Preparation and execution of Deuterium-tritium experiments in JET with the ITER-like wall

J. Mailloux on behalf of JET contributors*
2016-2021: JET TFL for Integrated Operational Scenario
UKAEA JET science programme leader

*see the author list of list of J Mailloux *et al.* Nucl. Fusion 62 (2022) 042026
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J. Mailloux on behalf of JET contributors*

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JET

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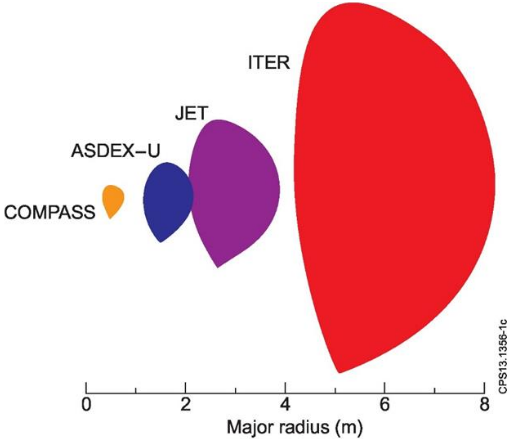
JET provides key contribution to ITER



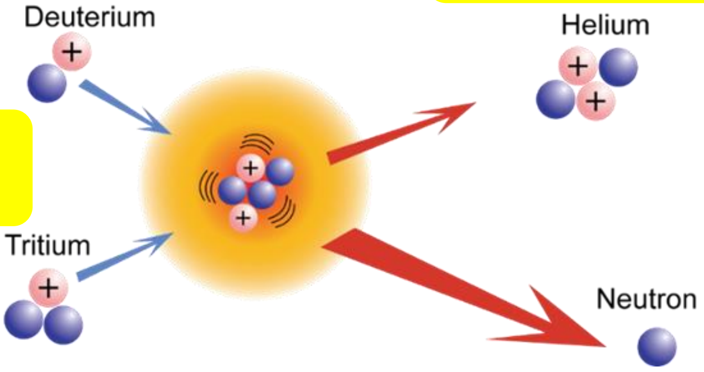
JET bridges gap from medium size tokamaks to ITER

With unique set of capabilities:

- Tritium handling
- ITER-like wall (ILW): beryllium & tungsten wall
- Plasma current up to 4MA & heating power up to 40MW
- ITER relevant D-D & D-T neutron fluence
- Shattered Pellet Injection
- Improved set of diagnostics

D-T: key step to prepare fusion power plant operation

Fuel of nuclear fusion reactors



alpha particle (α)
+3.5 MeV

Isotope effects

+14 MeV

D-T experiments inform:

- **Plasma physics & operation**
- First wall lifetime & fuel retention
- Material & components irradiation
- Tritium cycle
- Waste management
- Regulatory aspects

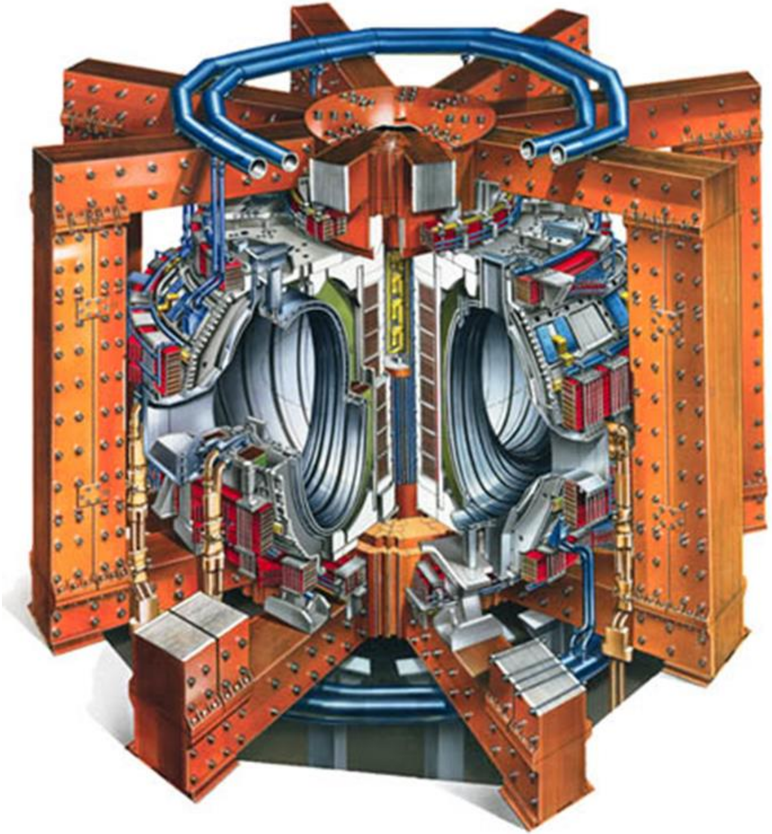
→ Impact design and preparation of nuclear power plants operation & decommissioning

Outline

1. JET operations
   - Motivation for JET-ILW
   - JET systems
   - T&D-T ops constraints
2. Preparation and execution of scenarios for sustained high fusion power
3. Some DTE2 results
   - Isotope impact
   - Integrated scenarios
   - energy record and alpha particle results

Summary

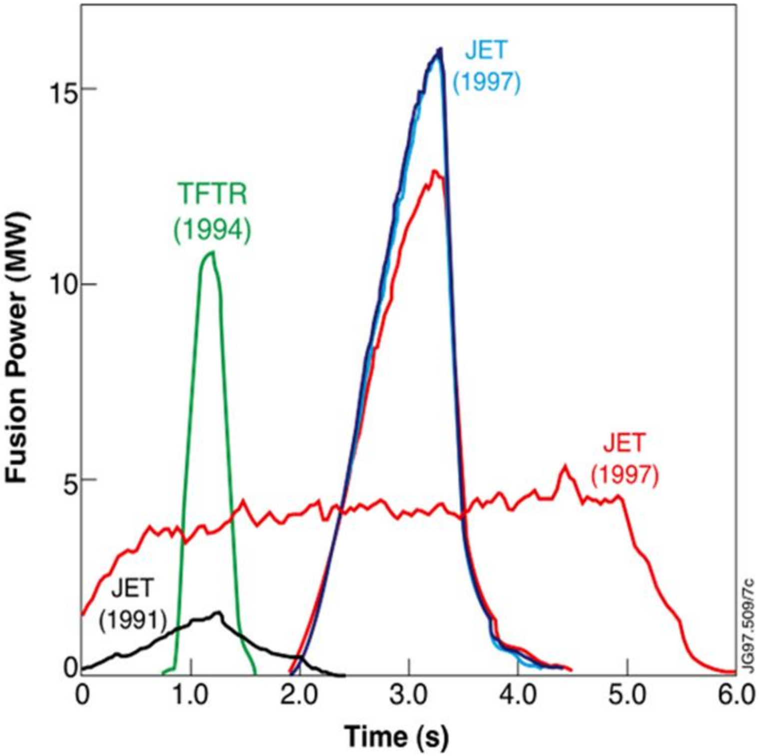
JET characteristics



Major / minor radius (m)	2.96 / ~0.8-0.9
Max plasma current (MA)	4.5 (3.5 in DTE2)
Max toroidal field (T)	3.9
Discharge duration (s) with high input power	Up to 20s flat top
Main fuel	H / D / T / He Pellets: H, D
Extrinsic impurities	N (not in D-T), Neon, Ar
Ion Cyclotron Heating with ELM resilience	~ 6MW / 25-56 MHz
Neutral Beam Injection after recent upgrade	≤ 34 MW (D / T) ≤10 MW (H) < 25 MW (He)

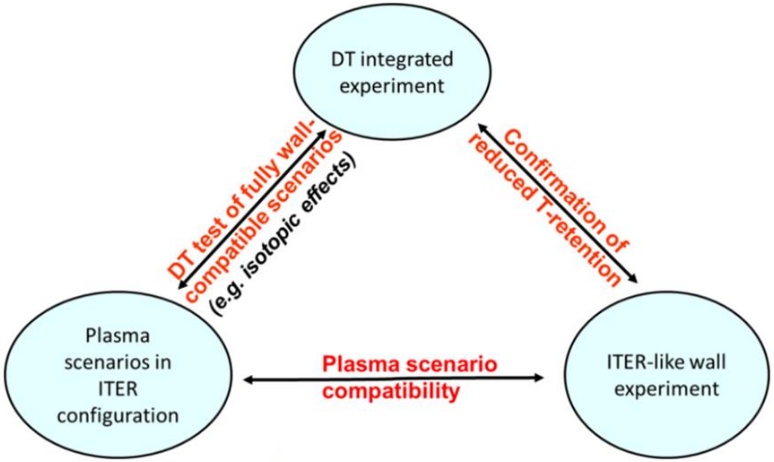
Previous D-T experiments

- Previous D-T experiments:
  - 1991 PTE - JET
  - 1994-96 TFTR (US)
  - 1997 DTE1 on JET
  - (2004 Trace T exp. on JET)
- Demonstrated:
  - D-T Fusion
  - Plasma behaviour affected by use of D-T mixture
  - Clear α effects seen on TFTR, but JET results ambiguous
  - Too high retention of tritium by carbon first wall components → impacted ITER decision of first wall materials



Plan for JET with ITER-like wall started 2006

- JET-ILW: W divertor & Be main chamber
- Key part of Europe's support to ITER
- Main goals:
  - Confirm reduced fuel retention
  - Assess compatibility with ITER relevant scenarios
  - **D-T integrated operation**
- Accompanied by several enhancements (e.g. heating power) & refurbishments



DT integrated experiment

DT test of fully wall-compatible scenarios

(e.g. isotopic effects)

Confirmation of reduced T-retention

Plasma scenarios in ITER configuration

Plasma scenario compatibility

ITER-like wall experiment

J. Paméla *et al.*, J. Nucl. Mater. 363–365 (2007)

JET operations: control room

Main roles:

- **Engineer in charge** ensure ops within safe limits
- **Session leader(s)** prepare & input pulse parameters
- **Scientific co-Ordinator(s)** lead experiment
- **Diagnostic co-Ordinator**
- **PDO** for RTCC
- **Operators** for HVPS, Heating and fuelling, Diagnostics, etc
- etc

First plasma in JET-ILW on 24th Aug 2011

Pulse preparation done well before the day of execution

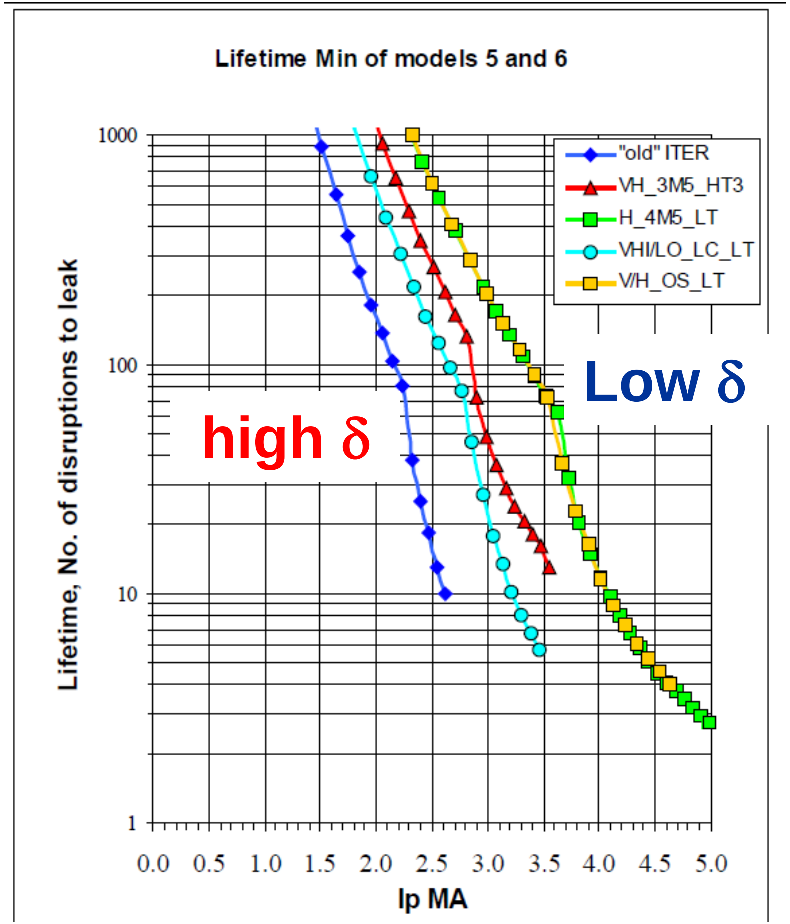
JET operations

- Safe and co-ordinated operation of JET systems
- JET operation instructions (JOIs) define permitted operating space
- Exceptions (blue forms) can be approved after assessment of risks vs scientific benefits
- Machine lifetime is a controlled scarce resource

Example:

- JOI 1.1 & 1.2 limit $\mathbf{I_P{*}B_T}$ & **vessel forces**
- The limits have been determined on the basis of a JET reliability assessment report and lifetime-to-leak analysis for:
  - Machine vertical port welds
  - ILW components
  - Pre-ILW components

Lifetime-to-leak analysis for representative configurations



- lifetime to leak for representative low and high δ configurations
  - Recent example of risky experiment: 4MA baseline in 2020 D campaign
    - → Disruption budget allocated
    - → Prescribed cautious steps in I_P, B_T

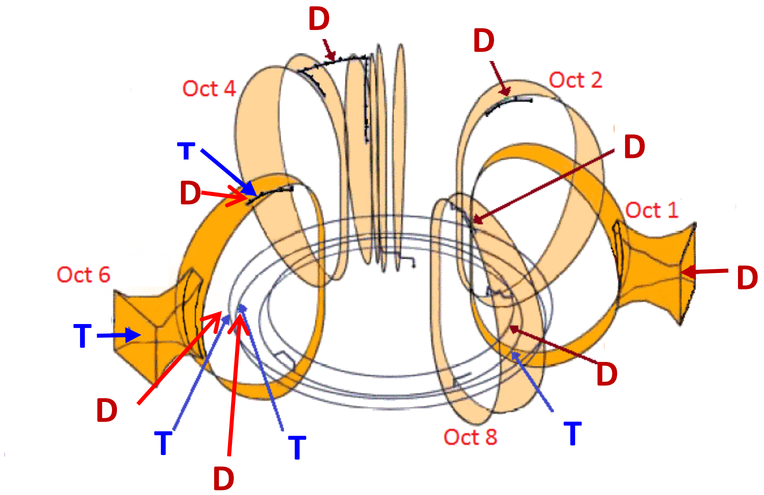
- Additional limitations may constraint I_P increase, e.g. high δ configuration used for integrated seeding scenario with S-P on vertical tiles limited to 3.2 MA by divertor coils current capability

- JOI address other machine or people safety risks

- **Pulse design and validation includes checking JOI limits not exceeded**

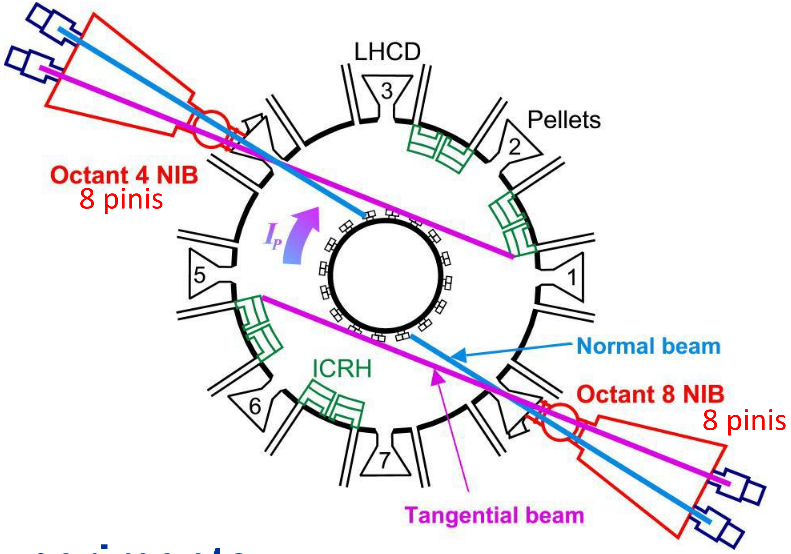
Key tritium capabilities: heating and fuelling

5 Tritium Injection Modules (TIMs) (only 1 module in DTE1)



T can be fed to both Neutral Beam Injection Boxes (only 1 in DTE1)

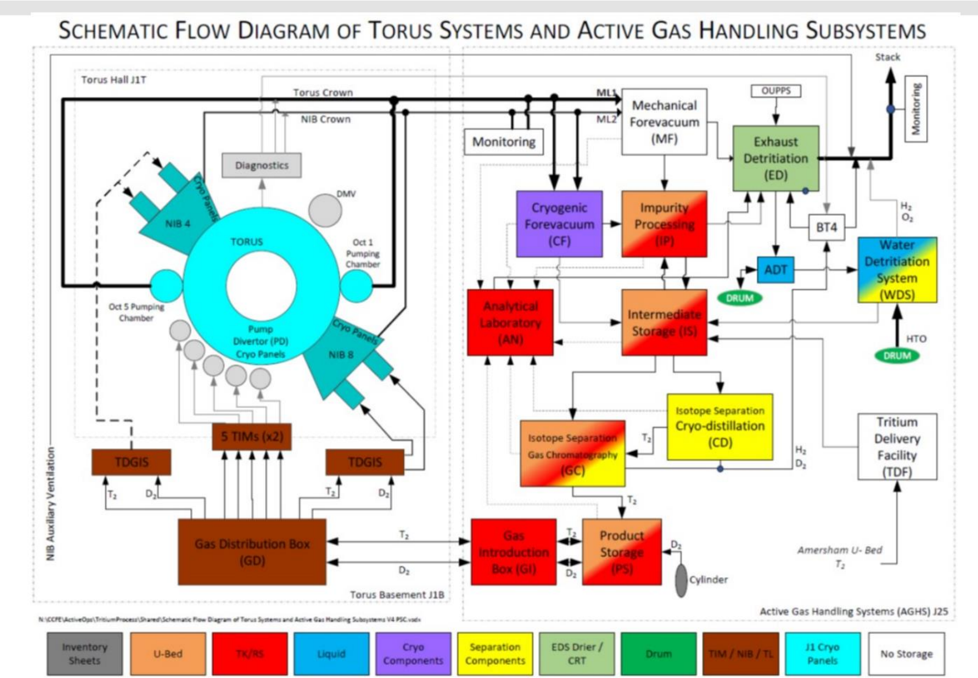
P_{NBI} upgraded to 34MW



→ **Capability for 100% high power Tritium experiments**

→ **More flexibility for experiment & pulse design**

Key tritium capabilities: Active Gas Handling



Lässer R. *et al* 1999 Fusion Eng. Des. 46 & 1999 Fusion Eng. Des. 47

→ **69g Tritium on site for T and DTE2** (21g in DTE1)

→ **T&D-T experiments used 1kg T overall: 240g (TIMs) and 763g (T-NBI)** (100g in DTE1)

- Stores, supplies and recycles T going to and from JET systems
- AGHS Plant capabilities limits:
  - Operational days (10 days in 4/5 weeks for T reprocessing & accounting)
  - daily tritium budget: 44barL (11g)

→ Needed to budget experiments and minimise pulse tritium consumption, e.g.:

- Plasma initiation in H or D
- Pulses shortened to minimum needed for conclusive results
- Detect and stop dud plasmas
- Prepare pulse schedule in advance

JET operations: Real-time control capabilities

- Several Real-time measurements and calculations available, e.g.:
  - ELM frequency calculation (spectroscopy)
  - Te hollowness factor calculation (ECE)
  - Radiation and radiation tomography via Neural Network applications
  - Surface temperature from NIR cameras (wide-angle view and tile 6)
  - GIM/TIM flow calculation within PDLM
  - LIDAR and High Resolution Thomson Scattering
- The real-time central controller (RTCC) can drive gas, pellets, NBI and RF, including during a Jump To Termination (JTT)
- Plasma Event Triggering Avoidance and Mitigation (PETRA) runs event detectors and checks conditions to raise alarms
- RT early detection of unhealthy plasmas and JTT response was integral to scenario development for DTE2 to reduce risk of damage from disruptions
- Also used routinely to avoid wasting tritium or neutrons budget: dud detection with controlled pulse stop

D vs T & D-T experiments

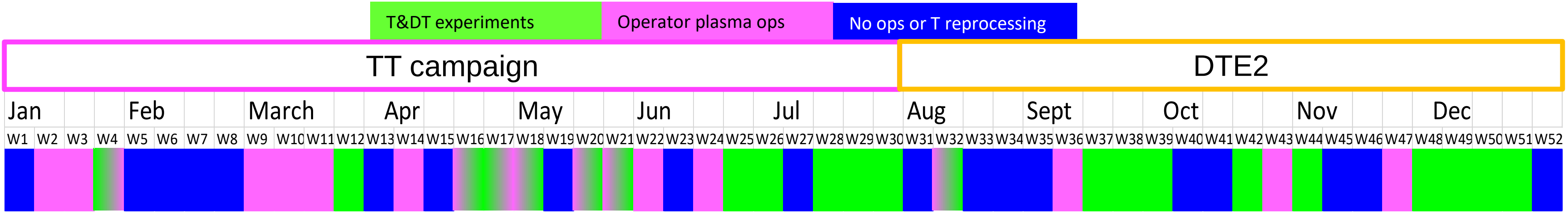
- D, H, He: ops 5 days a week, 2 shifts/day
- Sessions-based preparation
- Scarce resource (budget for disruptions, high TF, high tile temperature or energy, etc.) approval required
- Duty SL prepares pulses with the SC & team the week before

D vs T & D-T experiments

- D, H, He: ops 5 days a week, 2 shifts/day
- Sessions-based preparation
- Scarce resource (budget for disruptions, high TF, high tile temperature or energy, etc.) approval required
- Duty SL prepares pulses with the SC & team the week before

- T & D-T: 10 ops days in 3 weeks, + 2 weeks for T reprocessing & accounting
- ‘Pulse-based’ preparation with several experiments per session
- Each scientific goal attributed pulse(s), T and neutron budget, additionally to usual scarce resources
- Reference SL submit detailed pulse(s) for approval ≥4 weeks ahead, with predicted T & neutron
  - Must have D reference executed with TIMs (in D) & relevant RTC schemes
  - Must have demonstrated tolerable disruption rate, etc

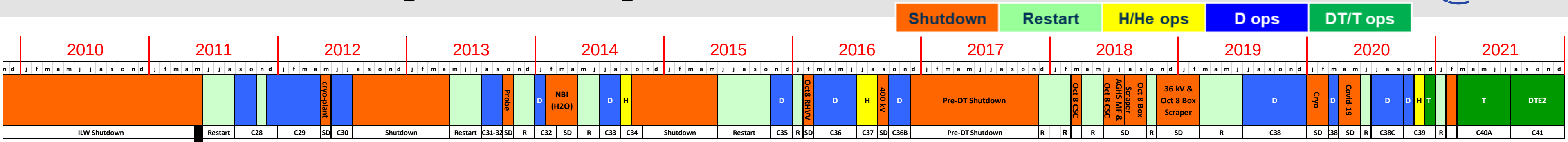
Successful T & D-T campaign despite many challenges

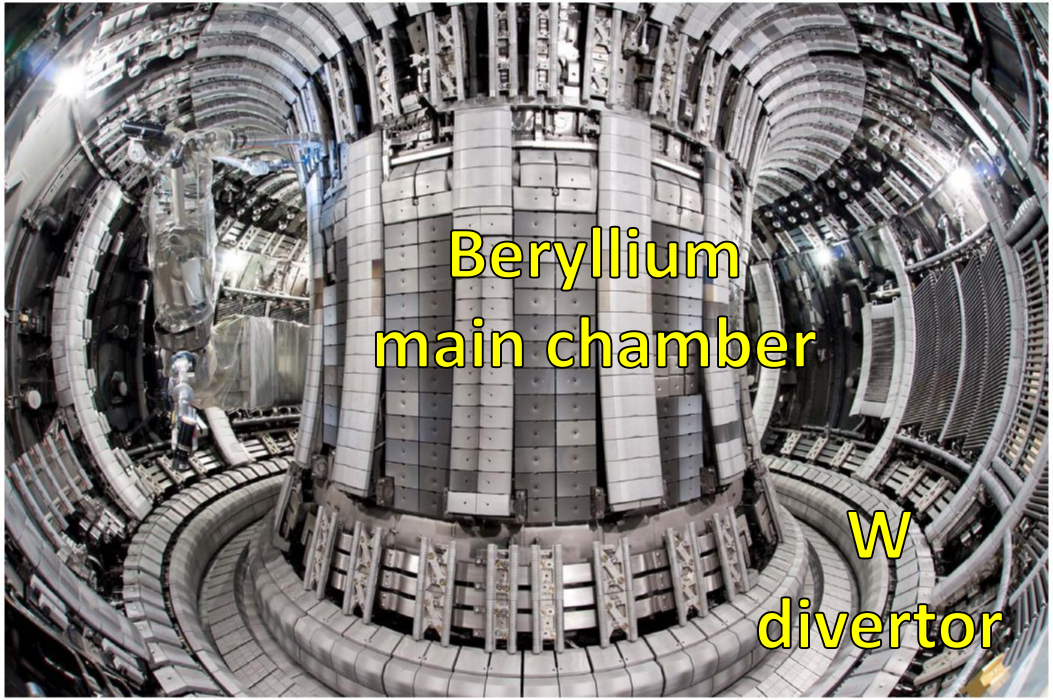


- Machine issues frequently interrupted the campaigns
- Sustained D-T NBI ≈ 30MW available only in last D-T cycle
- Having the detailed pulse prepared in advance helped with the frequent timeline re-optimisations, though the pulse approval process would gain in being streamlined
- COVID-19 meant all scientists had to participate remotely

Part 2 - Preparation and execution of scenarios for sustained high fusion power

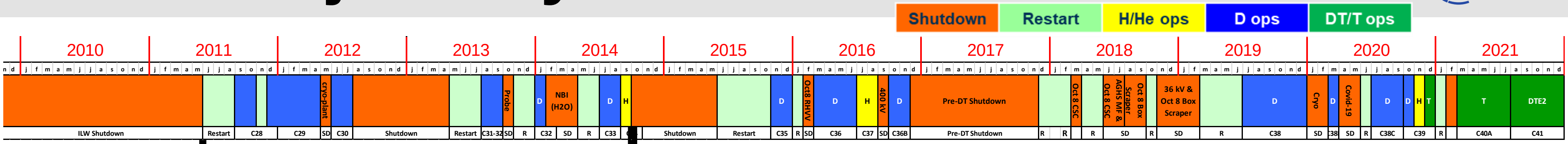
JET-ILW: journey towards DTE2

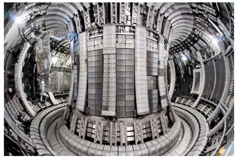




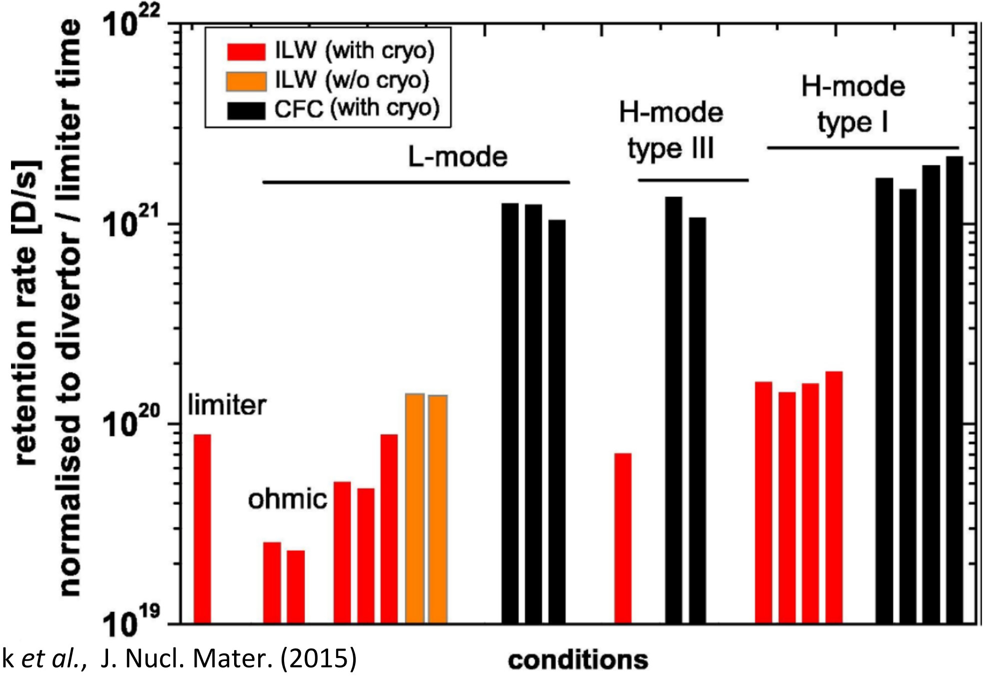
- ILW installation completed May 2011

JET-ILW: journey towards DTE2





2011

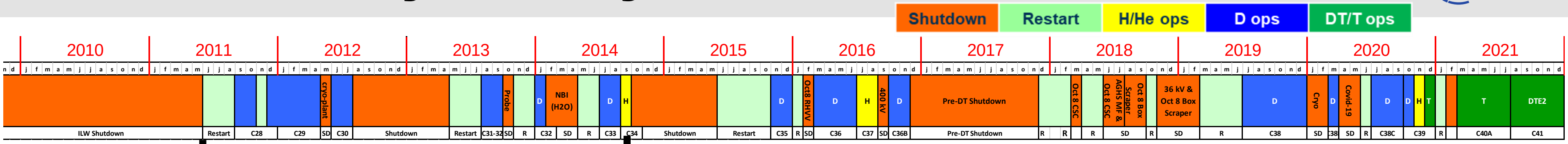


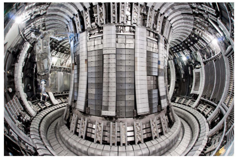
S. Brezinsek *et al.*, J. Nucl. Mater. (2015)

First set of campaigns 2011-2014:

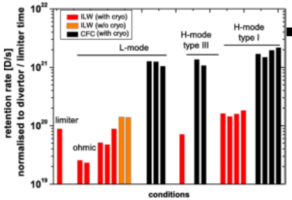
- Lower fuel retention (D) in JET-ILW compared to JET with carbon wall (JET-C) confirmed
- **But difficult to match plasma performance achieved in JET-C → more on this in later slides**

JET-ILW: journey towards DTE2





2011



2011-2014

2015-2020 Plasma preparation for DTE2

- Development of scenarios for:
  - sustained high fusion power → today's focus
  - Integrated seeded plasma
  - for clear α effects or isotope effects
- Set of H, D, T campaigns to study the impact of isotope mass in preparation for DTE2 and ITER
- Plasmas addressing specific physics questions to better prepare ITER – including clarifying impact of parameters not ITER relevant, e.g. high rotation

Development requirements for high P_{FUS} scenarios

D experiments

- **Demonstration in deuterium of sustained high fusion power in JET-ILW with:**
  - Divertor plate temperature within limits
  - Tolerable high Z impurity content
  - Detrimental MHDs avoidance
  - Tolerable disruption rate and/or impact
  - T-ops constraints (TIMs, tritium and neutron saving methods, etc.)

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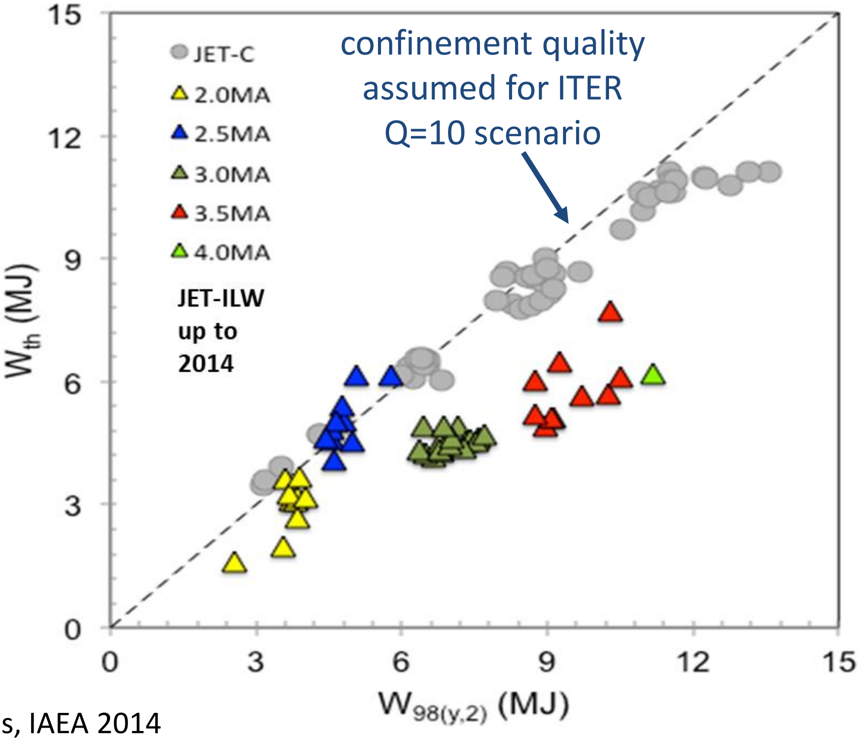
  - T-ops constraints (TIMs, tritium and neutron saving methods, etc.)

Strategy:

- **2 routes pursued to maximise chances:**
  - Baseline, ‘high current’ route
  - Hybrid, ‘High beta’ route
- **Large amount of experimental time in D to scenario development**
  - Included documenting impact of gas & power to prepare strategy in case of unexpected behaviour in D-T
- **Pure tritium experiments helped to prepare response to isotope effects**
- **‘Predict first’ approach guided experiments**

Baseline scenario development to high I_P in JET-ILW

D experiments

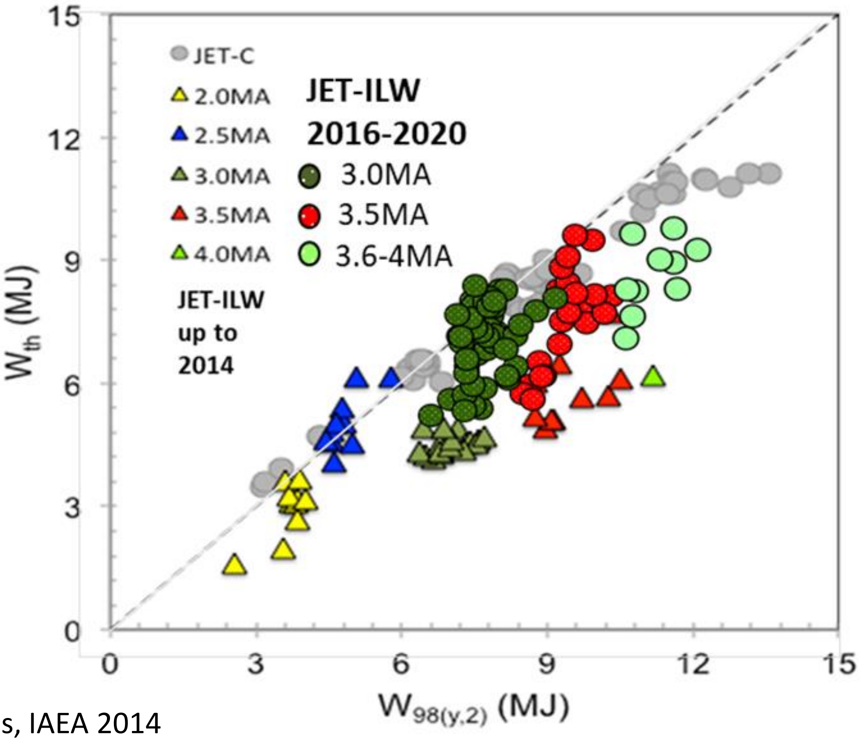


I. Nunes, IAEA 2014

- **ILW up to 2014**: lower confinement for I_P>2.5MA than equivalent plasmas in JET with C-wall
  - **W in the plasma → high gas to reduce W source → loss of performance**
  - **loss of C as intrinsic impurity → impact on edge radiation and transport**

Baseline scenario development to high I_P in JET-ILW

D experiments



I. Nunes, IAEA 2014

J. Mailloux, IAEA 2021

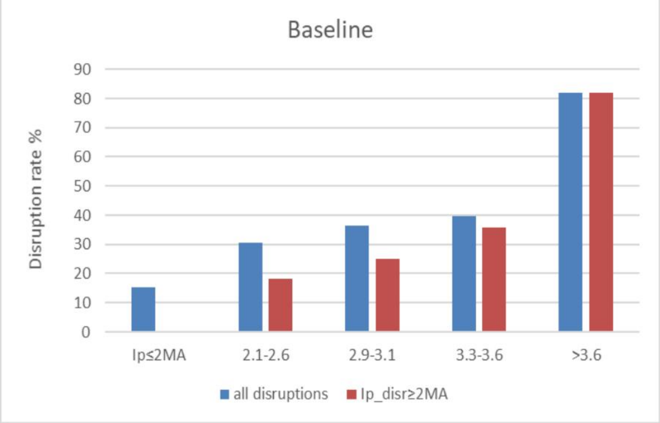
- **ILW up to 2014**: lower confinement for I_P>2.5MA than equivalent plasmas in JET with C-wall
- **ILW 2016**: Confinement recovered at 3MA, thanks to:
  - D pellets pace ELMs → **flush impurities**
  - Low fuel injection, for improved pedestal and core confinement
- **ILW 2019-2020**: successful recipe extended to 3.5MA, with clear progress at 3.6-4MA
- Recipe not relevant to ITER baseline flat-top but could be in ramp-up & ramp-down

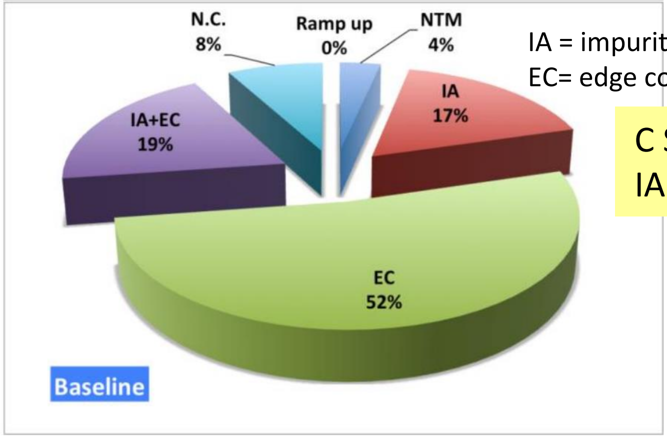
High performance at high I_P compatible with ILW

Dedicated effort to reduce disruption rate in Baseline

D experiments

Baseline disruptions (D plasmas)





IA = impurity accumulation
EC= edge cooling

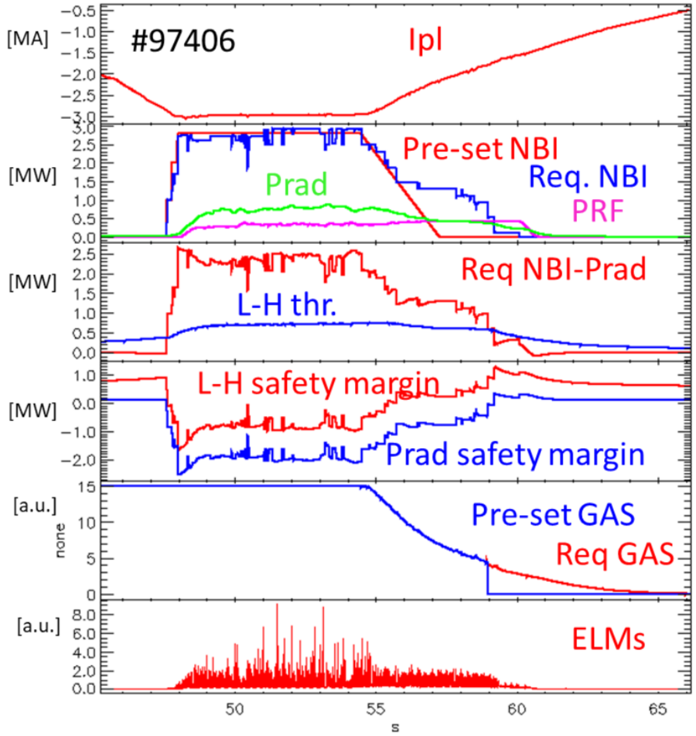
C Sozzi *et al.*, IAEA 2021

- High disruption rate in baseline plasma motivated dedicated disruption avoidance effort
- Most disruptions during ramp-down, when near H-L threshold: high radiation leads to back transition & loss of ELMs accelerate impurity accumulation & lead to disruption
- RTC schemes implemented to identify ‘unhealthy’ plasmas by monitoring:
  - Radiation peaking or high edge radiation detected with fast tomographic reconstruction (NN)
  - Proximity to H-L threshold (next slide)
- Overall disruption rate not significantly reduced though taking place at lower I_P

Optimised termination algorithm for baseline plasmas

D experiments

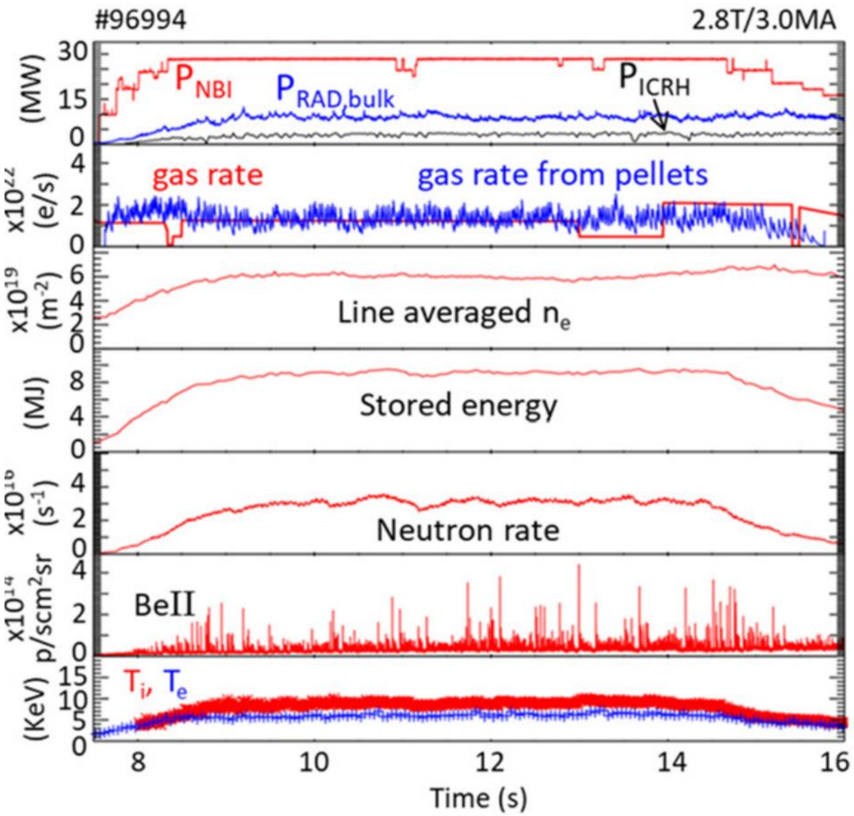
Disruption avoidance during plasma termination by controlling power and gas



- Algorithm monitors proximity to H-L and density limit and acts on power and gas requests
- Successfully applied in several 3 MA flat top baseline cases
- Application at higher current so far much less reliable because of reduced margin in input power vs P_{RAD}

Best baseline sustained performance

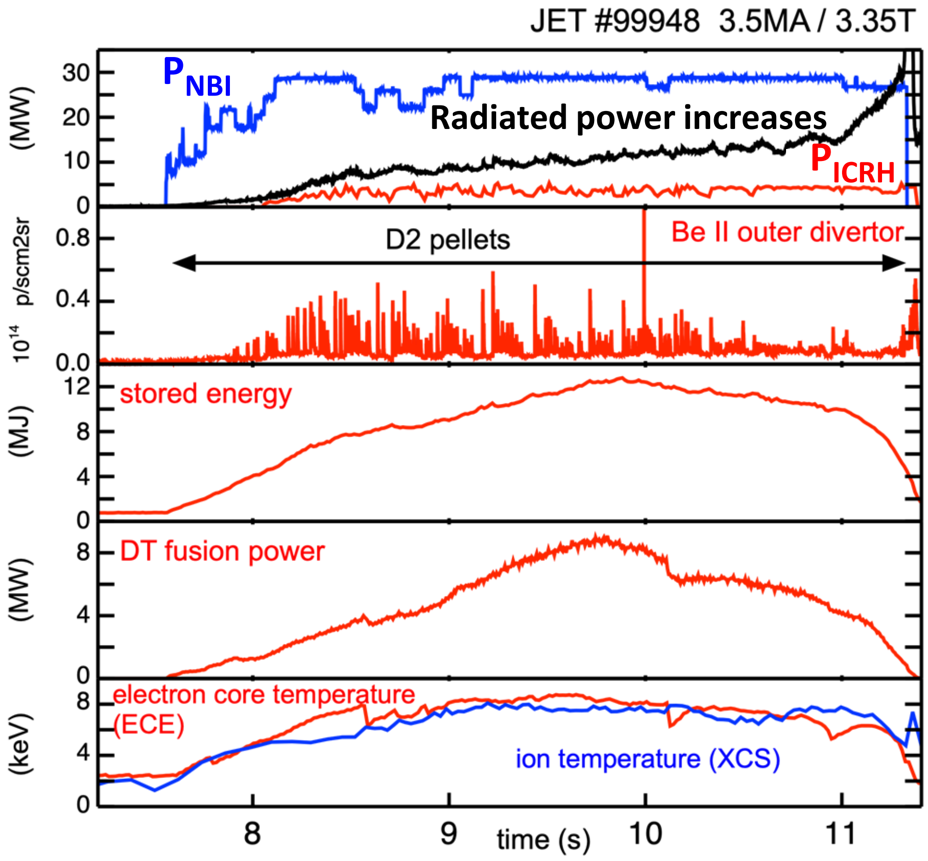
D experiments



- Best sustained performance for 3MA
- Equivalent D-T fusion power: 8MW
- Good 3.5MA reference also obtained though slightly less performing
- Overall disruption rate high:
  - 3MA: 60% in 2015–2016 to 20% in 2019-2020
  - ≥3.5MA: 70% in 2020
- Baseline D-T experiment given go ahead after detailed review of disruption data because of high scientific value

Baseline scenario: reduced operational space in D-T

50/50 D/T results

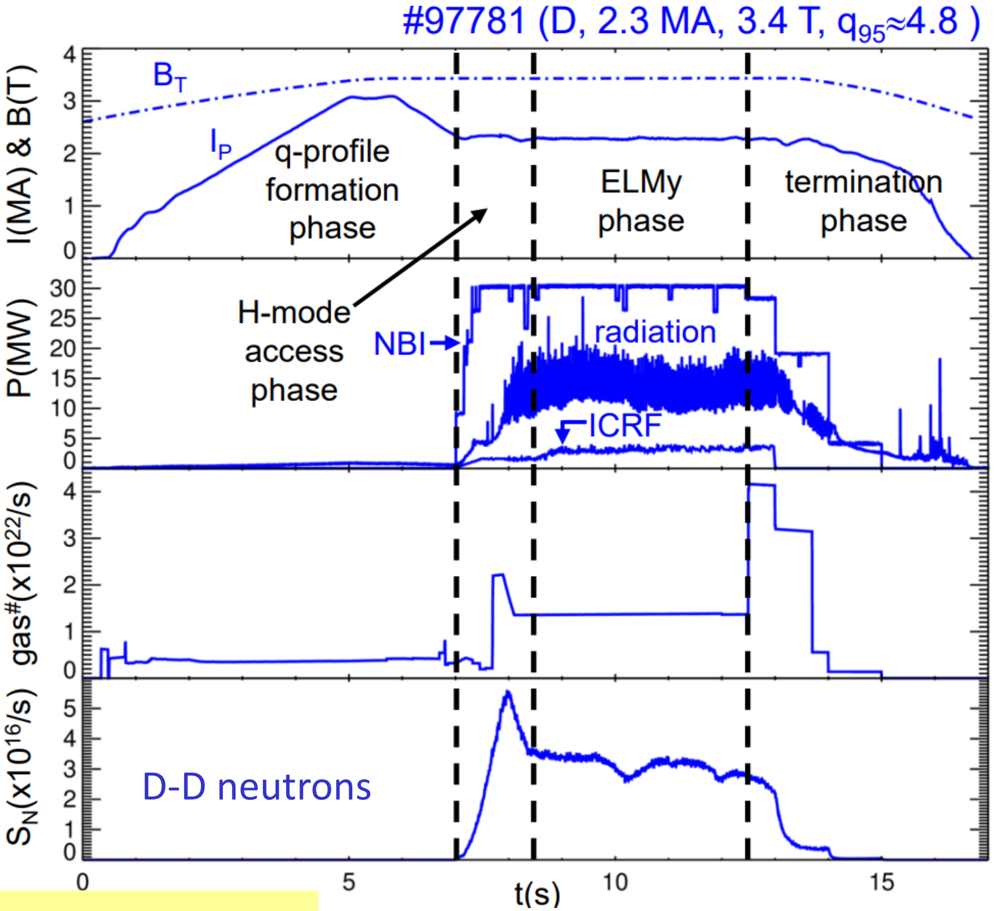


D. Frigione, L. Garzotti, F. Rimini, D. van Eester

- Very few pulses because of low availability of high P_{NBI}
- Good access to H-mode after re-optimisation to compensate for combined isotope effects
- Stopped by too high impurity radiation due to less effective W flushing by ELMs
  - higher density in D-T + higher impurity radiation → reduced operational space
  - Complex interplay between MHD modes, sawtooth instability, energetic particles & radiation
- More time needed in D-T!

Hybrid Scenario overview

D experiments



- Equivalent D-T fusion power: 8MW
- Disruption rate reduced to 5%

#neglects gas system response time

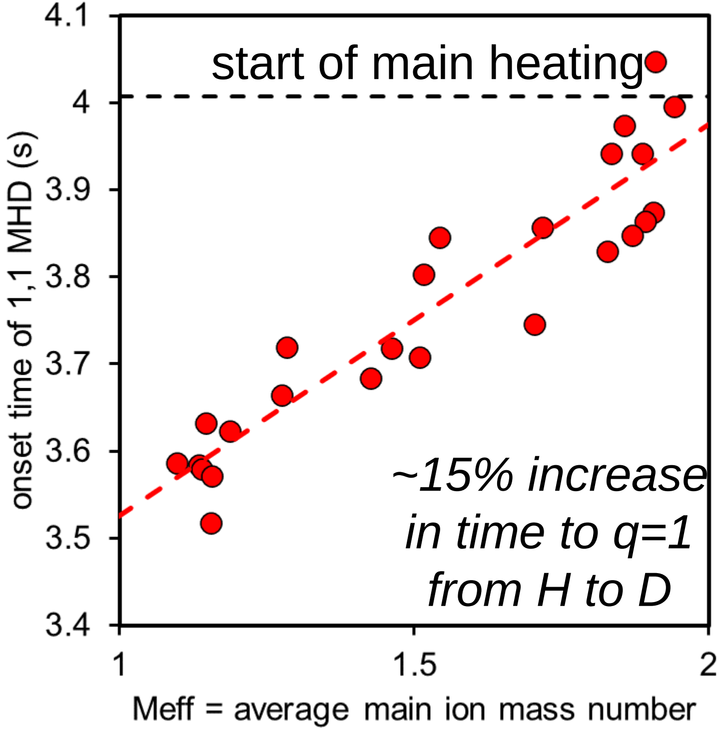
CD Challis *et al.*,EPS 2022

Impact of isotope mass on Hybrid ramp-up

D/H experiments

CD Challis *et al.*,NF **60** 2020

Mixed H-D plasmas from single week of operation with similar current ramp, magnetic field & density



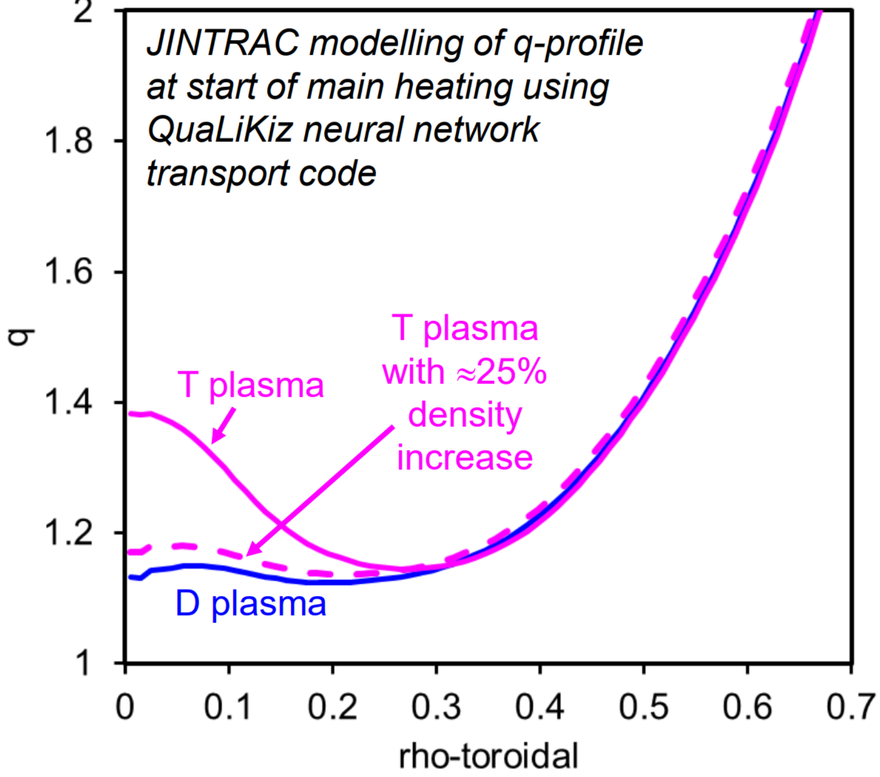
- q-profile evolution sensitive to main ion isotope mass in Ohmic current ramp phase of JET ‘hybrid’ plasmas due to impurities
- Can lead to disruptions:
  - ➢ Central cooling→Reduced or reversed magnetic shear→2/1 tearing mode→Locked mode
- Strategies developed to avoid I_P ramp disruptions in T & DT plasmas due to q-profile changes
  - ➢ Increase plasma density to restore temperature peaking
  - ➢ Early pulse termination when hollow temperature profile detected

Prediction of impact of tritium on q

- q_0 increases with isotope mass due to core radiation
  - ➢ *Increased W sputtering and/or reduced ion temperature (e-i decoupling)*
- Effect compensated by increasing density during Ohmic ramp phase

CD Challis *et al.*, EPS 2022

D & T predictive modelling done before T experiments

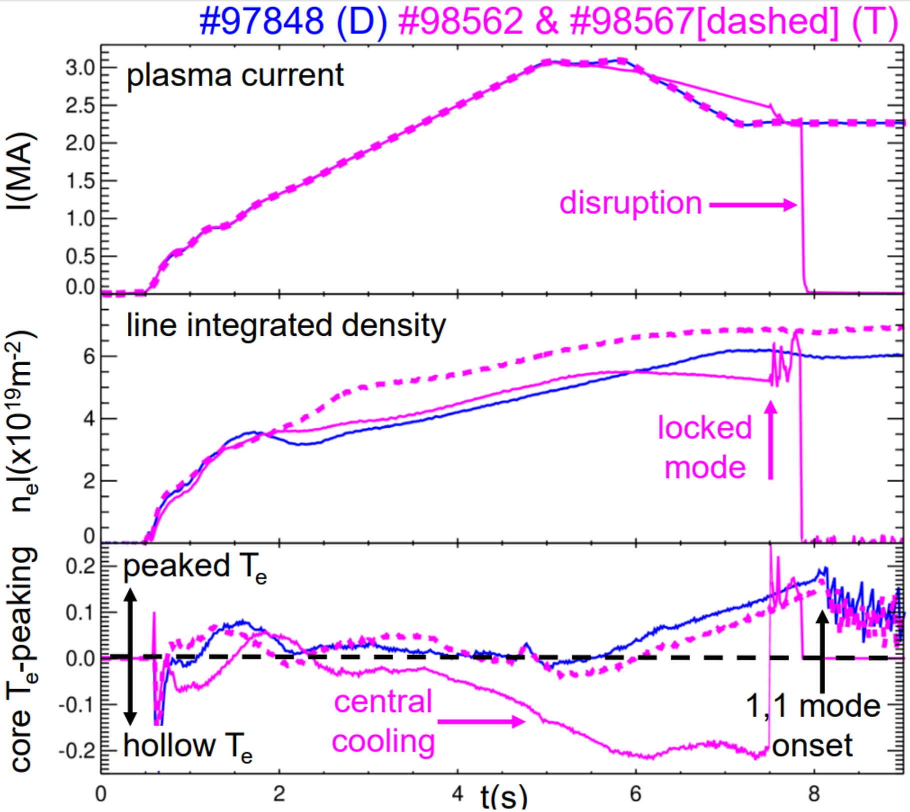


T plasma profile matched to D reference

50/50 D/T results

- Ohmic tests used to tune q-profile
- D reference repeated using T:
  - *Hollow T_e profile*
  - *Locked mode*
  - *MGI triggered*
  - *Mitigated disruption*
- D plasma q-profile matched in T by increasing density, as predicted

CD Challis *et al.*, EPS 2022

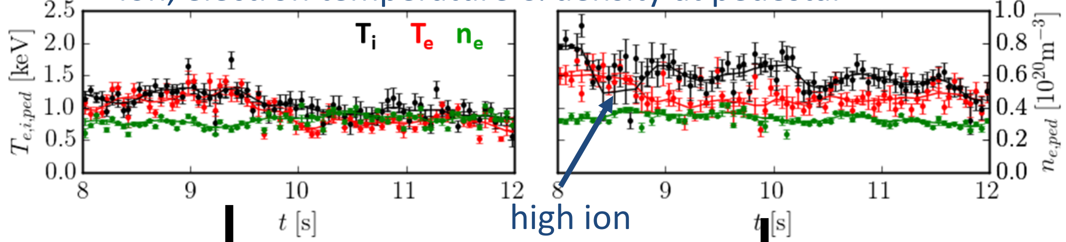


Hybrid scenario optimised for sustained performance

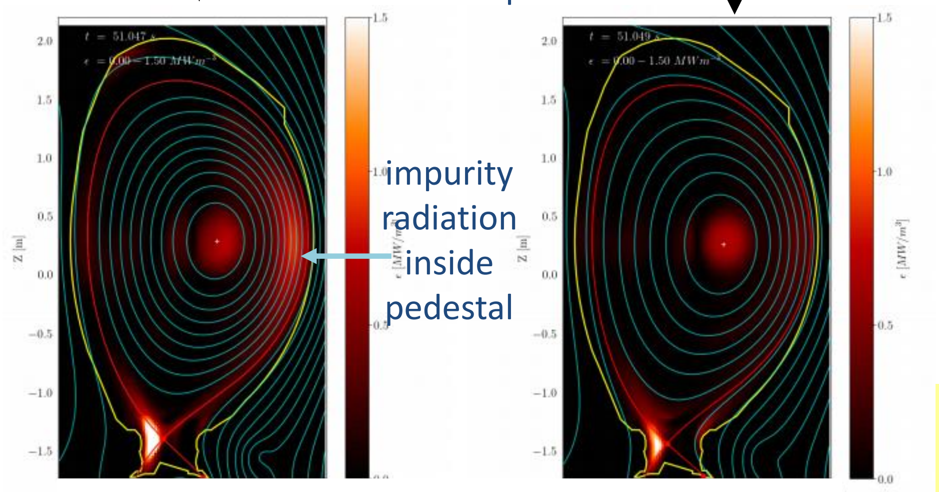
D experiments

high initial gas flow **low initial gas flow**

Ion, electron temperature & density at pedestal



high ion temperature



impurity radiation inside pedestal

radiation over plasma cross-section at t=11s

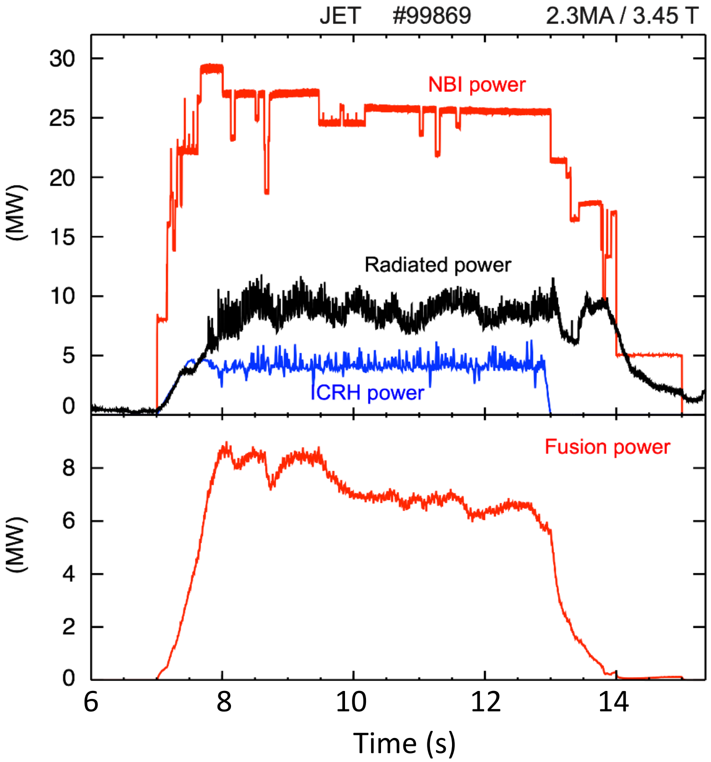
- Initial Hybrid experiments in JET-ILW 2011-2014: good confinement but not sustained due to impurity accumulation
- Optimisation of ramp-up phase led to high pedestal ion temperature & clear demonstration of outwards W convection at plasma edge → **'impurity screening'**

Increases confidence that this will take place in ITER as predicted (R. Dux *et al.*, PPCF 56 (2014) & Nucl. Mat. and Energy 12 (2017))

J. Garcia et al., IAEA 2021
A. Field, submitted to NF

Hybrid scenario: sustained performance

50/50 D/T results

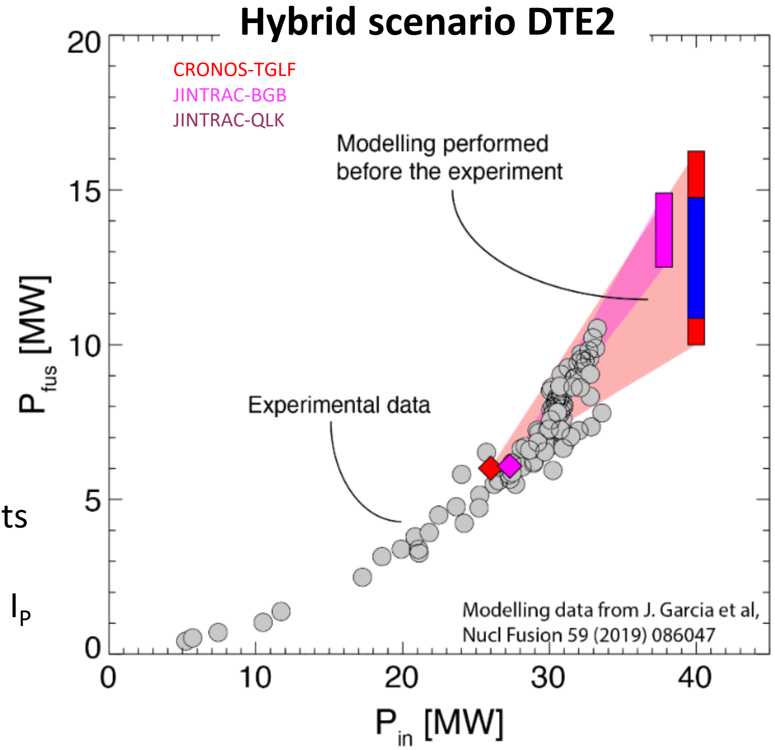


CD Challis *et al.*, EPS 2022

- Hybrid scenario run for the first time in D-T
- Successful sustained pulse after re-optimisation
- Fusion energy record for 50/50 D/T plasmas (42MJ)
- Analysis on-going to disentangle effects on edge and core, and identify isotopic and α effects

Fusion power confirms predictions made before DTE2

50/50 D/T results



simulation range accounts for models differences & I_P range

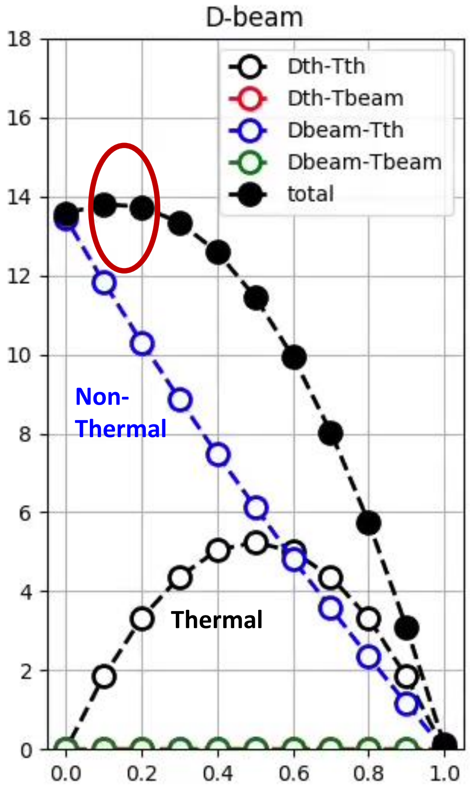
CD Challis *et al.*,EPS 2022

- Predict-first approach applied as part of preparing for DTE2
- **D-T fusion power achieved in hybrid plasmas is in range predicted**, when taking into account power available
- Also for baseline scenario (not shown)
- Improvements to models and codes needed to reproduce details of the experiments

Fusion power boosted by optimising heating & fuel mix

Predicted fusion power [MW]

Non-thermal: D-T reactions between NBI Fast ions or between Fast Ions and thermal ions



Plasma D/T ratio

- Fusion reactions from JET 50/50 D/T plasmas NBI comprise ‘thermal’ and ‘non-thermal’ D+T reactions
- Non-thermal part can be maximised with D-only-NBI in plasma with high tritium
- Further boost with Ion Cyclotron Radiofrequency heating of D ions

→ Significantly more fusion power at same plasma energy

[predictions carried out for T_e = 10keV and T_i = 12 keV] with TRANSP [1]

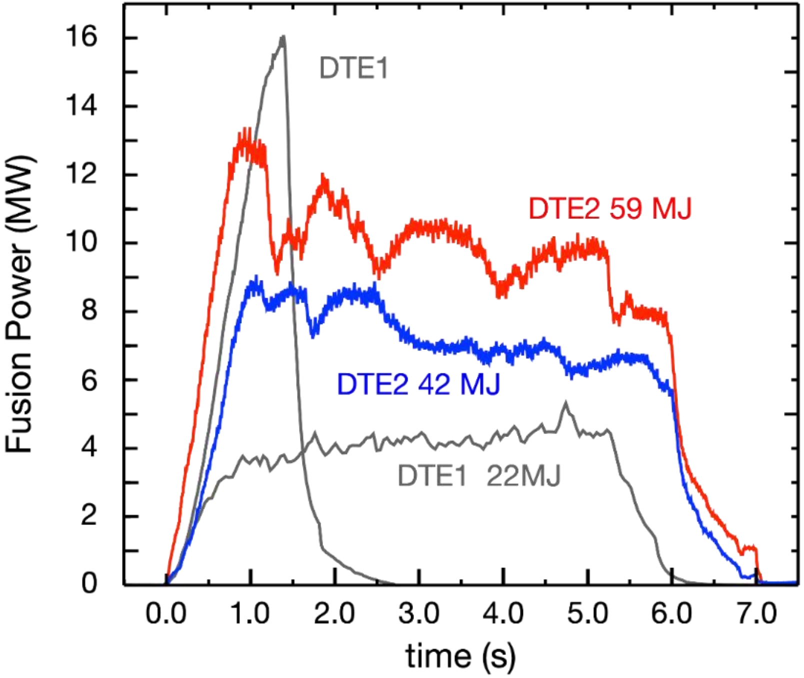
[1] Goldston R.J. et. al.., 1981 J. Comput. Phys. 43; Breslau J, et al., 2018 TRANSP Computer Software (https://transp.pppl.gov/index.html)

DTE1 Fusion energy record surpassed

D/T results

#99869 (2.3MA/3.45T) Hybrid with ~50/50 D/T NBI and plasma
#99971 (2.5MA/3.86T) Hybrid with D-NBI in T-rich plasma

CD Challis, J. Hobirk, A. Kappatou, E. Lerche
M. Maslov, E. Lerche



- Fusion energy record surpassed with hybrid scenarios
- Demonstrates compatibility of ILW with sustained high fusion performance

Part 3 – other DTE2 results with impact on ITER IRP

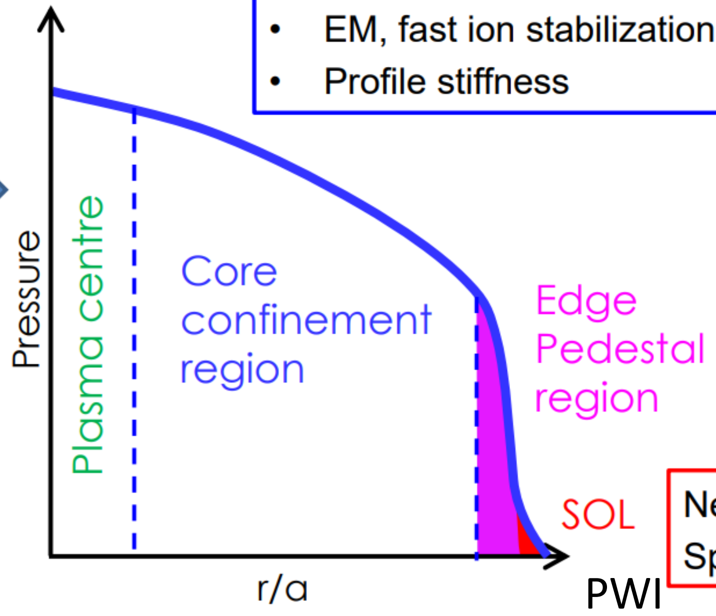
Isotope mass impacts properties in all regions of tokamak plasma

$A = m_i / m_p$
Hydrogen Isotope mass

- Turbulent transport at **small scale, ion Larmor radius size:** $\rho_i^* \sim (A\,T)^{1/2} / (a\,B)$
- ExB shear stabilization: $\gamma_{ExB}/\gamma_{ITG} \sim A^{1/2}$
- Collisions: $\nu_{ii} \sim A^{-1/2}$
- EM, fast ion stabilization
- Profile stiffness

Offset local $\rho_i \sim A^{1/2}$ dependence

Heating
e.g power, torque, particle sources by NBI depend on A…



ELMs
e-scale turbulent transport
NC transport
Ion-scale turbulent transport
Edge neutral source

Core MHD
Sawteeth: τ_{ST} (D) < τ_{ST} (T)
Fast ions
NC transport

Neutrals thermal velocity $v_{th} \sim A^{-1/2}$
Sputtering of PFCs depends on A

Detailed W sputtering measurements in H, D, T , DT

- **Unique set of JET W-erosion experiments in H, D, T and D-T, combined with ERO2.0 PWI simulations, provide improved predictions of W erosion in ITER**
- **Support JET operation and interpret challenging W behaviour in T & DT**

[S Brezinsek et al., PSI 2022]

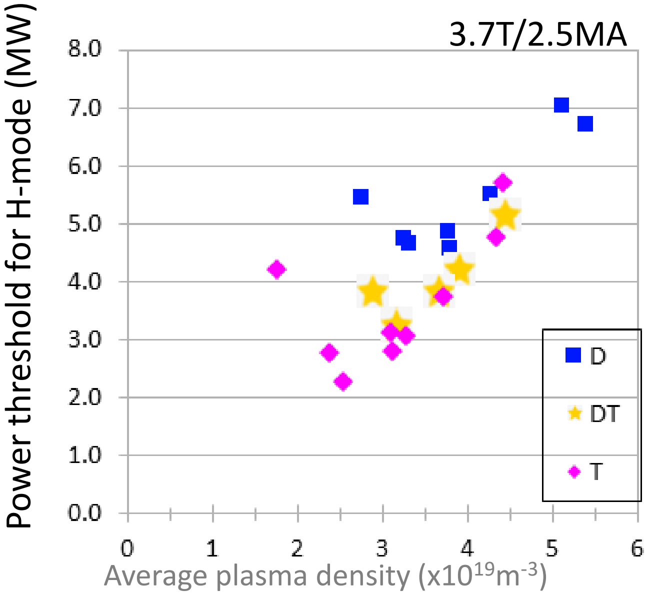
- W sputtering caused by:
  - a mix of impinging hydrogenic (H,D,T) and impurity ions (Be)
    - Be sputtering increases with isotope mass (see previous slide)
  - a mix of intra-ELM (E_{in}>500 eV) and inter-ELM sputtering (E_{in}<500 eV)
  - CAPS as additional minor channel for erosion identified via WH, WD, WT molecules

[E Pawelec et al., EPS 2021]

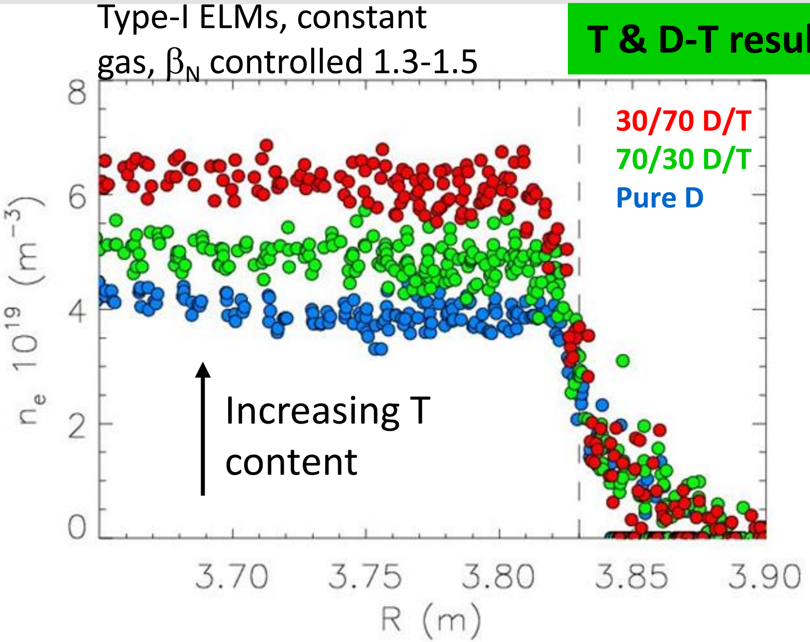
- **Increase of total W source from H → D → T measured on JET-ILW**

Impact of fuel mass clarified in T&D-T experiments

T & D-T results



Will improve ITER D-T preparation



- Power threshold for accessing H-mode lower at higher fuel mass
- Unique dataset to test hypothesis on underlying physics

G. Birkenmeier *et al.*, EPS 2022

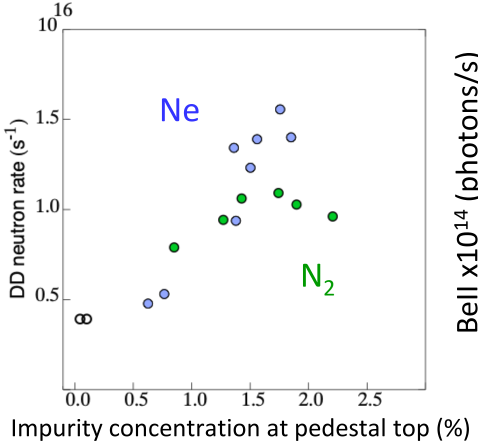
- Plasma pedestal density (& pressure) higher at higher fuel mass
- Improved diagnostic capabilities since DTE1 allow better understanding of role of pedestal

L. Frassinetti *et al.*, EPS 2022

Integrated neon seeded scenario in deuterium

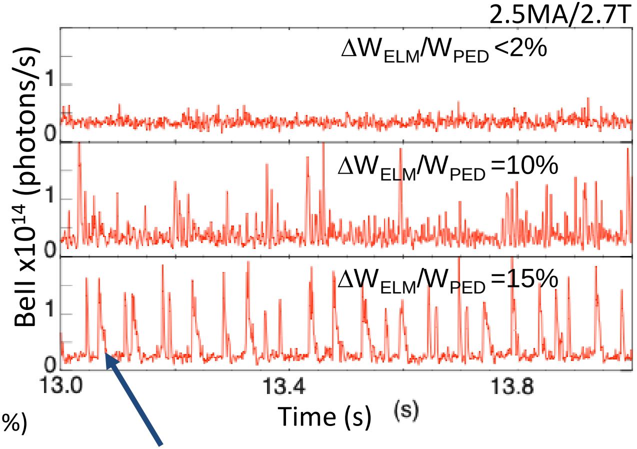
D experiments

Improved fusion performance



Increasing seeding rate

Inherently small ELMs



Increasing seeding rate

- ELMs: plasma edge instabilities leading to energy loss ($\Delta W_{elm}/W_{ped}$)
- Risks intolerable heat load in ITER divertor

Neon seeded scenario developed to high power:

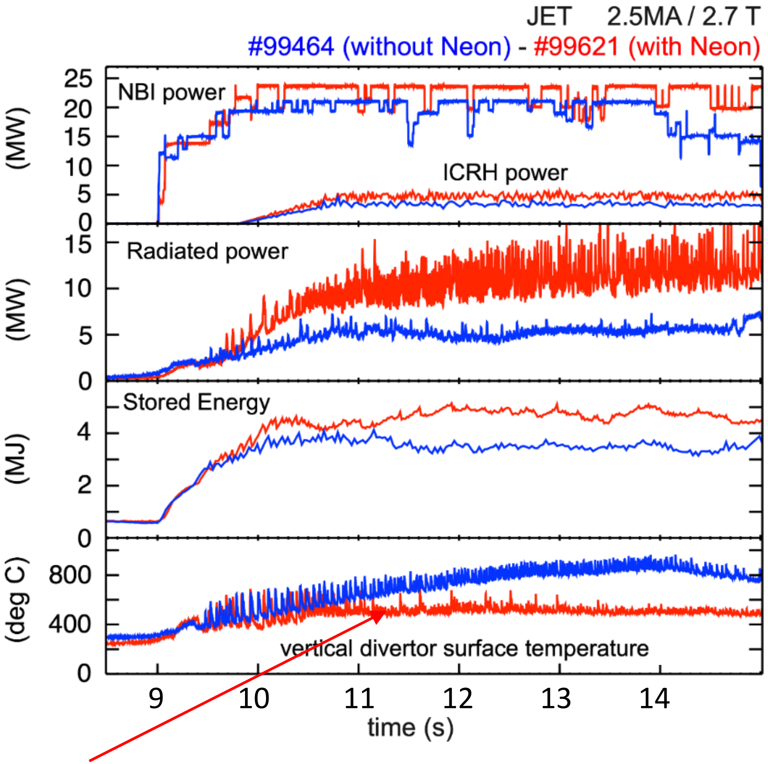
- Confirmed high divertor radiation with neon as predicted by SOLPS-ITER
- Compatible with high fusion performance
- Inherently small ELMs
- Compares favourably to nitrogen

→Influential results for ITER decision on seed gas

C. Giroud *et al.,* IAEA 2021, EPS 2022

Ne seeded radiative H-mode achieved in D-T

50/50 D/T results



Strongly reduced divertor temperature with Ne seeding

C. Giroud *et al.*, EPS 2022

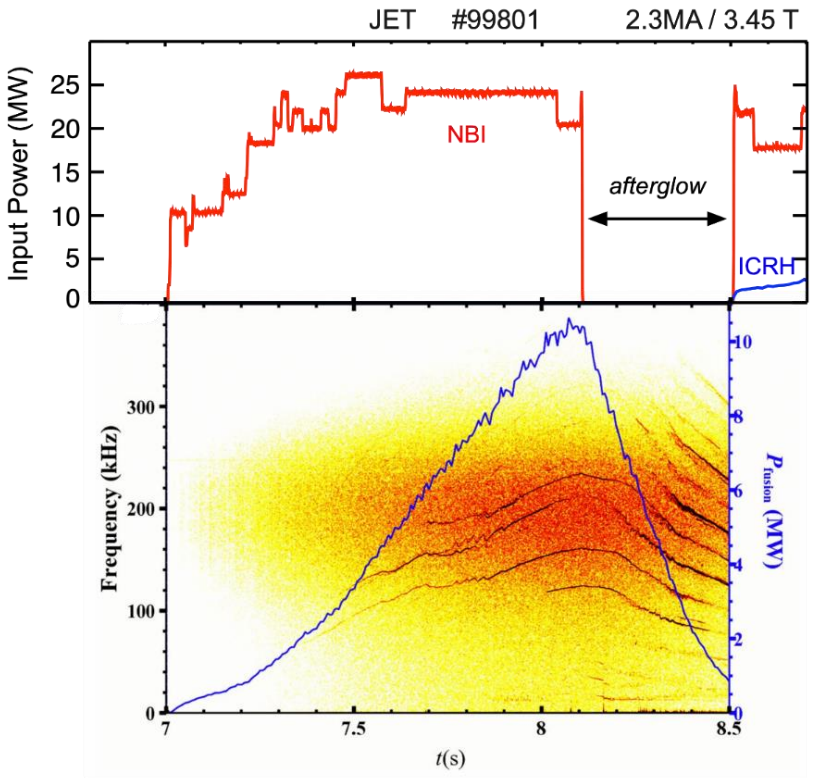
- **Ne seeded scenario performed for the first time in D-T, with ITER-relevant Be/W wall**
- Sustained pulse with detached divertor plasma & high radiated fraction

→ Confirms neon as promising for ITER

- More time in D-T with sustained high power needed to
  - Confirm improved confinement & small ELMs with neon as seen in D
  - Test our understanding of isotope mass effects on seeded plasma & detachment physics

Clear observation of instabilities triggered by α-particles

50/50 D/T results



- DTE2 included a range of experiments designed to ensure clear α effects observed
- Dedicated ‘afterglow’ scenario **to test models used to predict α-driven instabilities in ITER**
  - Inspired by TFTR D-T afterglow experiment (R. Nazikian *et al* PRL 1997)
- α triggers high frequency modes before and during afterglow - Only observed in D-T plasmas

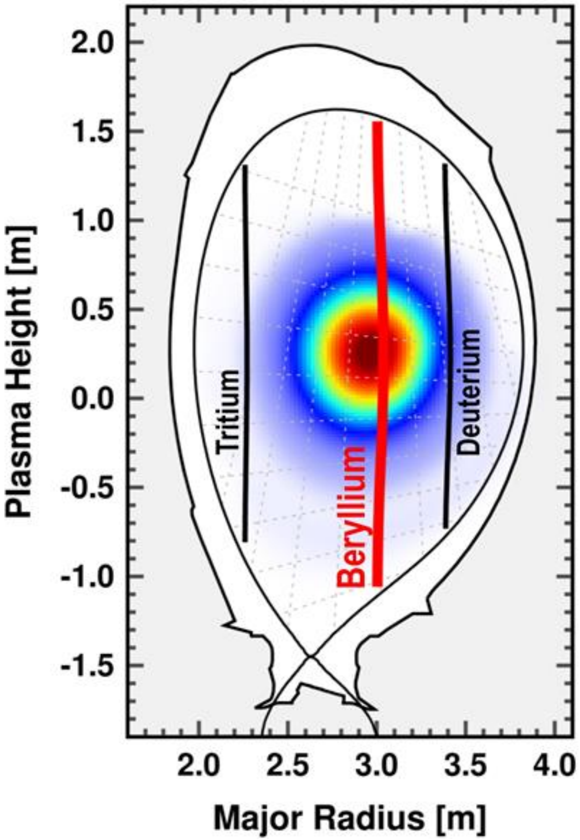
R. Dumont, M. Fitzgerald, D. Keeling

ITER relevant D-T RF schemes demonstrated

50/50 D/T results

2MA/3.7T

‘3-ion’ RF scheme
Relies on presence of T-^{9}Be-D



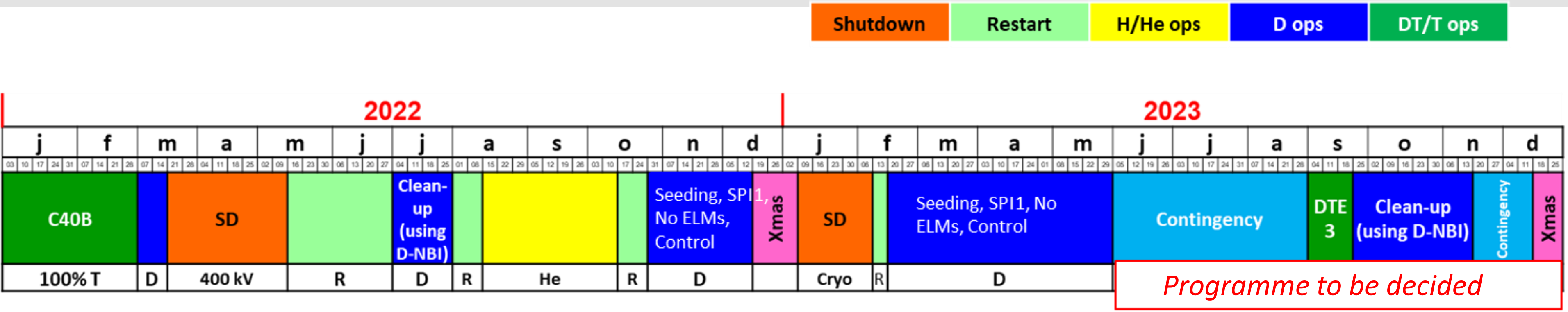
- **Efficient core heating demonstrated with novel RF heating scheme**
  - Clear increase in T_i with ICRF
  - Increased neutron rate & Generation of α-particles
- JET DTE2 provided unique chance to validate this technique & to investigate other ITER relevant ICRF heating schemes

Y. Kazakov, M. Nocente

Summary

- Tritium constraints required a change to experiments management and pulse preparation & validation
- Integrated scenario operation impacted by higher isotope mass, but required few adaptation shots thanks to preparation strategy
- Record sustained high P_{FUS} obtained and compatibility of high D-T performance with ILW demonstrated
- Sustained baseline & disruption-free ramp-down not demonstrated
- Preliminary ‘lessons learnt’ for ITER FPO:
    - Needs to take into account isotope mass impact on PWI, SOL, pedestal, core in codes & control
- Months & years of analysis & modelling needed before fuller implications of D-T results understood and applied in preparation for ITER RP execution & future reactors

Final JET experimental campaigns in 2022-2023



- JET scientific programme under EUROfusion WPTE leadership. TFLs: E. Joffrin, M. Wischmeier
- WPTE: Research Topics across machines with experimental time on AUG, JET, MAST-U, TCV, WEST
- JET D campaigns in 2022-2023 includes
  - 14 sessions for '**RT22-04: Physics-based machine generic systems for an integrated control of plasma discharge**', SCs: F. Felici, L. Piron, B. Sieglin
  - 13 sessions for **'RT22-05: Physics of divertor detachment and its control for ITER, DEMO and HELIAS operation'**, SCs: M. Bernert, D. Brida, H. Reimerdes, N. Fedorczark

Additional slides

Improved diagnostic capabilities compared to DTE1

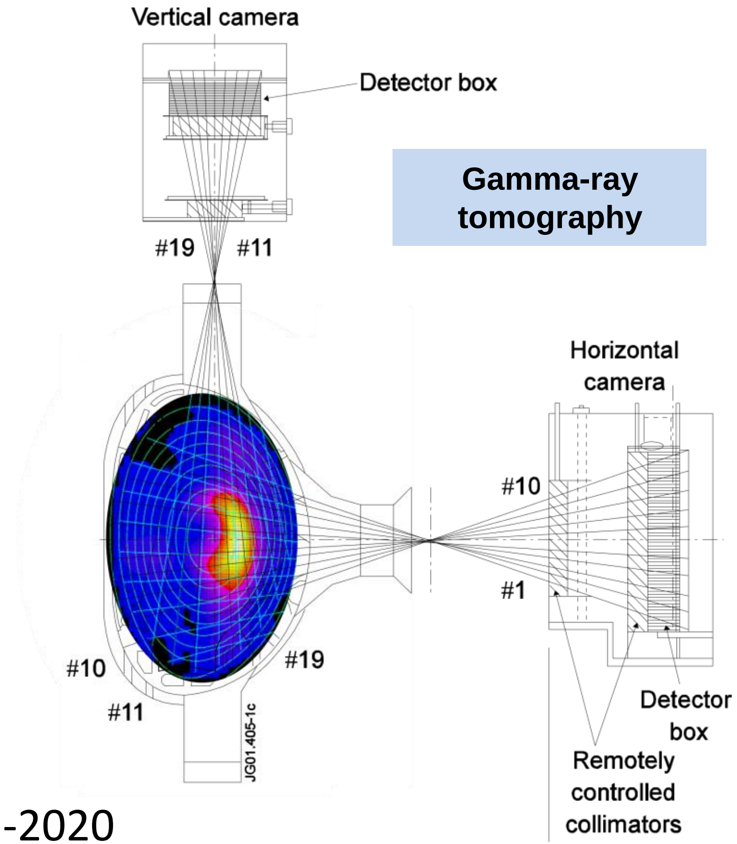
➔ **better spatial and temporal edge coverage**

➔ **Improved edge/divertor spectroscopy**

➔ **Better diagnosed fusion quantities, e.g.:**

- TAE antenna (α instabilities)
- Neutron camera & spectrometer
- γ-ray tomography
- Fast Ion Loss Detector (alpha losses)
- high-resolution sub-divertor residual gas analyser for measuring H, D, T, ^{4}He & ^{3}He

J. Figueiredo et al., IAEA FEC 2018



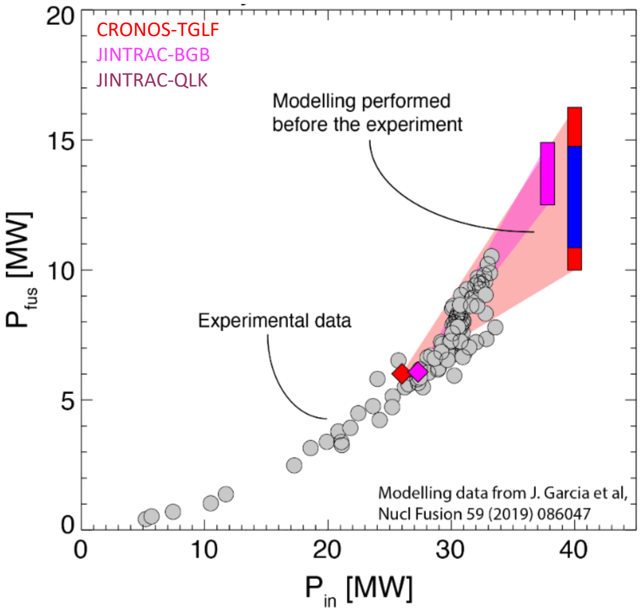
Gamma-ray tomography

Final enhancements installed & commissioned in 2019-2020

Fusion power confirms predictions made before DTE2

~50/50 D/T

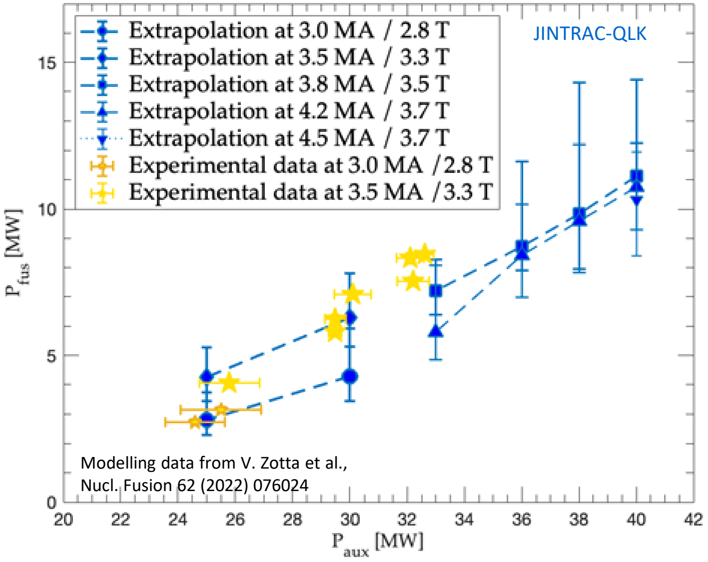
Hybrid scenario DTE2



Modelling data from J. Garcia et al, Nucl Fusion 59 (2019) 086047

simulation range accounts for models differences & I_P range

Baseline scenario DTE2



Modelling data from V. Zotta et al., Nucl. Fusion 62 (2022) 076024

- Predict-first approach applied as part of preparing for DTE2
- D-T fusion power achieved is in range predicted, when taking into account power available
- Improvements to models and codes needed to reproduce details of the experiments