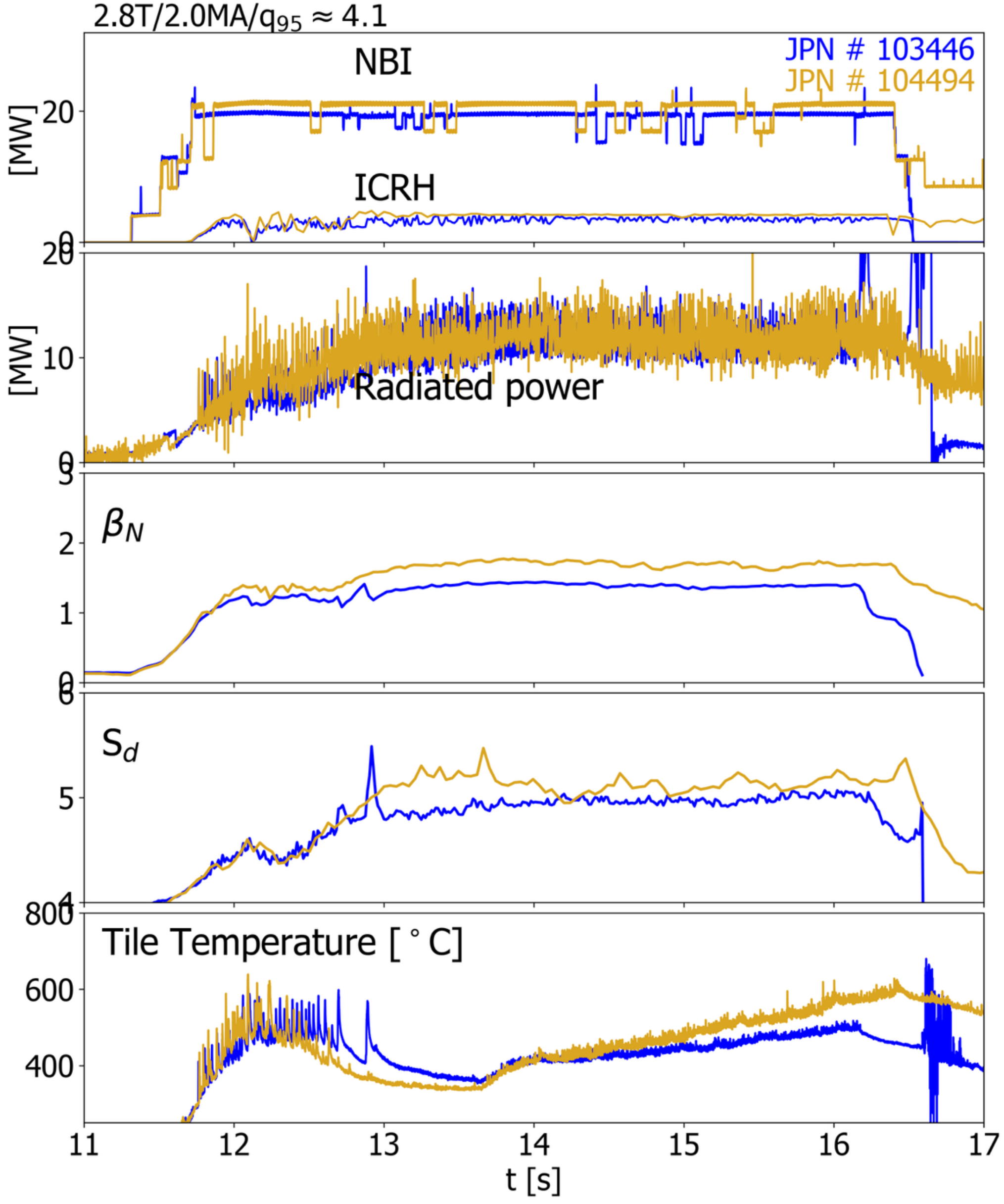
Ported to JET (up to 2.25MA in D) from mid-size tokamaks (AUG,TCV) to:

- Confirm predictive capabilities and machine-size scaling compatibilies
- Achieve lower pedestal top collisionality at fixed separatrix collisionality

See M. Dunne, regular oral 15 Oct 2025, 16:30

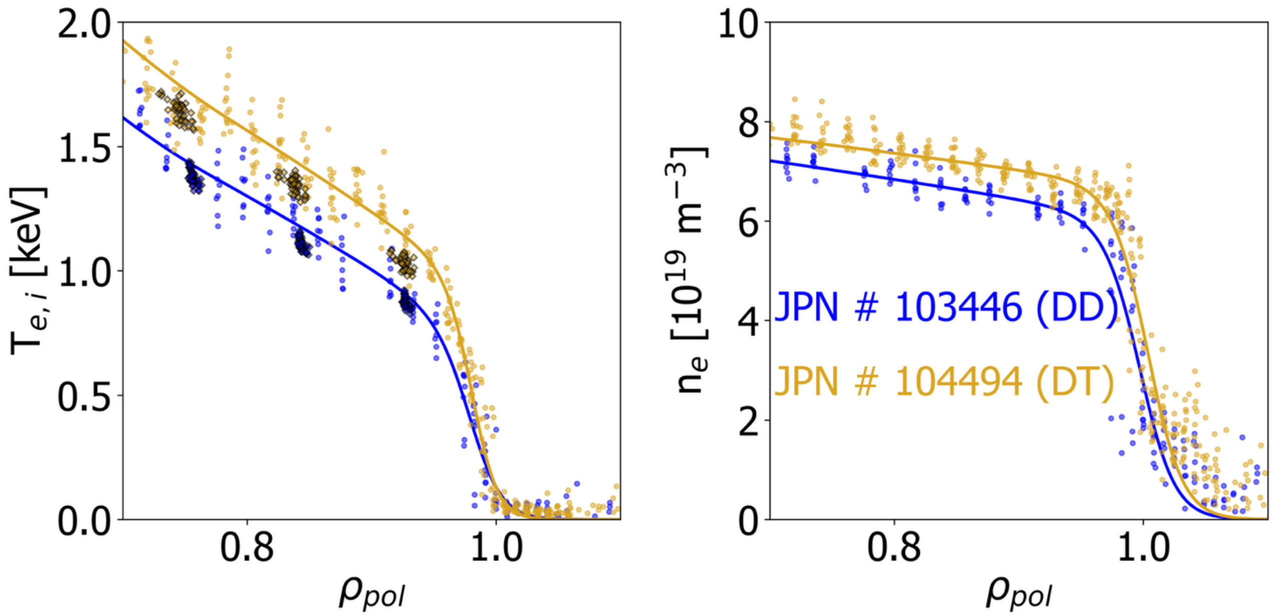
The Quasi Continuous Exhaust (QCE)

JET

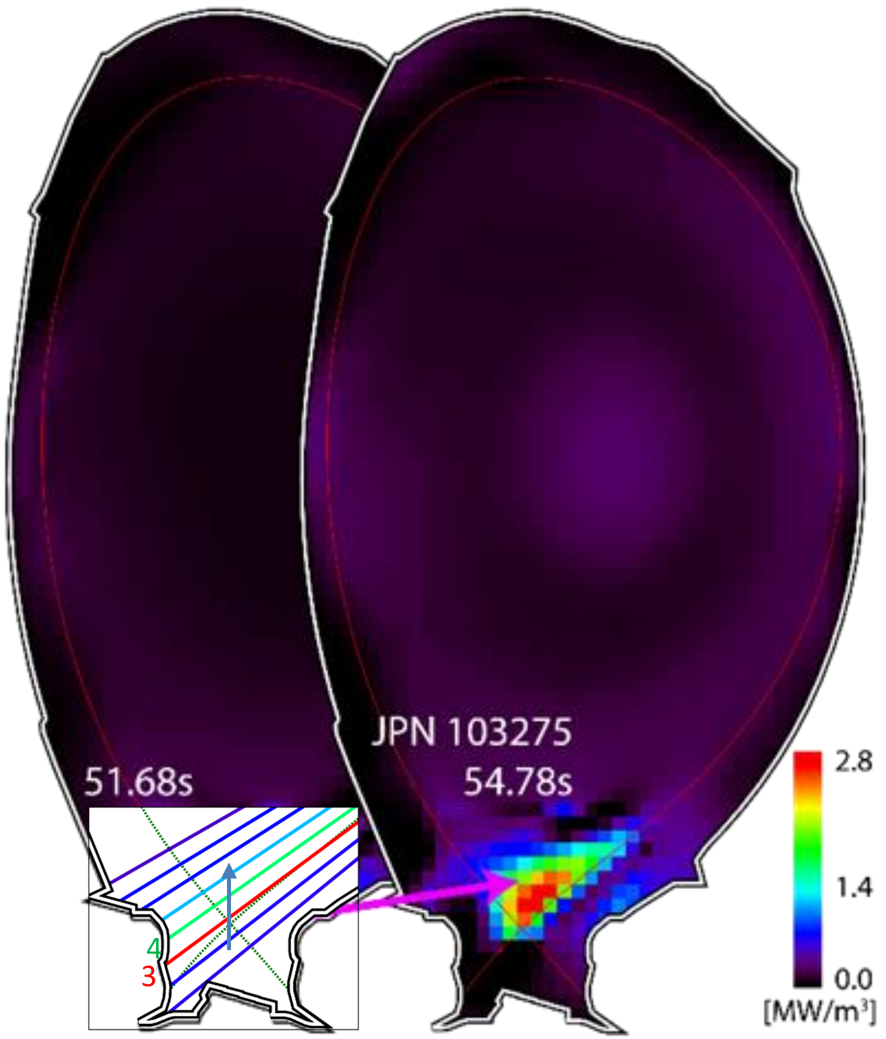


See M. Dunne, regular oral 15 Oct 2025, 16:30

- Successfully ported in D-T w/o any isotope induced showstopper
- Higher confinement due to known isotope effects



The X-Point Radiator XPR: a power exhaust solution in view of DEMO JET



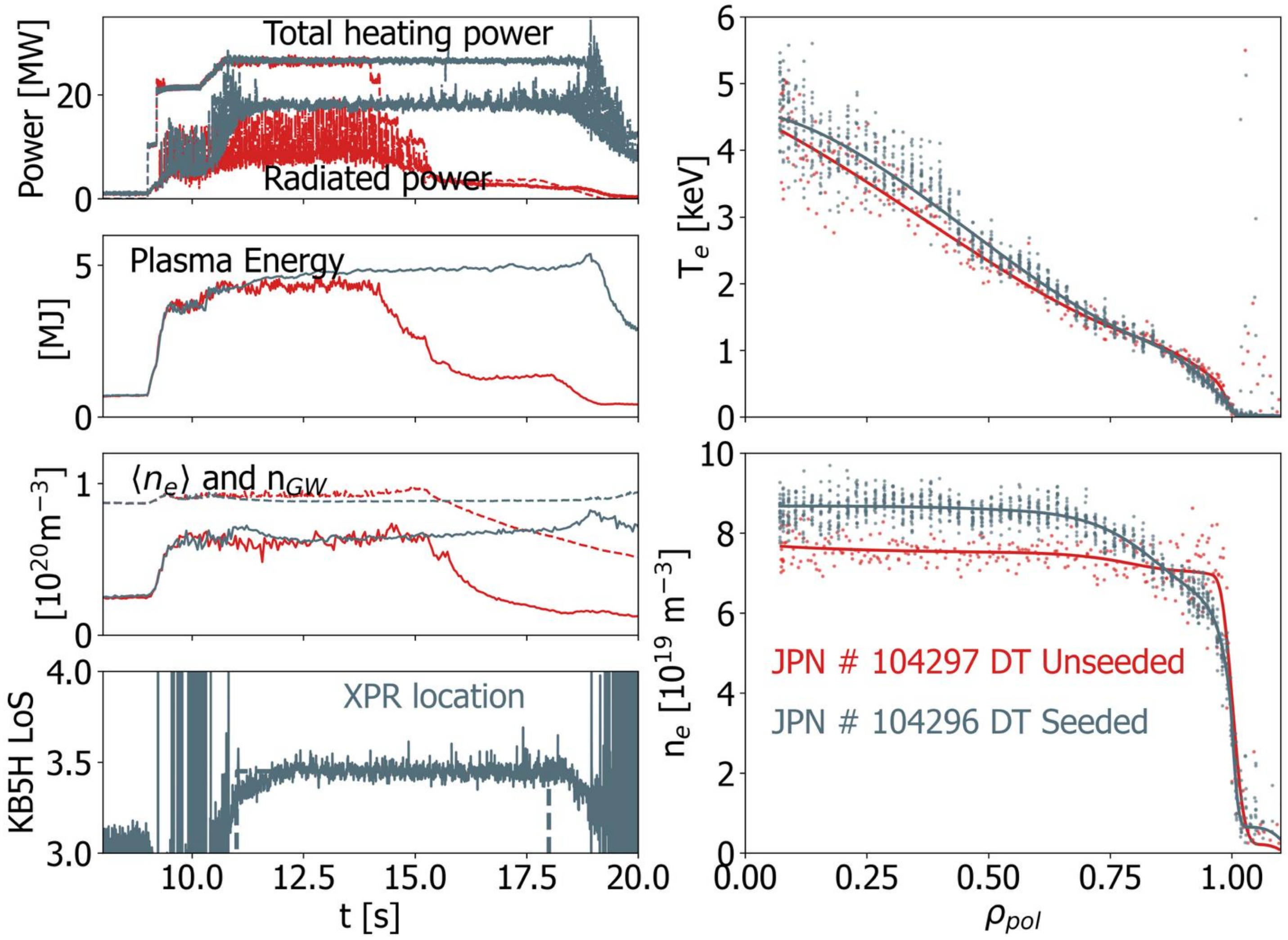
- **The X-Point Radiator Regime (XPR): viable stable solution for high radiation fraction (>90%), fully detached plasma with H-mode grade confinement***
- Solutions is robust, resilient to transients, controllable and can provide ELM suppression
- Characterized by a small region of high radiation, low temperature and high density inside the confined region at/above the X-point
- Operation extended from medium-size tokamaks to JET with implementation of Real-Time control compliant with ITER constraints**

**M. Bernert et al, NME 2025*

***T. Bosman et al, NF 2025*

The X-Point Radiator XPR: a power exhaust solution in view of DEMO JET

- Operation at 2.5MA/2.T at medium power (25 MW). **Combined seeding of Ar (feedback controlled) + Ne (feed forward) provided the more stable solution compatible and successfully exported to DT operation**



Scenario achieved:

- RT control implemented both in DD and DT
- full detachment
- small to no ELM
- smooth L-H and H-L transition
- Beneficial effect of seeding on confinement w/o edge deterioration

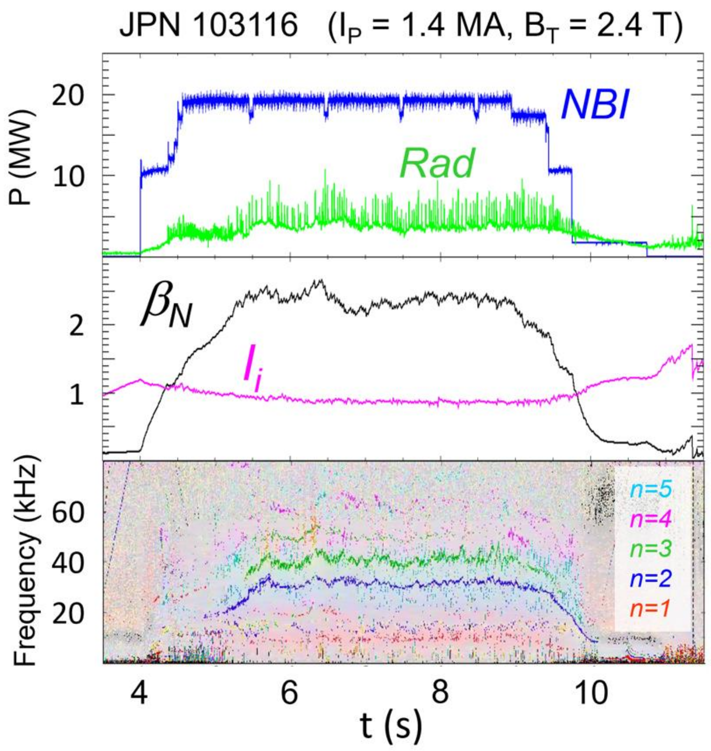
JET experiments in preparation of JT-60SA operations

JET

- Exploration of high-β pulses with dimensionless parameter (β_N, ν*, ρ*) values relatively close to the JT-60SA hybrid scenario, aiming at mild MHD activity to inform JT-60SA.

- MHD stability boundary tested at different toroidal fields *vs*:
  - β_N via NBI power scan
  - q_0, by tailoring NBI start-time scan

- Good confinement properties obtained, with $\rho^* \approx \boldsymbol{\rho}^*_{JT60}$, $\nu^* \approx 2x\nu^*_{JT60}$, mild MHD activity and relatively high β_N values



Information from JET experiments at 2.4 T and P_{NBI} = 16-24 MW will be useful for JT-60SA "similar" discharges at 1.7 T and P_{NBI} = 10-14 MW.

UNDERSTANDING OF KEY PHYSICS GAPS

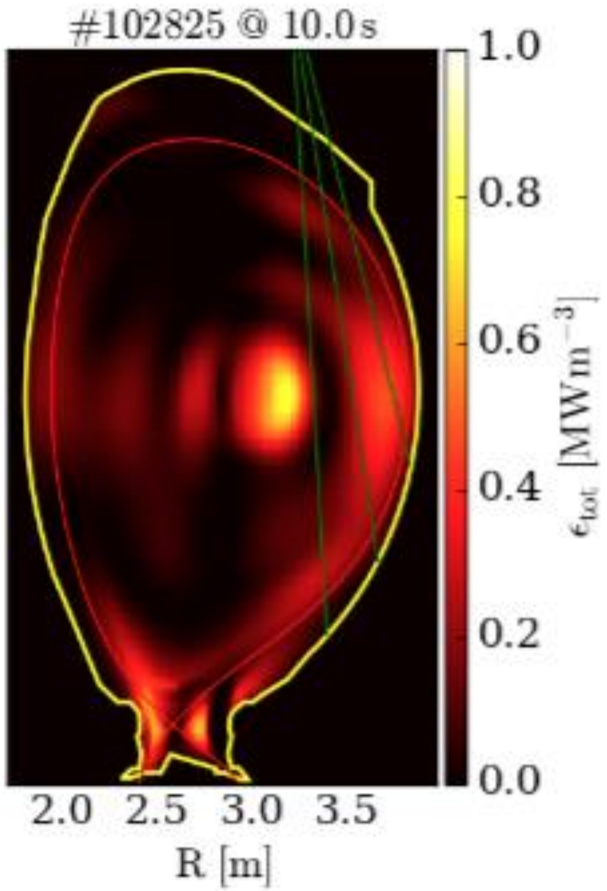
Operation with low W concentration and W screening

JET

Poloidal asymmetry — Screening

$$R\langle\Gamma_z^{\text{neo}}\cdot\nabla r\rangle \propto n_i T_i \nu_{ii} Z\left[P_A\left(-\frac{R}{L_{n_i}}+\frac{1}{2}\frac{R}{L_{T_i}}+\frac{1}{Z}\frac{R}{L_{n_z}}\right)-0.33P_B f_c\frac{R}{L_{T_i}}\right]$$

Pinch — Diffusion



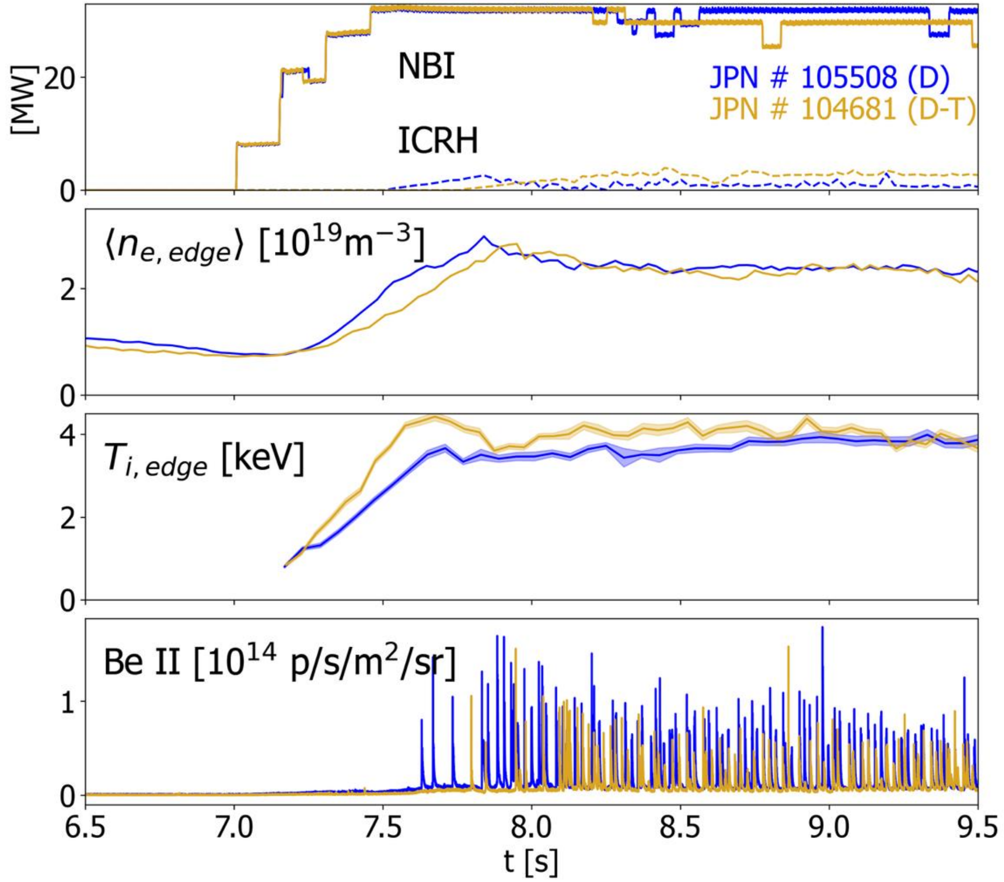
- Strong peripherical neclassical W screening observed in JET in D (A.R. Field et al, NF 2023) and DTE2 (J. Hobirk et al, NF 2023)
- **Scenario further optimized to improve screening condition :**
  - ✓ Lowering plasma current for further reduction of n_e
  - ✓ Tailoring of gas injection for diagnostic coverage optimization and time occurrence and size of first ELM
  - ✓ Increase of B_t in DT to account for lower L-H power threshold in ELM timing

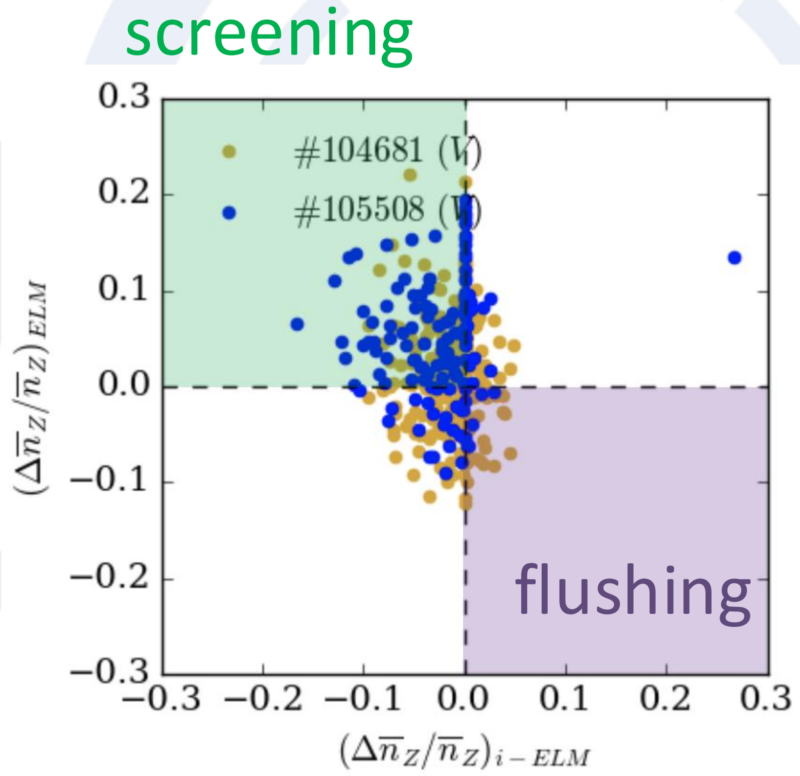
See D. King, regular poster Wednesday 15/10 AM

Operation with low W concentration and W screening

JET

- **Stronger W screening experimentally observed** from bolometry measurements in optimized scenario (D. King, this conference)
- NC computation via FACIT Code (D. Fajardo PPCF 2023) **unable to reproduce** the observed experimental screening (A. R. Field, submitted to NF): collisions with mid-Z impurities not accounted for? non-local effects? increased SOL screening?

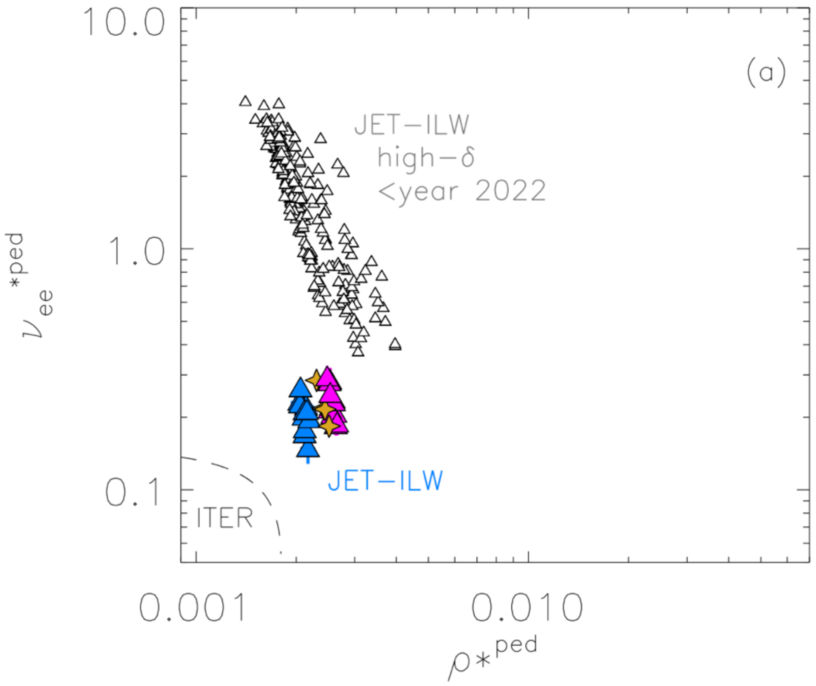


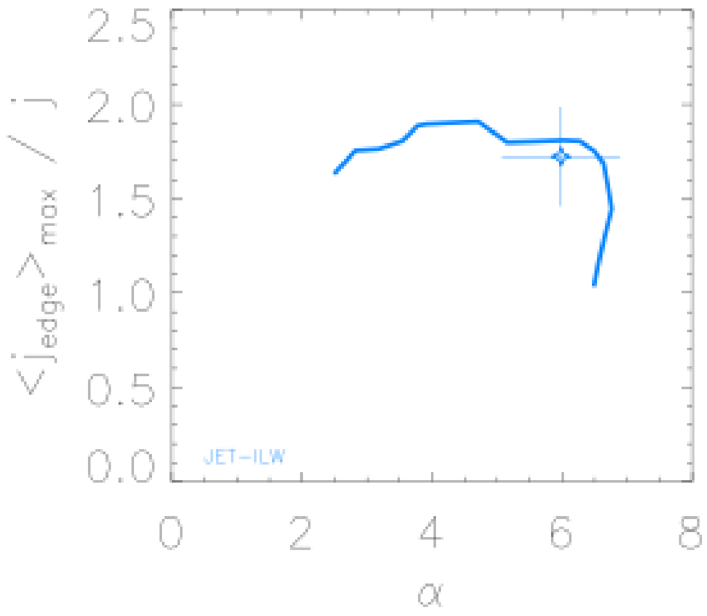


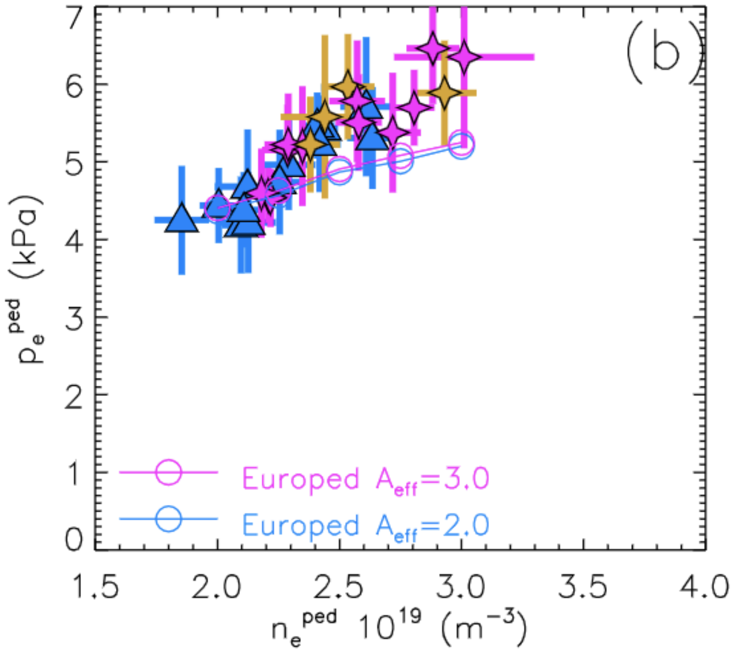
See D. King, regular poster Wednesday 15/10 AM

Peeling-limited pedestal investigations

- Efforts done to:
  - approach ITER-relevant $\nu^{*,ped}$ and $\rho^{*,ped}$
  - reach peeling limited pedestals (required high q95 operation)
  - validate pedestal predictions in these conditions in D, DT/ and T-rich” and emphasize the Europed results





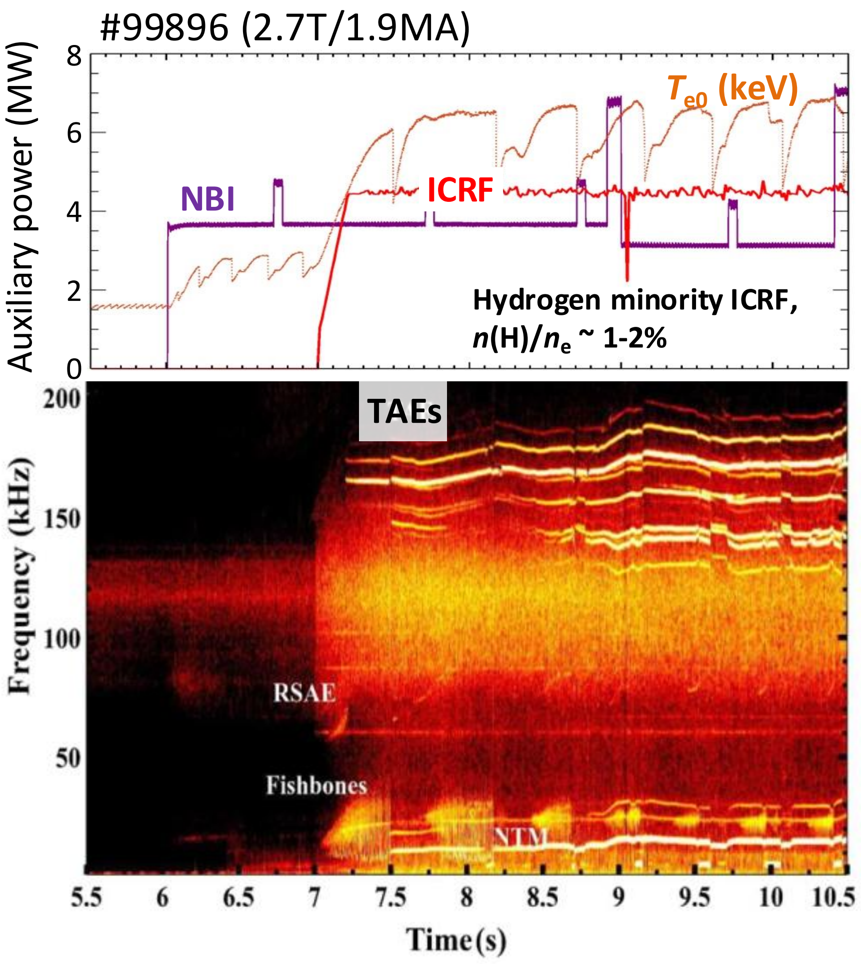


- Observed **positive trend of $p_{e,ped}$ with $n_{e,ped}$ w/o degradation as $n_{e,sep}/n_{e,ped}$ increases**
- **Pedestal pressure increase at higher A_{eff}** due to the stabilizing effect of an increased pedestal density in peeling limited plasmas.

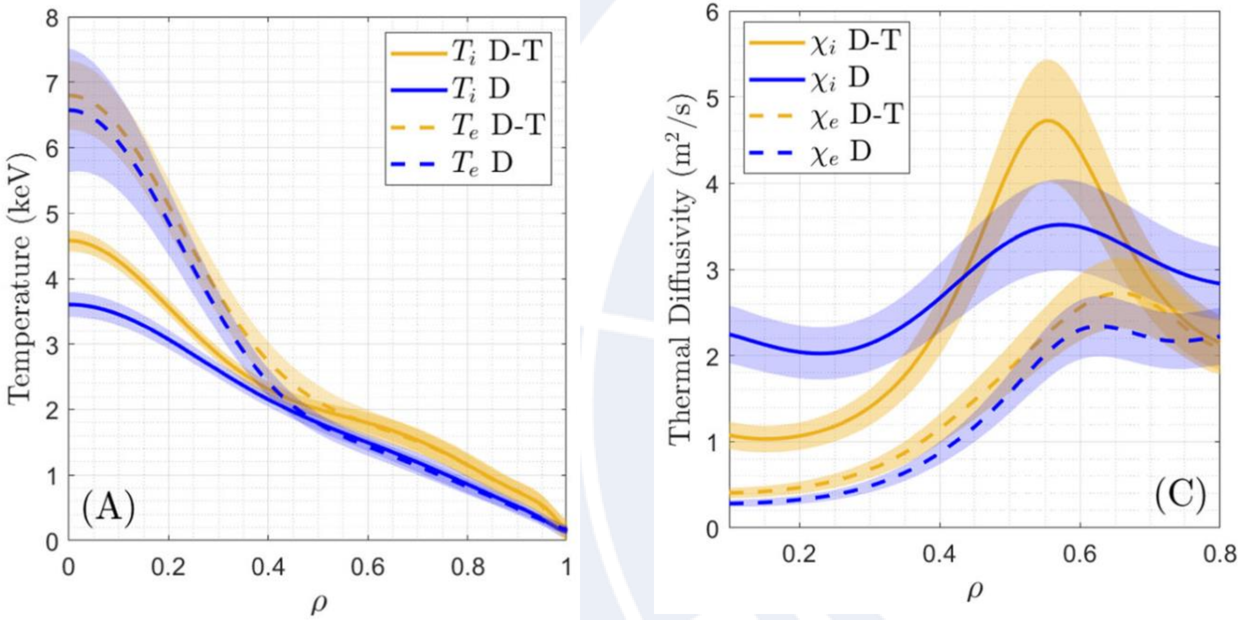
L. Frassinetti et al, NF 2025 and Regular oral 18 Oct 2025, 09:30-

MeV-range fast ions can improve thermal ion confinement

JET



D-T plasma with dominant **core electron heating** and **fast-ion-driven instabilities**



- **Improved** ion confinement in the core regions, supported by **local CGYRO and global GENE modeling**
- **Isotope effect**: fast-ion turbulence stabilization is stronger in D-T plasmas (than in D-D)
- Effect also observed in H-D plasma with MeV-range ^{3}He ions [J. Ruiz Ruiz et al., *Phys. Rev. Lett.* **134**, 05103 (2025)]

J. Garcia, Y. Kazakov et al., *Nature Comm.* **15**, 7846 (2024)
A. Di Siena et al., *Nucl. Fusion* **65**, 086019 (2025)
J. Varela et al., *Nucl. Fusion* **65**, 076044 (2025)

SAFE AND RELIABLE OPERATION

Extensive SPI exploitation in JET discharges

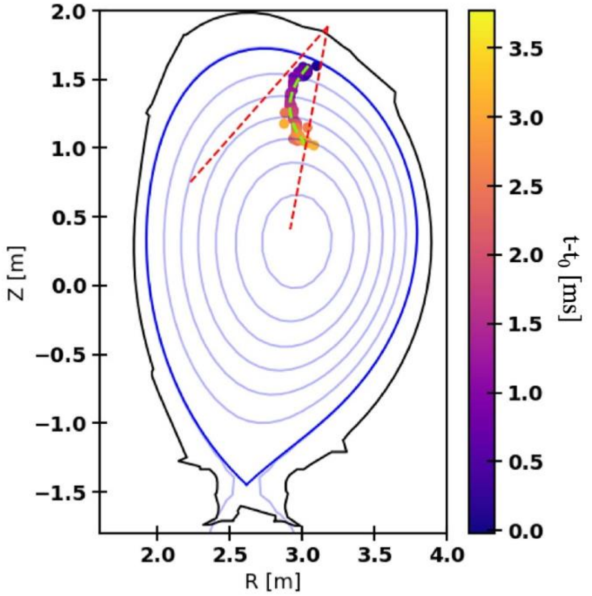
JET

- Plasmoid drift can reduce core density rise by 70%
- Modelling with JOREK reproduce experimental observation including the rocket effect, which pushes material to HFS
- Simulations show this can be suppressed with 2% neon doping of the pellets

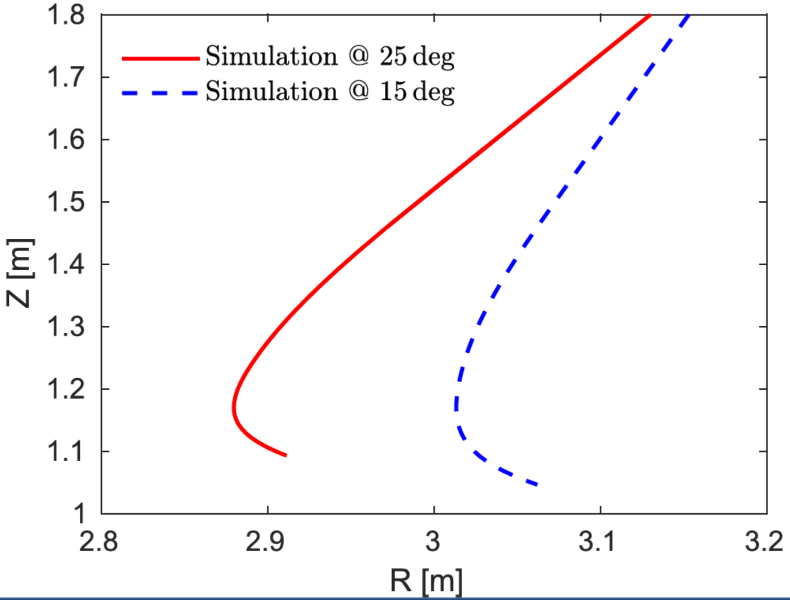
(Kong NF 2024)

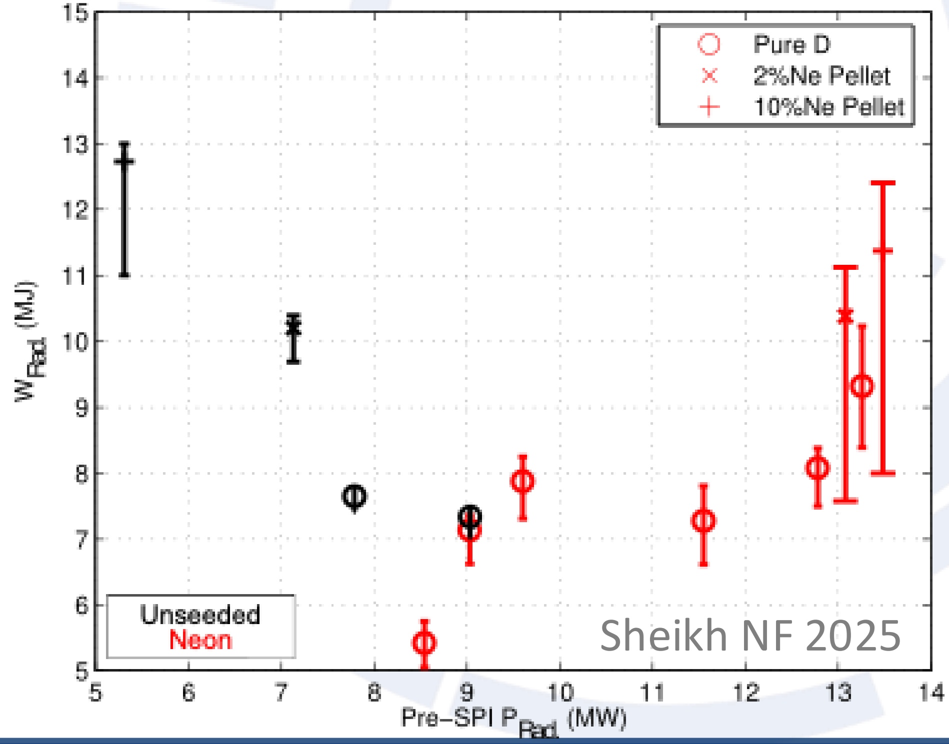
- Plasma with impurity seeding can enhance the efficacy of thermal and EM load mitigation with SPI → Seeded impurities enhance radiated energy (W_{rad}) in the mitigation sequence by ~25%

Experiment

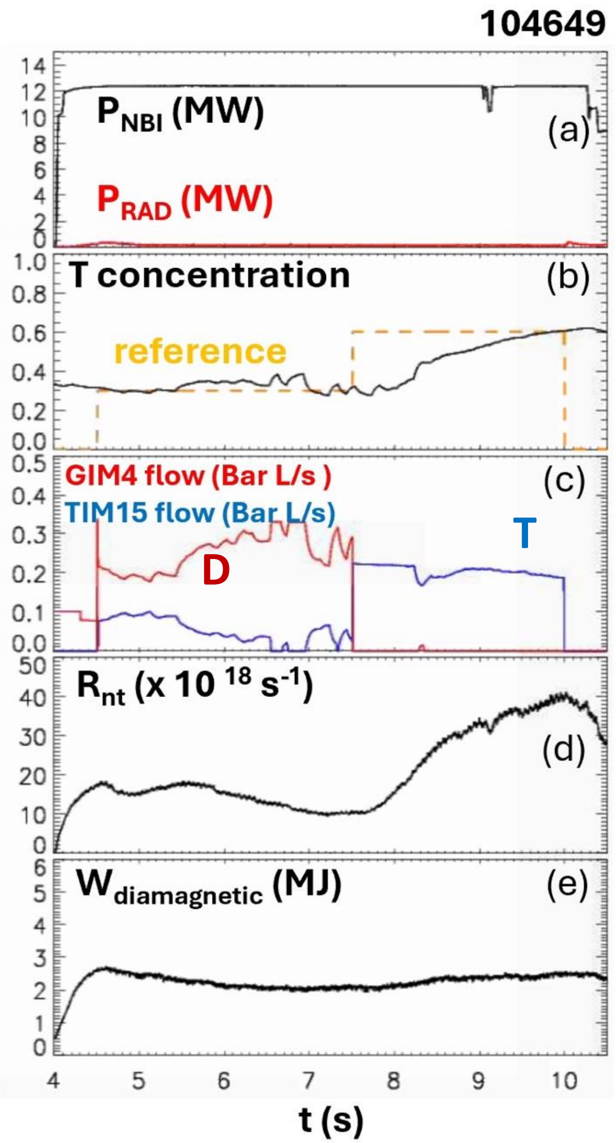


Simulation



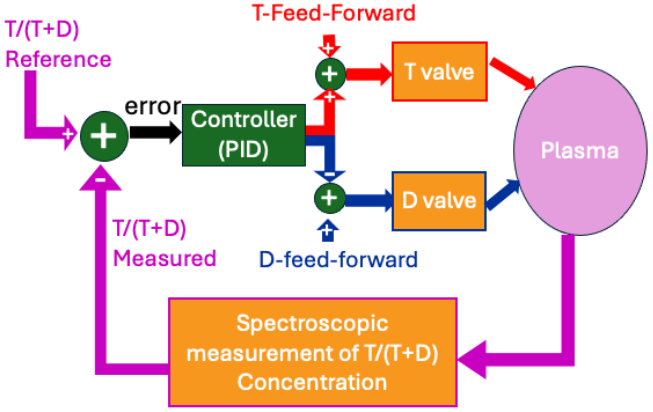


DT mixture control experiments at JET DTE3, 1.4MA/1.7T



Several real time controllers implemented in view of DT operation

- XPR vertical position control used for XPR
- Non performing pulse real time detector (DUD)
- H/L power threshold control during H mode exit
- **D/T isotope concentration real time control**



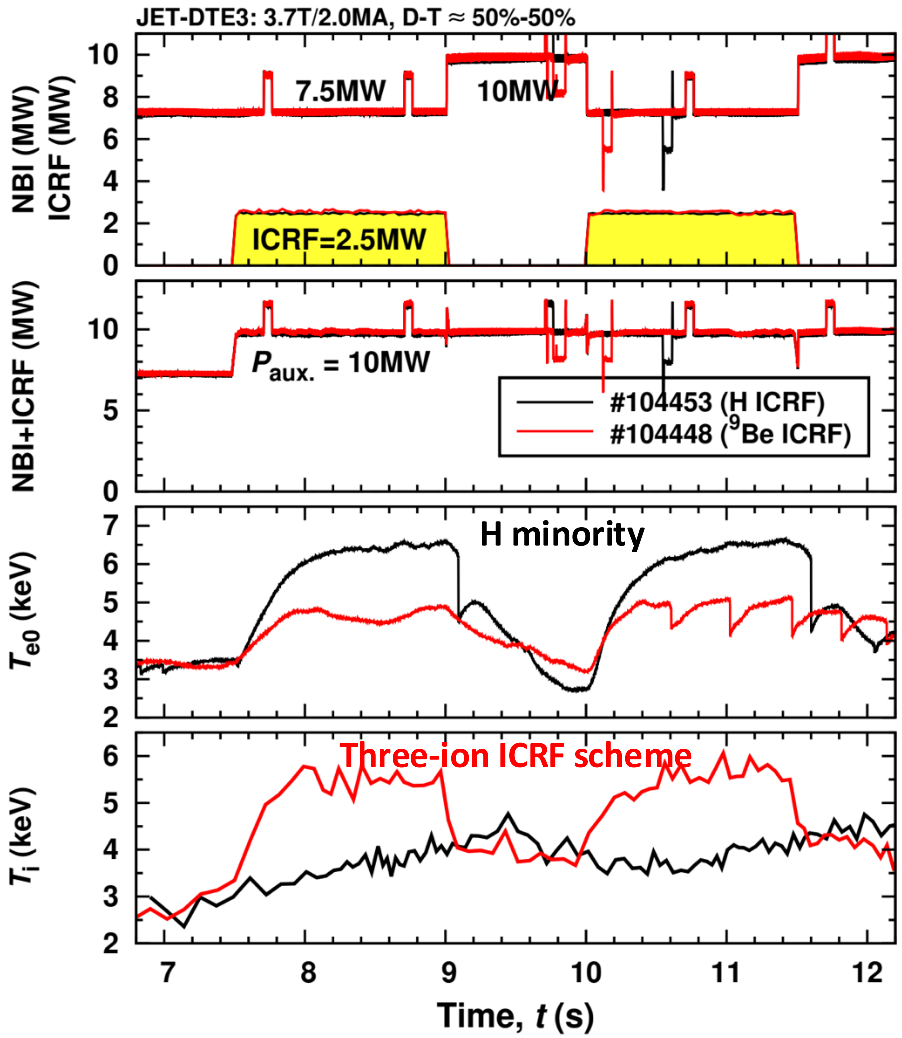
See M. Baruzzo, regular oral 17 Oct 2025, 12:00
See L. Piron, regular poster 16 Oct 2025 AM
M.Lennholm PRX Energy 25
K.Kirov NF 25

Further development of ITER-relevant ICRF schemes

JET

Several ITER-relevant ICRF scenarios further developed in DTE3, both in H-mode and L-mode

- $\omega = \omega_{ci}(^3He) = 2\omega_{ci}(T)$ (M. Mantsinen et al., EPS-2024)
  - Intrinsic ^3He concentration: ~0.2-0.4%
- $\omega = \omega_{ci}(D)$ (E. Lerche et al., this conference)
  - Operated both in H-mode and L-mode plasmas
- Three-ion ICRF scheme with ^9Be and Ar impurity ions (Y. Kazakov et al., this conference; A. Chomiczewska et al., this conference)
  - L-mode: stronger T_i increase than with H minority scheme
  - Tested in combination with Ar; T_i increase observed with argon levels up to ~0.1%



Fuel retention in JET DT operation : towards quantitative estimate

Global Particle Balance

- Challenging (low retention level with JET ILW, complex T handling system)
- No isotope effects evidenced in global particle balance between D and DT
- Modelling of gas distribution during in vessel gas balance experiments
- **T accountancy expected to be completed in spring 2026**

See D. Matveev, regular oral 16 Oct 2025, 17:50
A. Widdowson, NF 2025

Fuel retention in JET DT operation : towards quantitative estimate

JET

Global Particle Balance

- Challenging (low retention level with JET ILW, complex T handling system)
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Local Particle Balance (during campaign): LID-QMS

- Extensively used during Cleaning and final D campaign
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M. Zlobinski, NF2024

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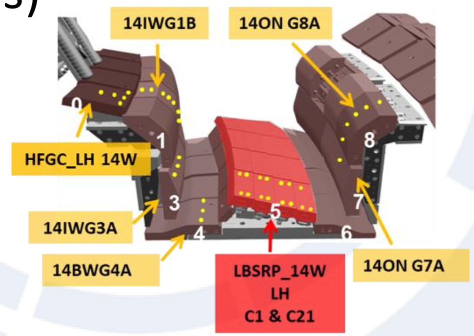
Local Particle Balance (Vented Vessel): LIBS

- Heavy Be deposition on inner divertor upper tiles as expected
- Fuel content correlated with Be
- Detection of T challenging (efficient cleaning + D ops + disruptions)



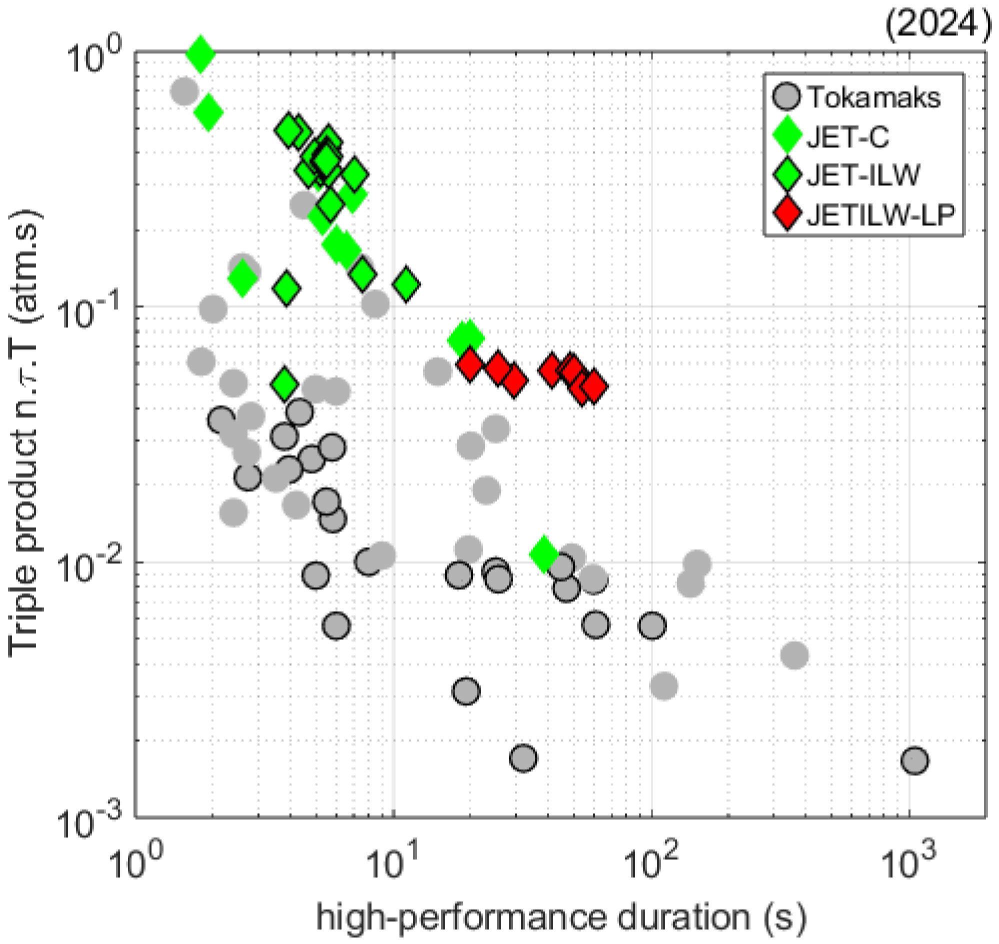
J. Likonen, S. Almaviva, PFMC2025, A. Hakola, LAPD2025

Laser-based diagnostics extensively used in JET DT environment for measuring fuel retention, providing invaluable operational experience for ITER

BEYOND JET LIMIT

Long H-mode discharges in JET-ILW

JET



See X. Litaudon, regular poster 16 Oct 2025, PM
E. Lerche, PPCF 2025

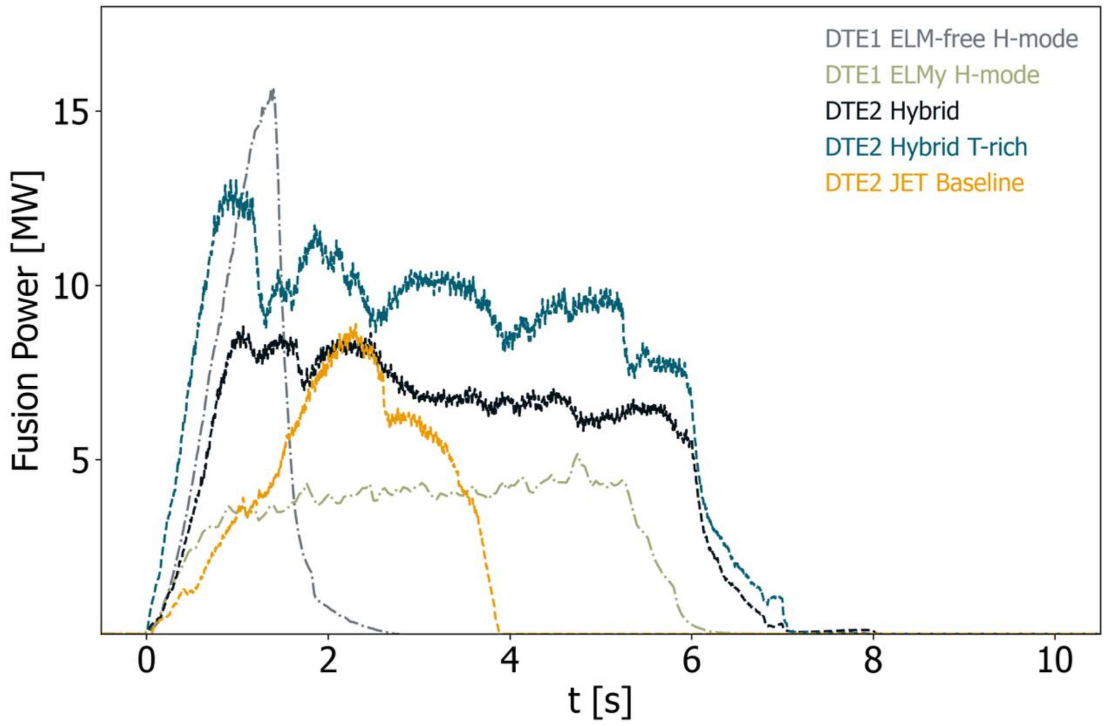
- H-Mode plasma operation extend up to 60s in DD
- Extended present high-performance triple product pulse length in tokamak operation
- NBI + ICRH heating (P_{IN}~6MW)
- Operation performed within energy limit of inertially cooled divertor
- No impurity accumulation, no MHD
- T_e ~ T_i (ion heating from NBI)
- Good performance: W_{dia}=1.7MJ, t_E=270ms
- Input energy = 322MJ (standard operation limit = 315MJ)

→ Pulse duration limited by engineering (not physics) constrains

Overall performances and energy record

Despite being physics driven, effort devoted to revisit record energy scenario at higher P_{ICRH}:

- Increased resilience to high-Z impurity
- Increased DT fusion due to D acceleration by ICRH
- Confirmed the reproducibility of the scenarios



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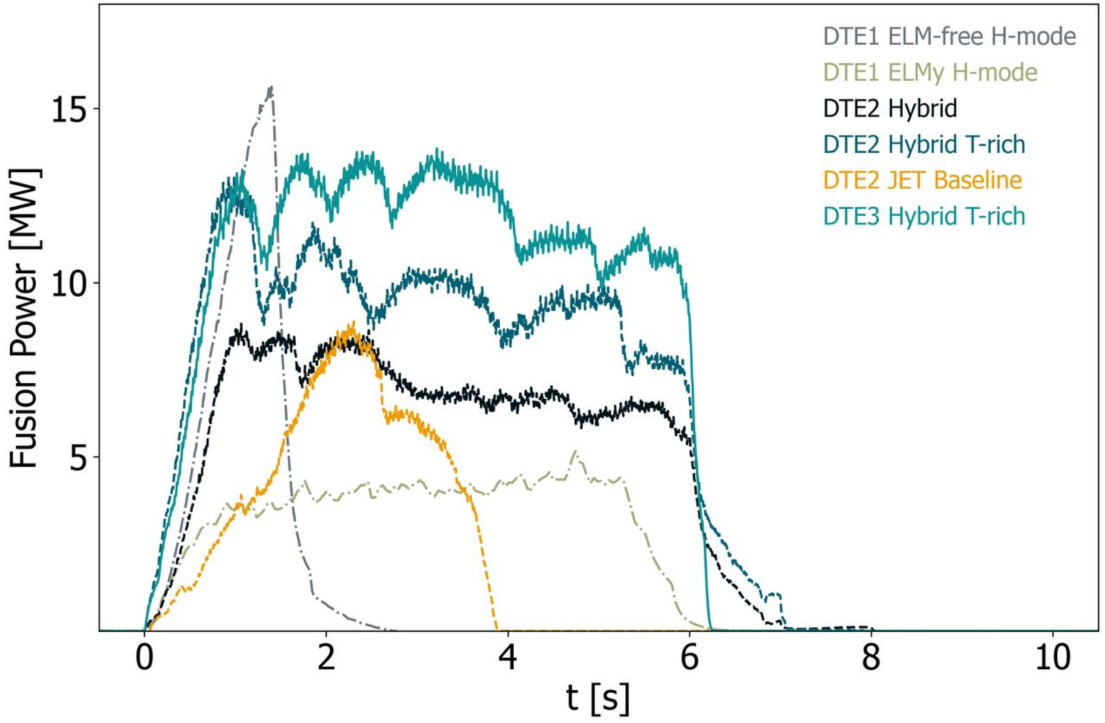
- New Fusion Energy record achieved 69 MJ with consistent work towards increase of high-performance duration



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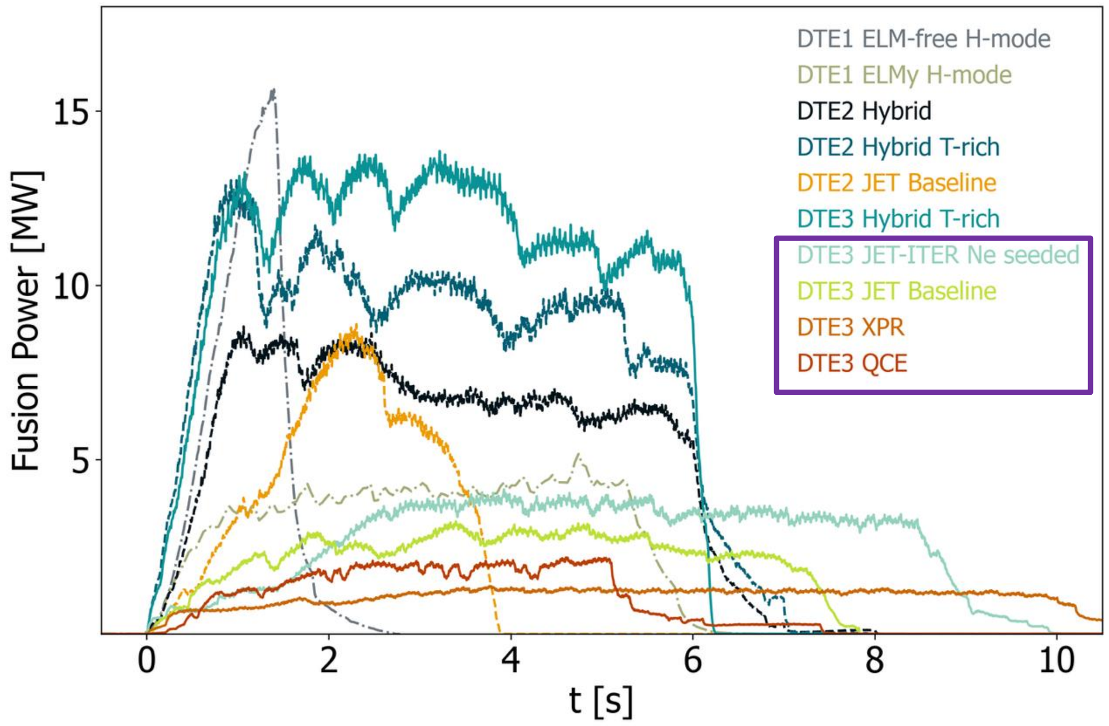


Plasma not optimized for performance and exploring domain where high P_{fus} not attainable on JET

The last DD and DT JET campaign

Last DD and D-T (DTE3) operation expanded our physics understanding and technological operation confidence in nuclear environments in preparation of ITER and DEMO

In preparation for ITER:

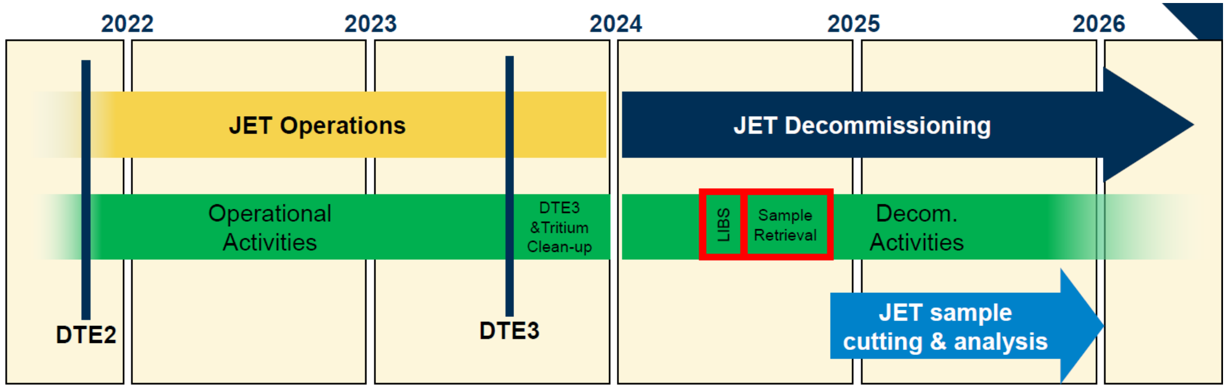
- Seeded JET-ITER baseline scenario extended dataset for modelling validation
- Increased physics understanding on key aspect as peeling limited in metallic devices and screening of high-Z impurities
- Consolidate the understanding of plasma scenario confirming predictive capabilities

In preparation for DEMO:

- Scale up most promising no-ELM/small-ELM scenario confirming accessibility also in D-T
- Confirm accessibility and controllability of XPR with mixed impurities in both DD and DT operation

For future nuclear fusion devices:

- SPI exploitation in large devices at high current
- Developed real-time control techniques (detachment control, isotope/burn control)
- Progressed the studies on tritium retention and clean-up, with valuable lessons learned



After 40 years of successful experiments JET has entered the shutdown & decommissioning phase

JET Scientific and Operational team vital and active: experimental database will represent a cornerstone for model validation / robust extrapolation towards next step devices

JET contributed oral presentations IAEA FEC 2025

JET

- S. Sharapov *Fusion alpha-particle-driven alfvén eigenmodes in jet d-t plasmas: experiments and theory* Regular Oral 17 Oct 2025, 11:20
- R. Villari, *Neutronics for iter nuclear phase: insights and lessons learnt from jet dt operation,* Regular oral *17 Oct 2025, 14:00*
- H. A. Kumpulainen, *Simulation of tungsten erosion and edge-to-core transport in neon-seeded JET plasmas*, Regular Oral 17 October 2025 16.50
- M. Dunne, *The physics of ELM-free regimes in EUROfusion tokamaks; Pedestal tailoring via ballooning modes*, Regular Oral 15 Oct 2025, 16:30
- D. Matveev, *Analysis of fuel retention and recovery in JET with Be-W wall,* Regular Oral 16 Oct 2025, 16:10
- C. Giroud, *High performance elm-free semi-detached scenario sustained at high-current in JET DTE3,* Regular Oral 15 October 16.10
- M. Baruzzo, *Plasma control experiments in JET Deuterium-Tritium plasmas,* Regular Oral 17 Oct 2025, 12:00
- L. Frassinetti, *Peeling limited pedestals in JET, MAST-U and TCV: effect of density and isotope mass in deuterium and tritium-rich plasma on pedestal structure and stability and validation of pedestal predictions for ITER*, Regular Oral 18th October 2025 09:10
- C. F. Maggi, *Core and edge transport of scenario with internal transport barrier in tritium and deuterium-tritium plasmas in JET with Be/W wall,* Regular Oral 18 Oct 2025, 08:30

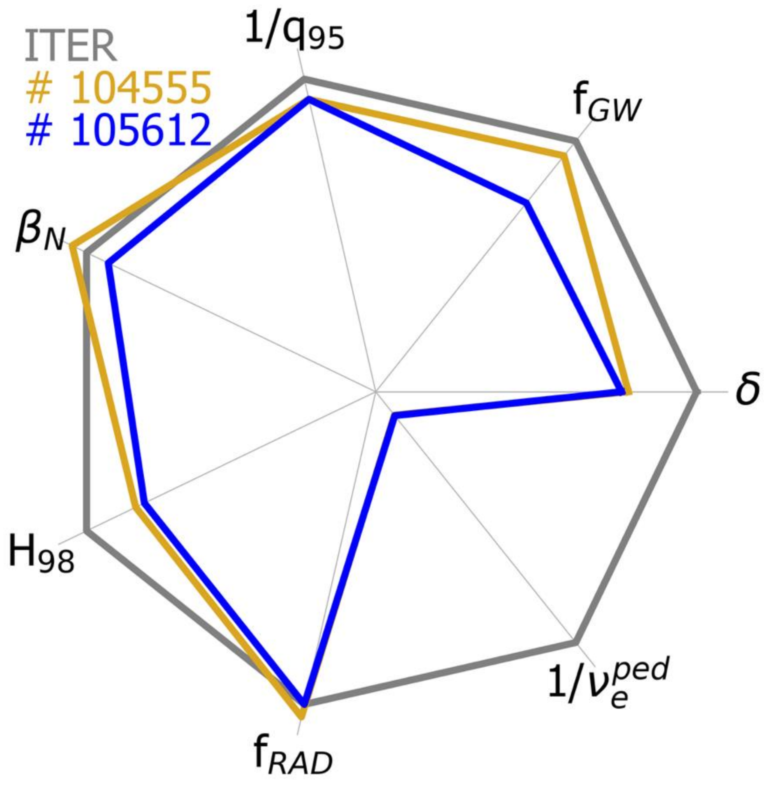
JET related posters presentations at IAEA FEC 2025

JET

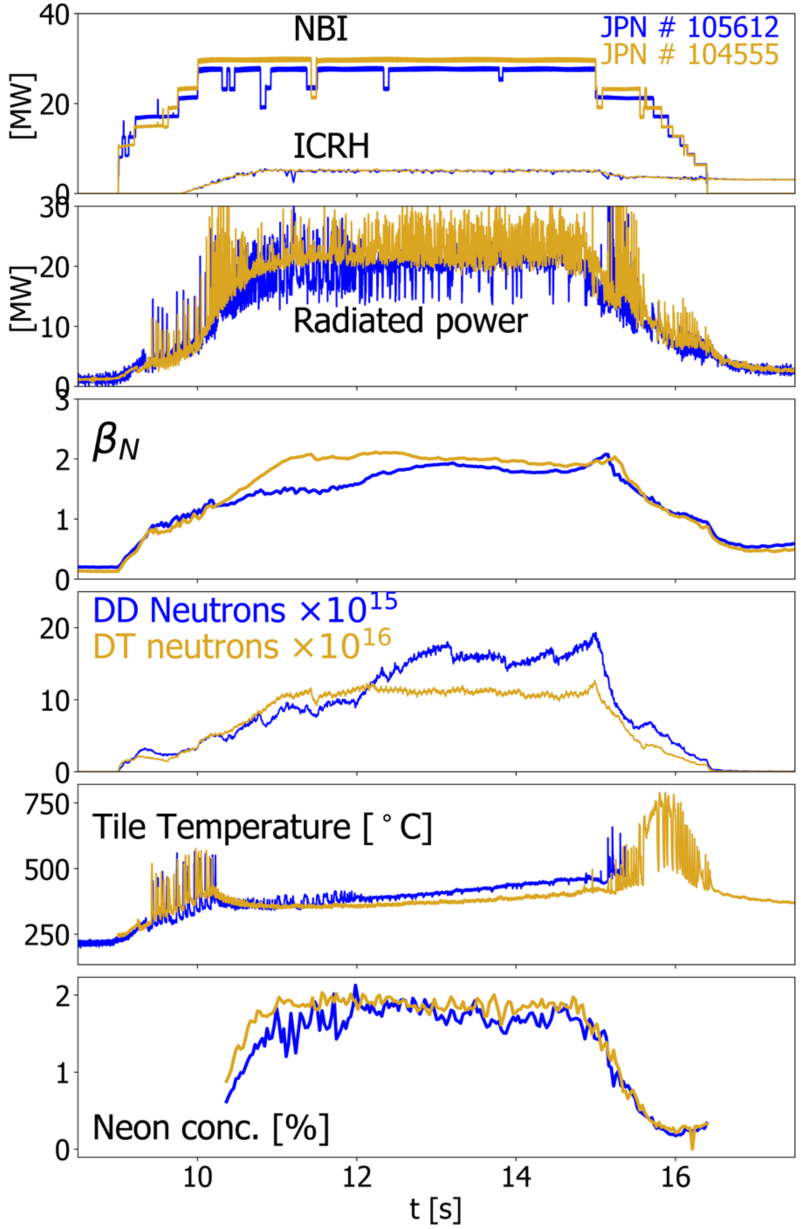
- V. Plyusnin *Runaway electrons in jet – summary on re data after the end of jet operations* Regular Poster, *17 Oct 2025 AM*
- Y. Kazakov, *Insights from fast-ion physics studies on JET in support of JT-60SA and ITER rebaseline,* Regular Poster 15 Oct 2025 PM
- C. P. Perez von Thun, *Key dependencies for the radial density decay in the far-SOL of JET H-mode plasmas,* Regular Poster 15 Oct 2025 PM
- H. Sun, *Impact of plasma boundary on machine operation and the risk mitigation strategy on JET* Regular Poster 15 Oct 2025 PM
- I. Ivanova-Stanik, Integrated numerical analysis of impurity transport and sources for high current-high power baseline pulses with t in JET-ILW, Regular Poster 16 Oct 2025 AM
- A. Chomizewska, *Investigation of impurity behaviour in three-ion icrf scenarios in H-D and D-T plasmas at JET* Regular Poster, 16 Oct 2025 PM
- A. Bock, *Flux Pumping in ASDEX Upgrade, JET and JOREK,* Regular Poster 16 Oct 2025 AM
- D. Silvagni, *Scaling of the H-mode electron separatrix density based on engineering parameters from C-Mod, AUG and JET data*, Regular Poster 15 Oct 2025 PM
- M. Kong, *Experimental analyses and numerical modelling of trace neon shattered pellet injection discharges on JET,* Regular poster 17 October 2025, AM
- L. Zannisi, *Data efficient digital twinning strategies and surrogate models of quasilinear turbulence in JET and STEP,* Regular poster 16 October 2025 AM
- T. J. Tala, *Dimensional Isotope Scaling of Heat and Particle Transport between JET Deuterium and Tritium L-mode Plasmas*, Regular Poster Regular Poster, 15 October 2025 AM
- L. Piron, *Machine learning aided neutron yield for dud detection based on JET and TFTR deuterium-tritium plasmas,* Regular Poster 16 October 2025 AM
- D. King, *JET hybrid scenario development in D-T for impurity screening study,* Regular Poster 15 October 2025, AM
- E. Lerche, *Heating d ions to optimal D-T fusion energies with ICRF waves,* Regular Poster, 16 October 2025 PM

Backup

JET-ITER baseline with seeding, achievement w.r.t. ITER



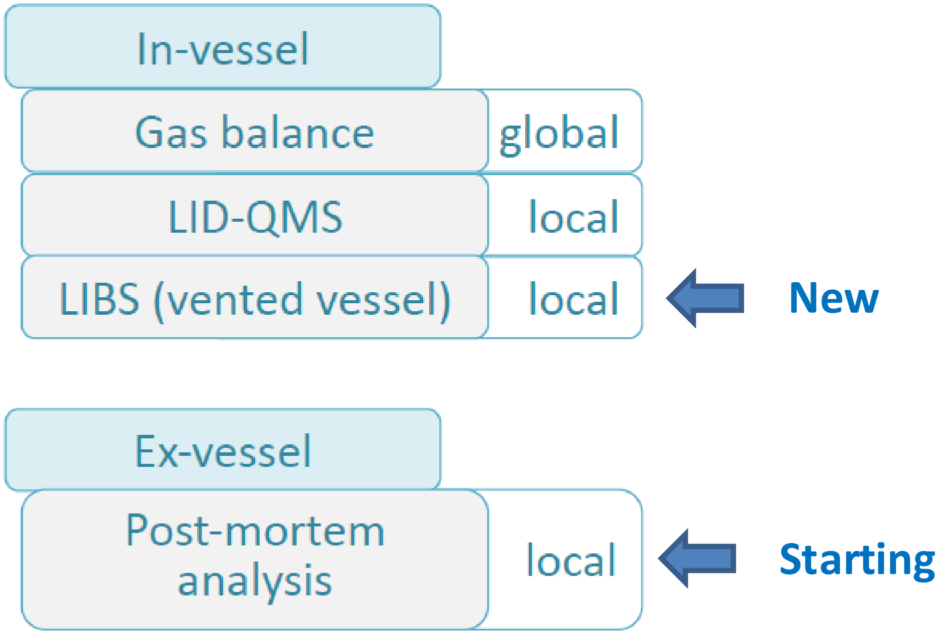
Closely matching ITER requirements apart from pedestal collisionality, unfeasible in present day device whenever operated at high Greenwald fraction/radiation fraction



Fuel retention in JET DT operation : effort ongoing towards quantitative estimate

JET

Fuel retention measurements



[Courtesy A. Kappatou, EPS 2024]

- Majority of sample retrieval completed in August 2025

T accountancy

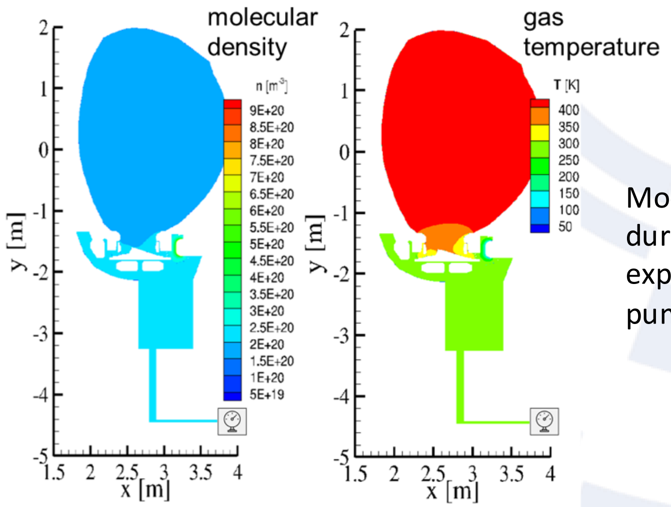
- Expected to be completed in spring 2026

See D. Matveev, regular oral 16 Oct 2025, 17:50

Global particle balance

- Proved to be challenging during DTE2-DTE3 (low retention level with JET ILW, complex T handling system)
- Qualitative analysis : no isotope effect evidenced in global particle balance between D and DT
- Faster decrease in outgassing rate observed for T compared to D: concentration and depth profile of T vs D ?
- Effort to refine particle balance through modelling of gas distribution during in vessel gas balance experiments

[A. Widdowson, NF 2025]

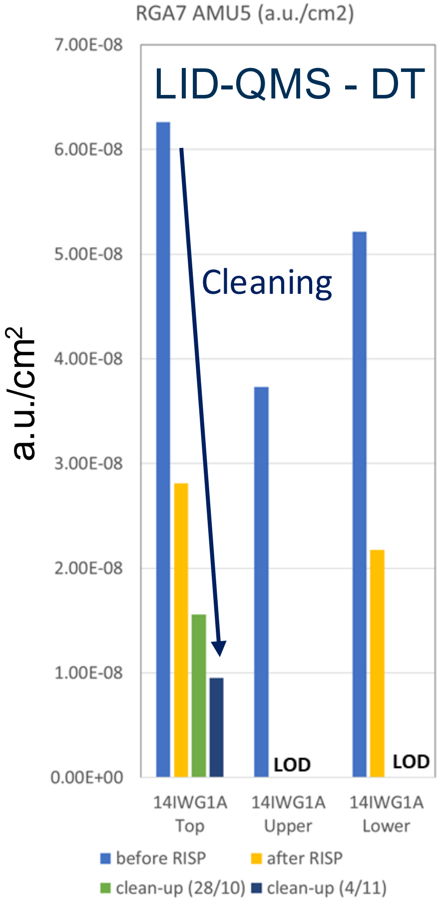


Modelling of the gas distribution during an in vessel gas balance experiment with no active pumping with the DIVGAS code

Extensive use of laser based diagnostics for fuel retention measurements

OPERATION												
2023									2024		
m	j	j	a	s	o	n	d		s	o	n
Deuterium				DTE3		Cleaning	Deuterium	… Vent …		LIBS	

LID-QMS

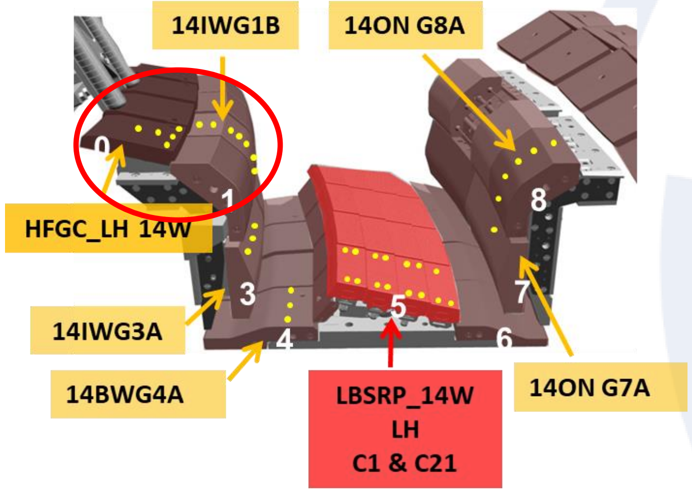


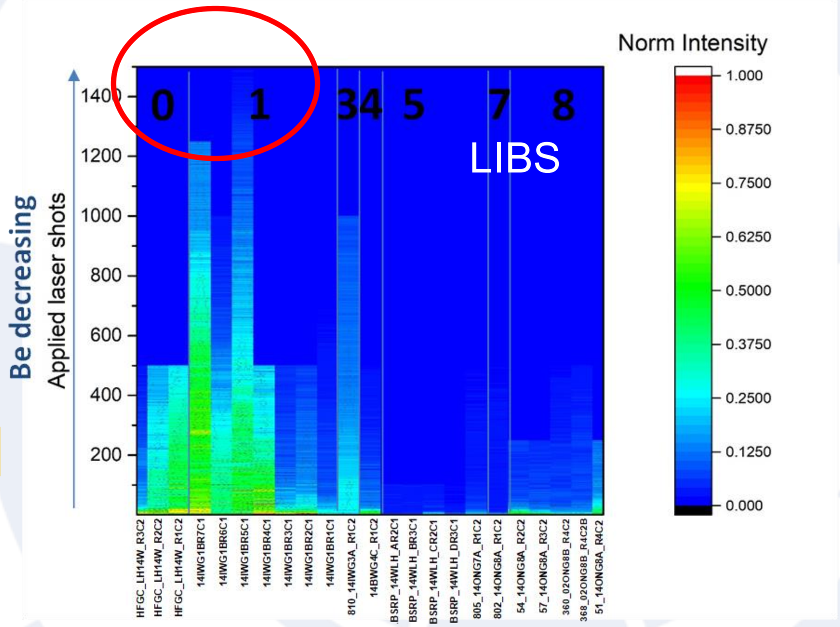
LOD : limit of detection

- Discrimination between D/T demonstrated
- Efficiency of cleaning monitored (RISP)

[M. Zlobinski, PFMC2025]

[A. Widdowson, NF 2025]



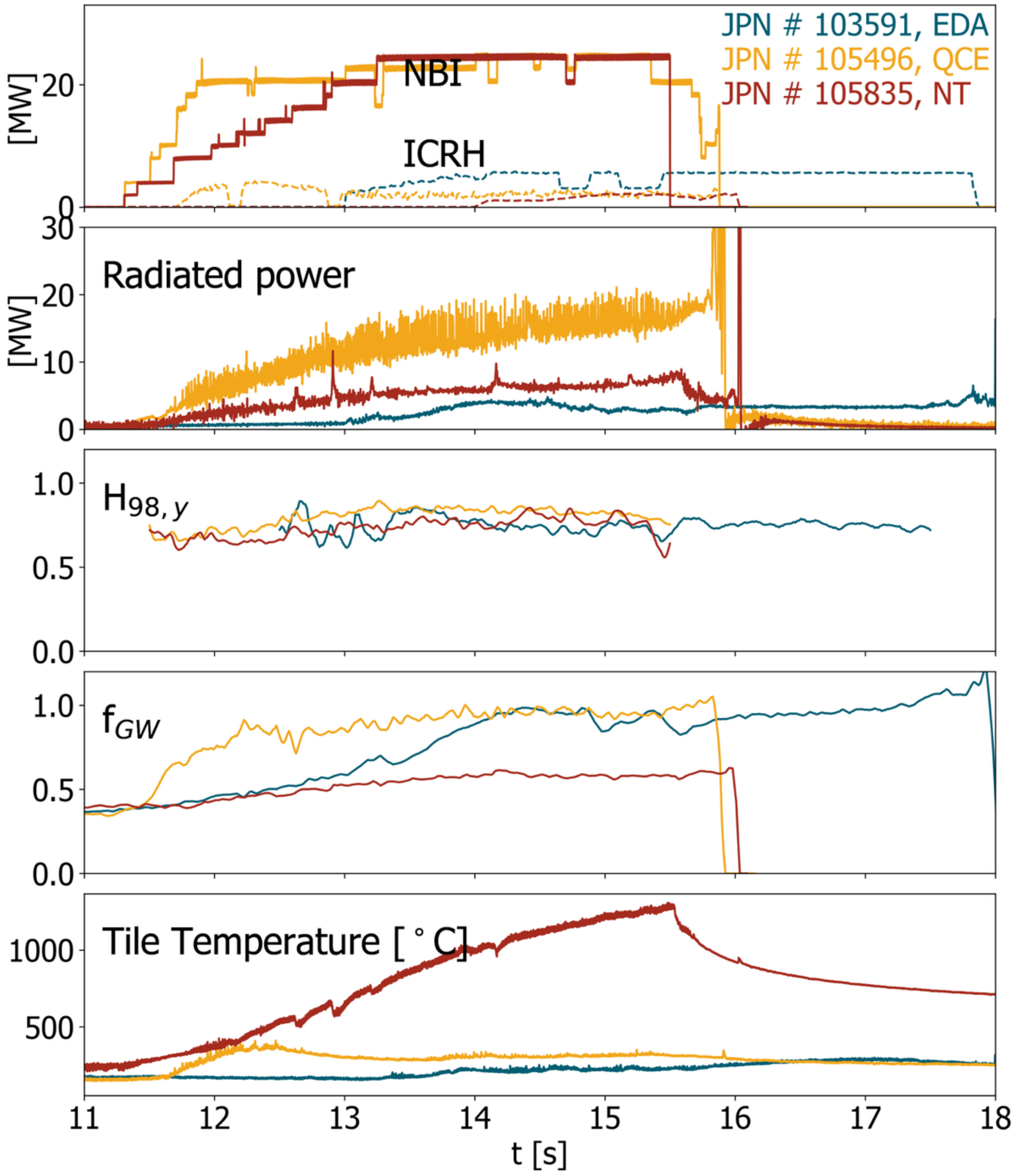


[J. Likonen, S. Almaviva, PFMC2025] [A. Hakola, LAPD2025]

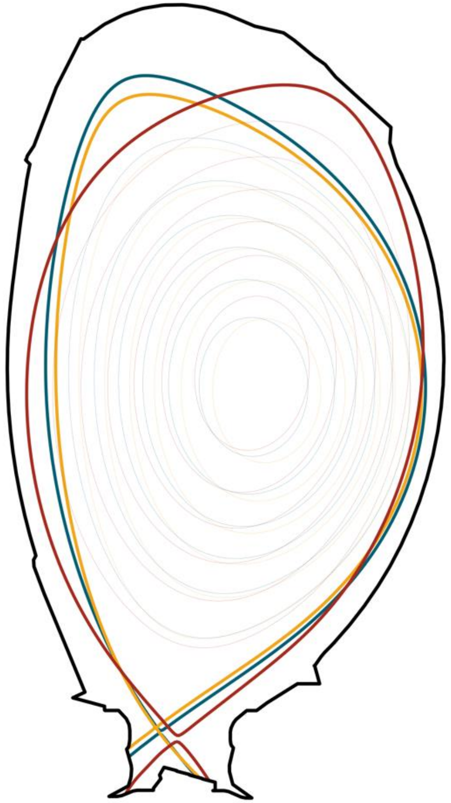
- Heavy Be deposition on inner divertor upper tiles as expected
- Fuel content correlated with Be
- Detection of T challenging (efficient cleaning + D ops + disruptions)

Extensive use of both systems : operational experience for ITER

Several small ELM scenarios for DEMO



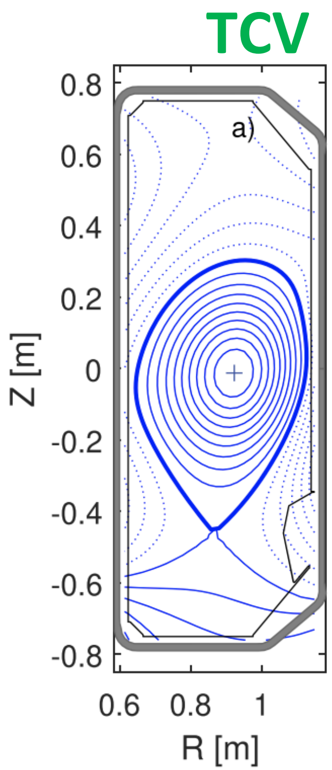
- Several other no-ELM scenarios explored as candidate for operation in next step devices as QCE/EDA and NT
- Investigation motivated by step-ladder approach to test scenarios accessibility understanding and extrapolation capabilities

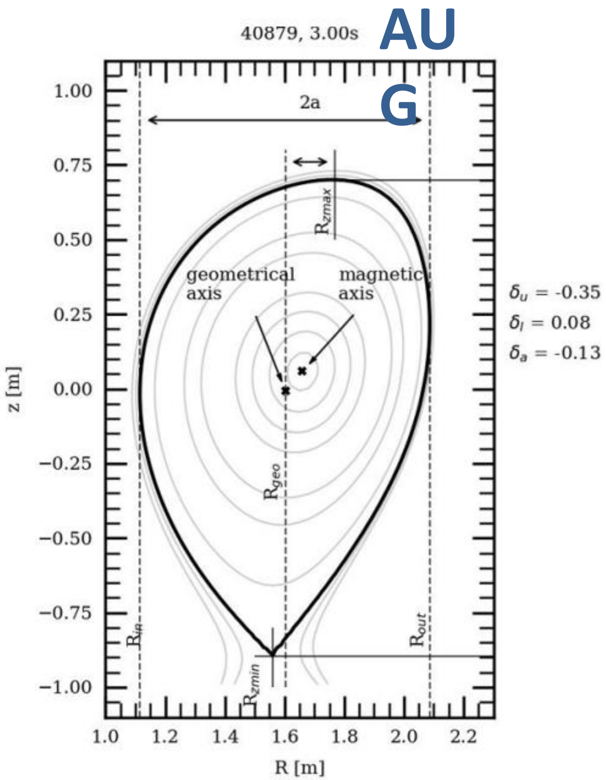


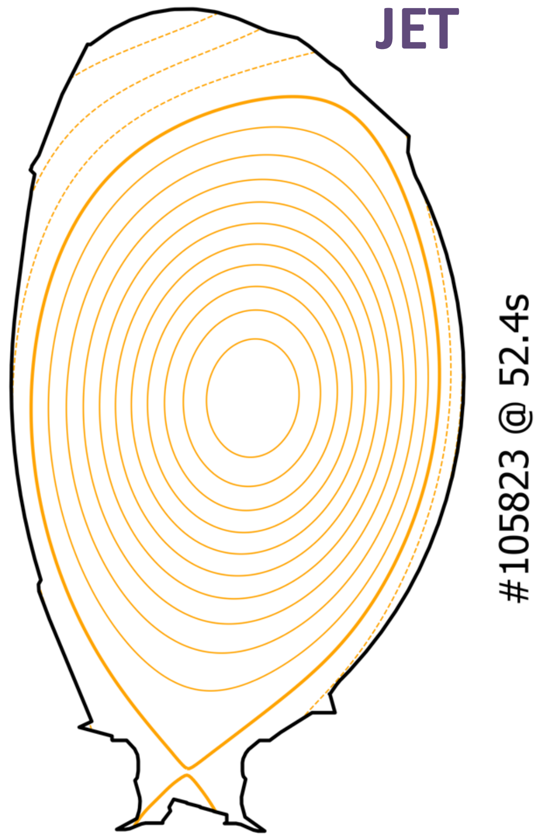
Negative Triangularity as alternative DEMO scenario

- Extensive investigation on the confinement capabilities of negative triangularity plasmas explored in all EUROpean devices (TCV, AUG, MAST-U,JET, WEST (planned for Dec 2024))
- Work performed in order to establish shaping dependence, transport properties, exhaust capabilities
- TCV device, thanks to the extreme shaping capabilities used as test bed to understand and extend the shapes explored in the other devices limited by operational constraints

- Non X-point triangularity sufficiently negative to avoid access to 2nd ballooning stability region and thereby H-modes □ improved L-mode
- X-point triangularity: free to optimize divertor / remote maintenance
- Surprising difficulties in achieving detachment via density ramp in Ohmic NT plasmas [O. Fevrier PPCF 2024]
- Aspect ratio R/a > 2.5
- No significant ρ^* effects



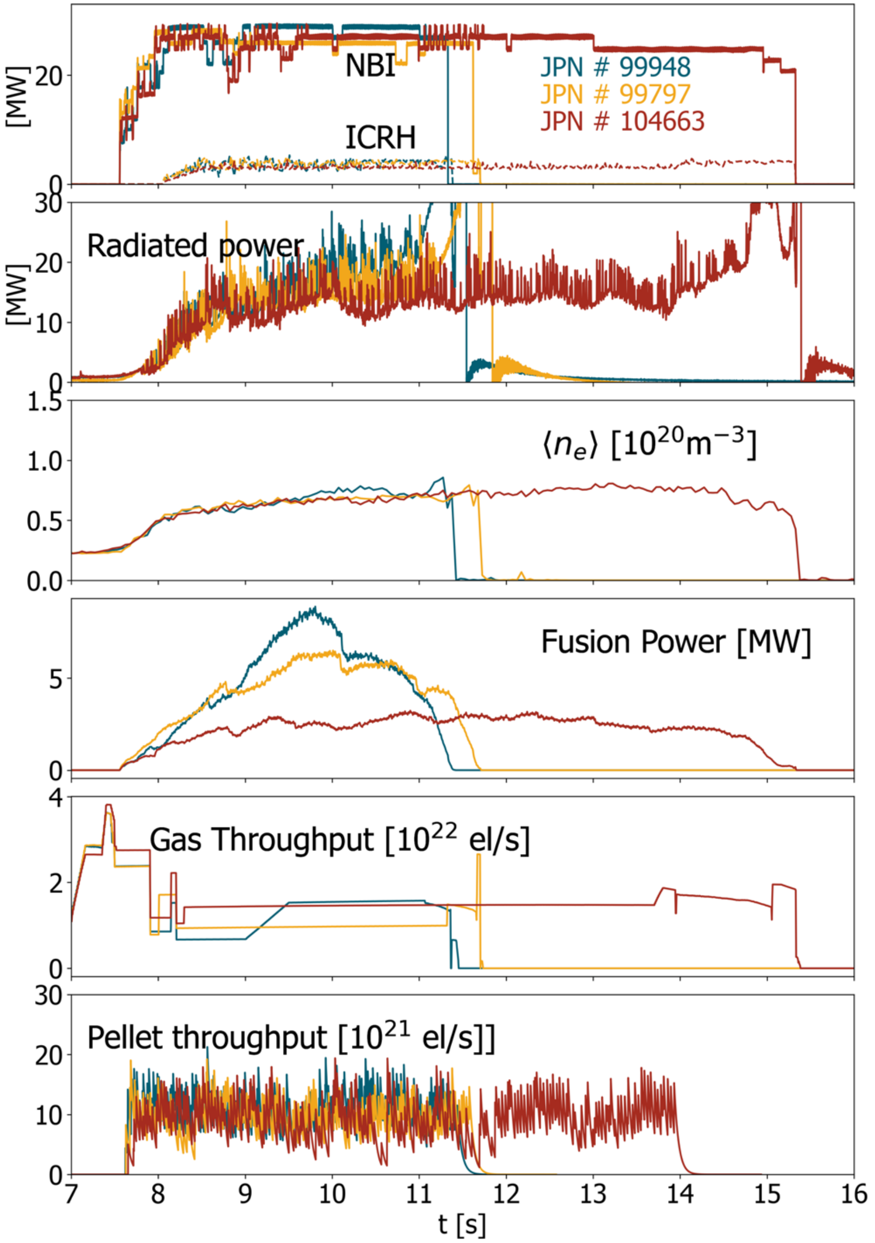




Extended stationarity of JET Baseline plasma scenario

- 3.5MA D-T baseline sustained scenario (> 5 s) at high power (~ 10 MW) not attained in DTE2 (Garzotti PPCF 2025) :
  - Machine underpowered
  - Pedestal and average density higher in DT than in D
  - ELM activity (and W flushing) ceasing earlier in DT than in D for the same particle throughput.

- Operation extended to 5 s in DTE3 at 3MA:
  - With reduced power (to avoid deleterious MHD)
  - With increased gas fuelling (⍰ benign compound ELMs)
  - With limited performances (not optimized)

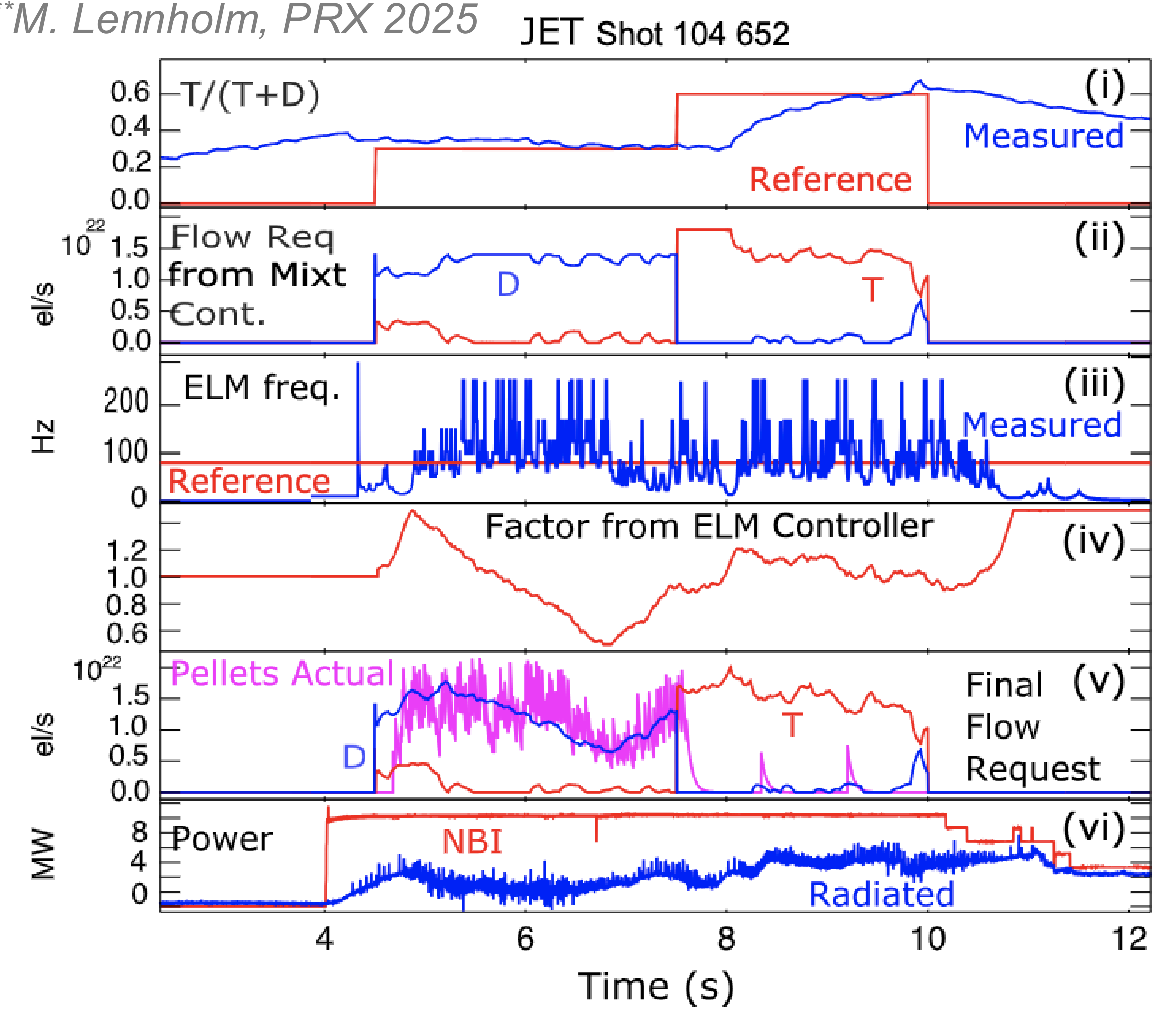


See L. Garzotti, EPS 2025 invited talk and PPCF to be submitted

D/T real time control experiments in JET

Several real time controllers have been developed on purpose for DT operation, or have been modified in order to cope with it

***M. Lennholm, PRX 2025*

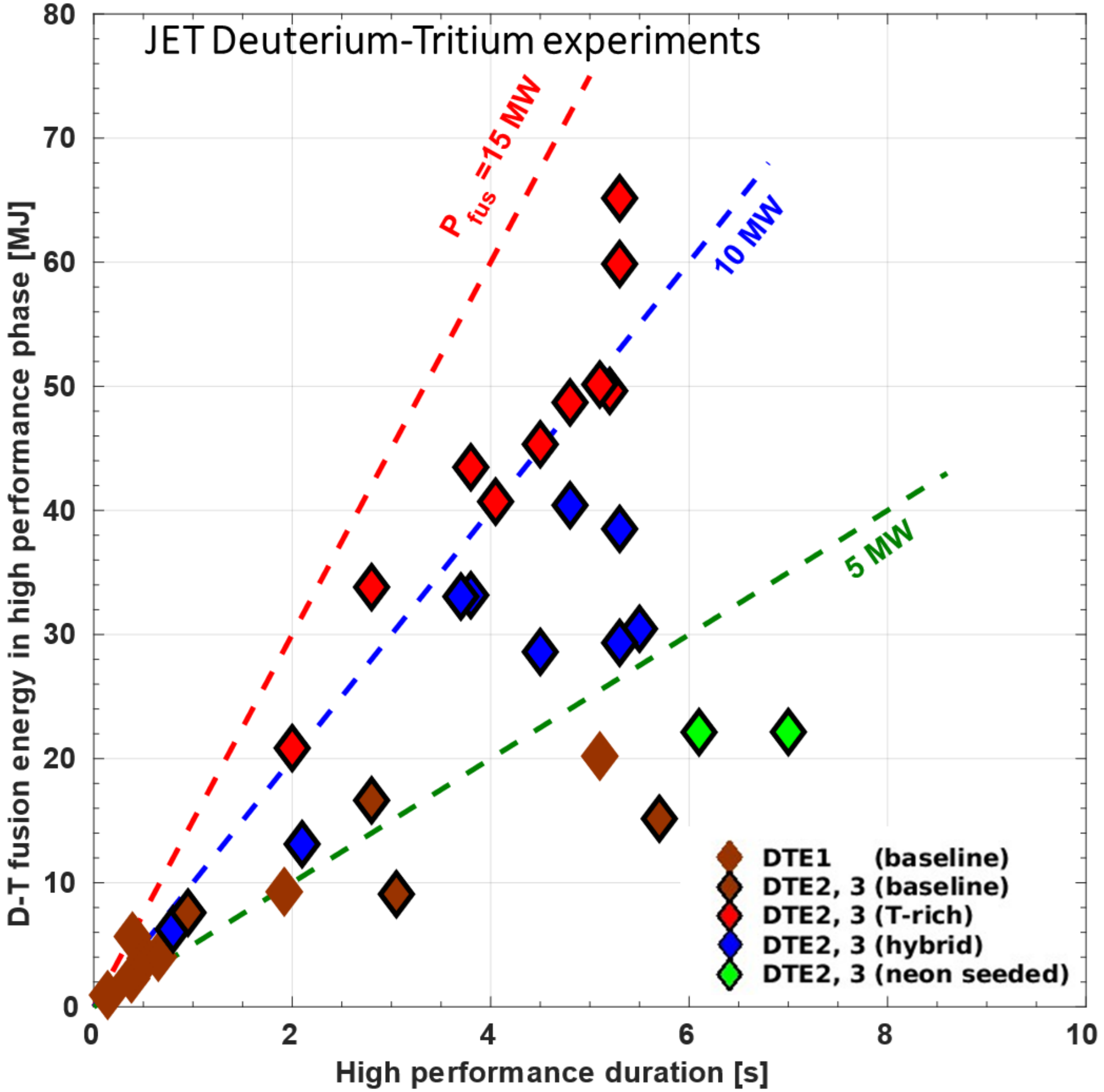


- Isotope mixture control in plasmas with reactor DT fuel mixes
- Fusion Power Responds, confirming that core Tritium fraction is changing as desired.
- The mixture control combined successfully with ELM frequency control gas fueling could be replaced seamlessly with pellet fueling

Several other controllers have been implemented as

- ✓ D/T isotope concentration real time control
- ✓ XPR vertical position control
- ✓ Non Performing pulse real time detector (DUD)
- ✓ H/L power threshold control during H mode exit

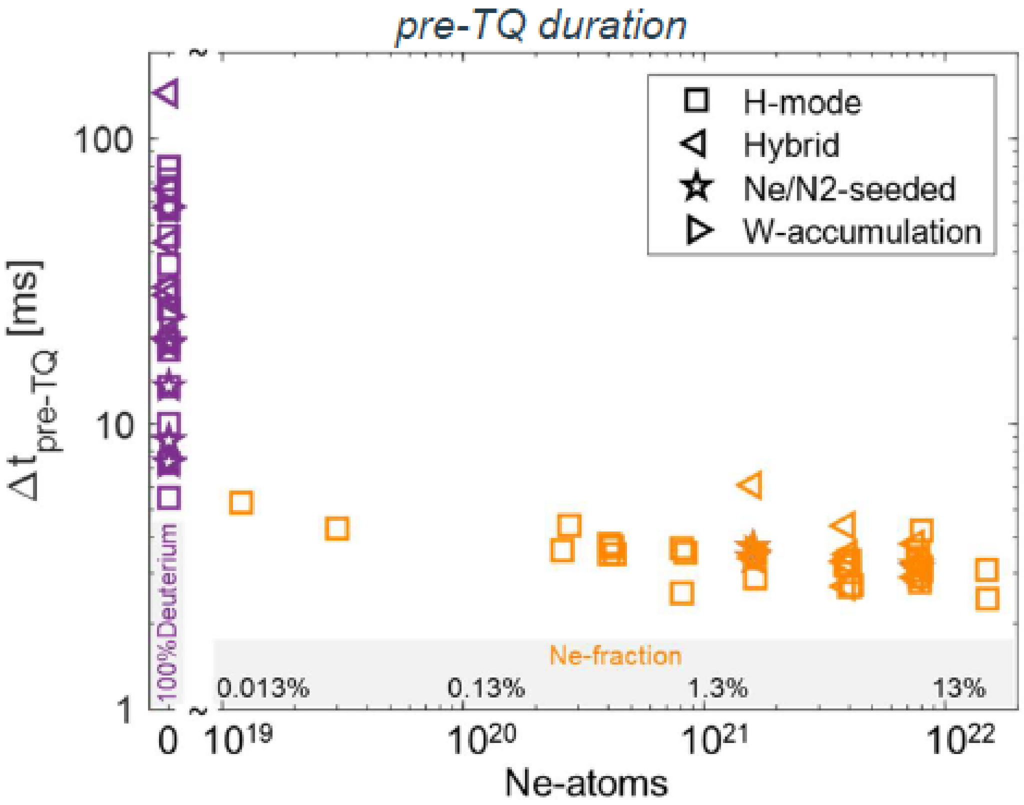
See M. Baruzzo, regular oral 17 Oct 2025, 12:00


JET Deuterium-Tritium experiments
P fus =15 MW
10 MW
5 MW
D-T fusion energy in high performance phase [MJ]
High performance duration [s]
DTE1 (baseline)
DTE2, 3 (baseline)
DTE2, 3 (T-rich)
DTE2, 3 (hybrid)
DTE2, 3 (neon seeded)

Last JET deuterium experiments in December 2023

JET

In 2023, JET has devoted 50 sessions to disruption & RE mitigation experiments with SPI



S. Jachmich, EPS 2024

 Smallest Ne-doped SPI is reliably shortening the pre-TQ to ~5ms in various conditions

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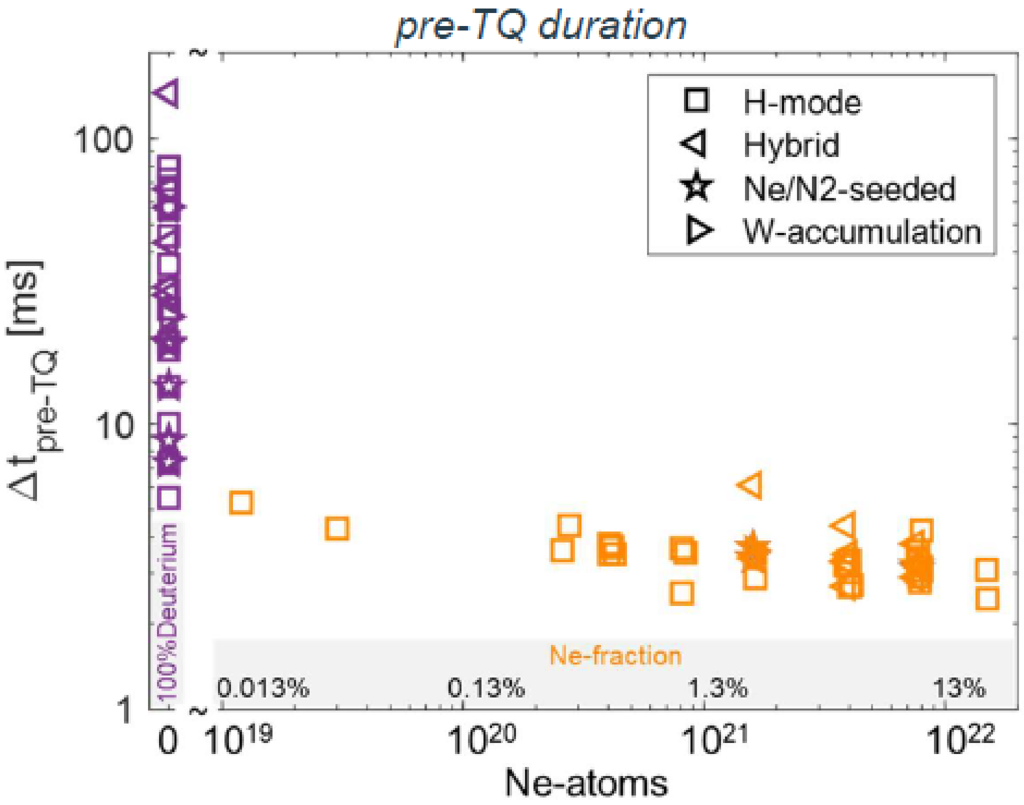
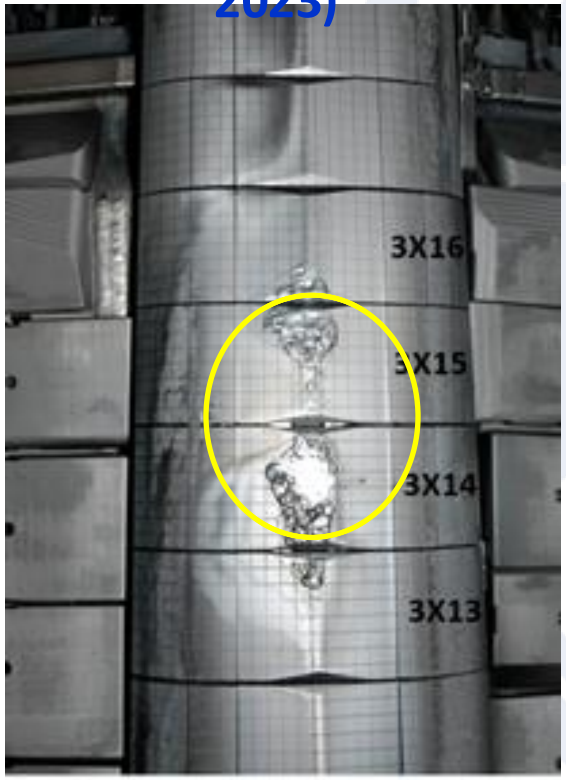


S. Jachmich, EPS 2024

Intentional RE impact on the Be inner wall (18th Dec. 2023)



Courtesy I. Jeput

⮚ Smallest Ne-doped SPI is reliably shortening the pre-TQ to ~5ms in various conditions

SPI related publications

JET

- **Journal papers published:**
- Sheikh, U., et al., (2025). Impact of Impurity Seeding on Shattered Pellet Injection Mitigations on the Joint European Torus. Nuclear Fusion, 65(3), 036035.
- Kong, Mengdi, et al. "Interpretative 3D MHD modelling of deuterium SPI into a JET H-mode plasma." Nuclear Fusion 64.6 (2024): 066004.
- Piron, Lidia, et al. "Radiation asymmetry in JET disruption mitigation experiments with shattered pellet injection." Plasma Physics and Controlled Fusion 66.8 (2024): 085007.
- Bodner, G., et al. (2025), Multi-Device Analysis of Thermal Quench Duration and Pellet Penetration with Implications for Shattered Pellet Injection in ITER, Nuclear Fusion, 2025.
- Schoonheere, N., et al. (2024), Spurious Radiated Power Signal Following Massive Material Injections in JET and the Effect of Neutral Gas Pressure on Resistive Bolometers, Review of Scientific Instruments, 95(12), 2024.
- Gerasimov, S. N., et al. "Interaction of SPI pellets with plasma on JET and associated disruptions." Physica Scripta 99.7 (2024): 075615.

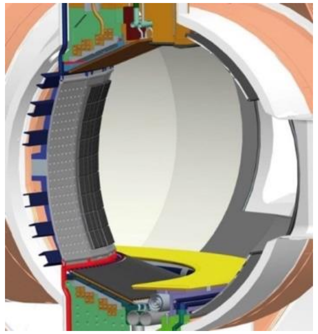
- **Journal papers in review:**
- Bonfiglio D., Hu D., Kong M., Nardon E., Artola F.J., Baylor L.R., Boboc A., Carvalho P., Gebhart T.E., Gerasimov S.N., Hawkes N.C., Hoelzl M., Jachmich S., Lee S.-J, Puglia P, Sheikh U., Silburn S., Stein-Lubrano B., Sun H., Sweeney R., Szepesi G, JOREK Team, JET Contributors. Validation of 3D MHD simulations of mixed Ne-D2 shattered pellet injection in JET. Nuclear Fusion (in review)
-
- **Conference papers:**
- Jachmich, S., et al. (2024), Validation of ITER Disruption Mitigation Physics on JET and ASDEX-Upgrade, 50th European Conference on Plasma Physics (EPS 2024), Salamanca, Spain, 2024.
- Reux, C., et al. (2024), Limits and Physics of the Runaway Electron Benign Termination Scenario, 50th EPS Conference on Plasma Physics (EPS 2024), Salamanca, Spain, 2024.
- Artola, F. J., et al. (2024), Current Quench Duration, Material Assimilation, and Plasma Re-Heating Studies for Shattered Pellet Injection Experiments in JET, 50th EPS Conference on Plasma Physics (EPS 2024), Salamanca, Spain, 1–5 July 2024

Towards the future of EUROpean program

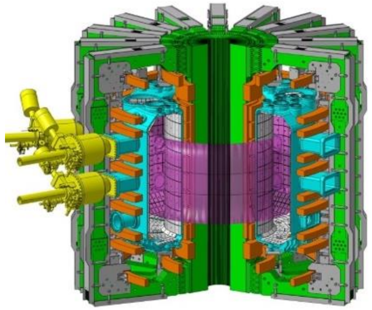
JET

AUG (DE)

WEST (FR)



TCV (CH)



MAST-U (UK)

JET (EU)

JT-60SA
Japan (Broader Approach)

COMPASS UPGRADE
Czech Republic

DTT
Italy