



HAL
open science

Deuterium-tritium experiments in JET with the ITER-like wall

Jeronimo Garcia

► **To cite this version:**

Jeronimo Garcia. Deuterium-tritium experiments in JET with the ITER-like wall. AAPPS DPP 2022 - 6th Asia-Pacific Conference on Plasma Physics, Oct 2022, Online Conference (Tokyo), Japan. cea-03949563

HAL Id: cea-03949563

<https://cea.hal.science/cea-03949563>

Submitted on 20 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Deuterium-tritium experiments in JET with the ITER-like wall

J. Garcia

on behalf of the JET Contributors

EUROfusion Consortium and CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.

JET

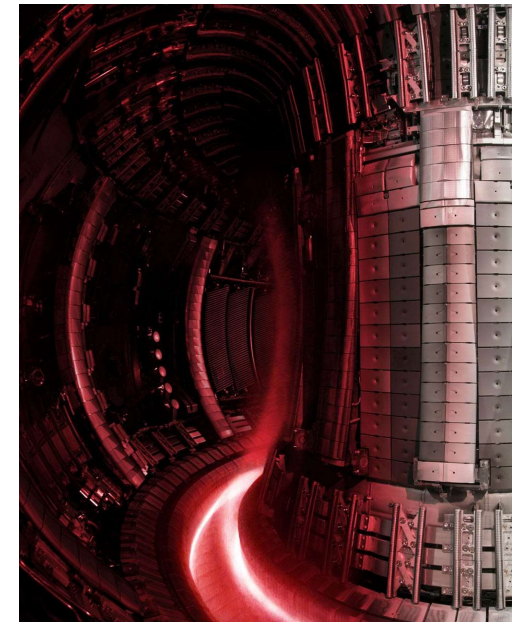
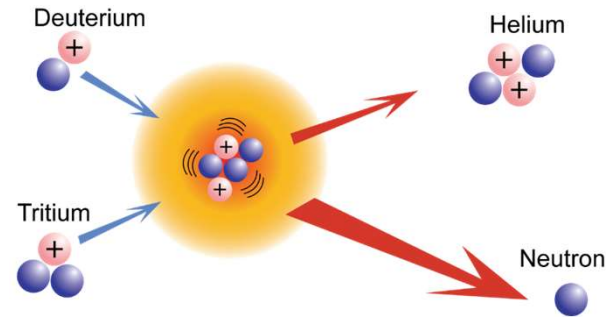


This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline



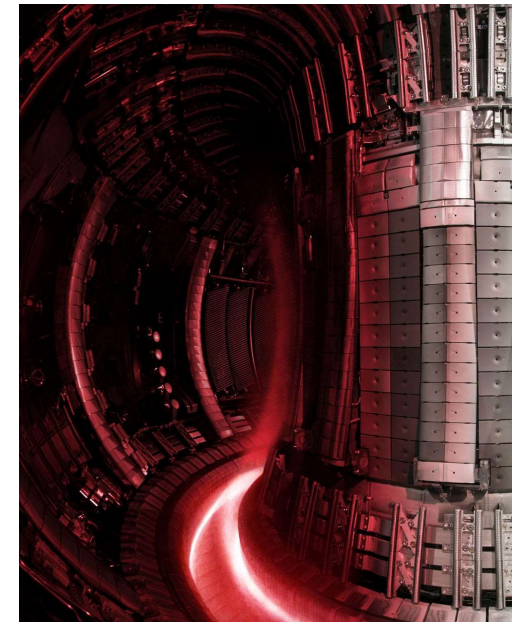
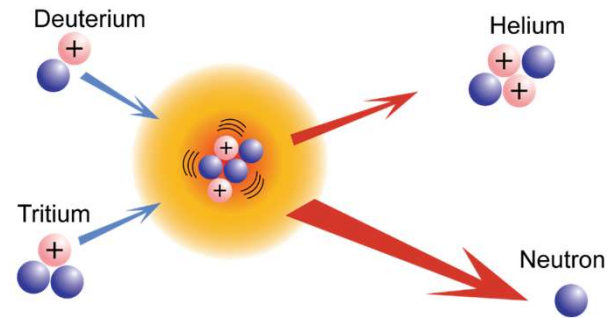
1. Why DTE2 at JET?
2. Fusion production world record
3. Physics studies in support of DT
4. Conclusions



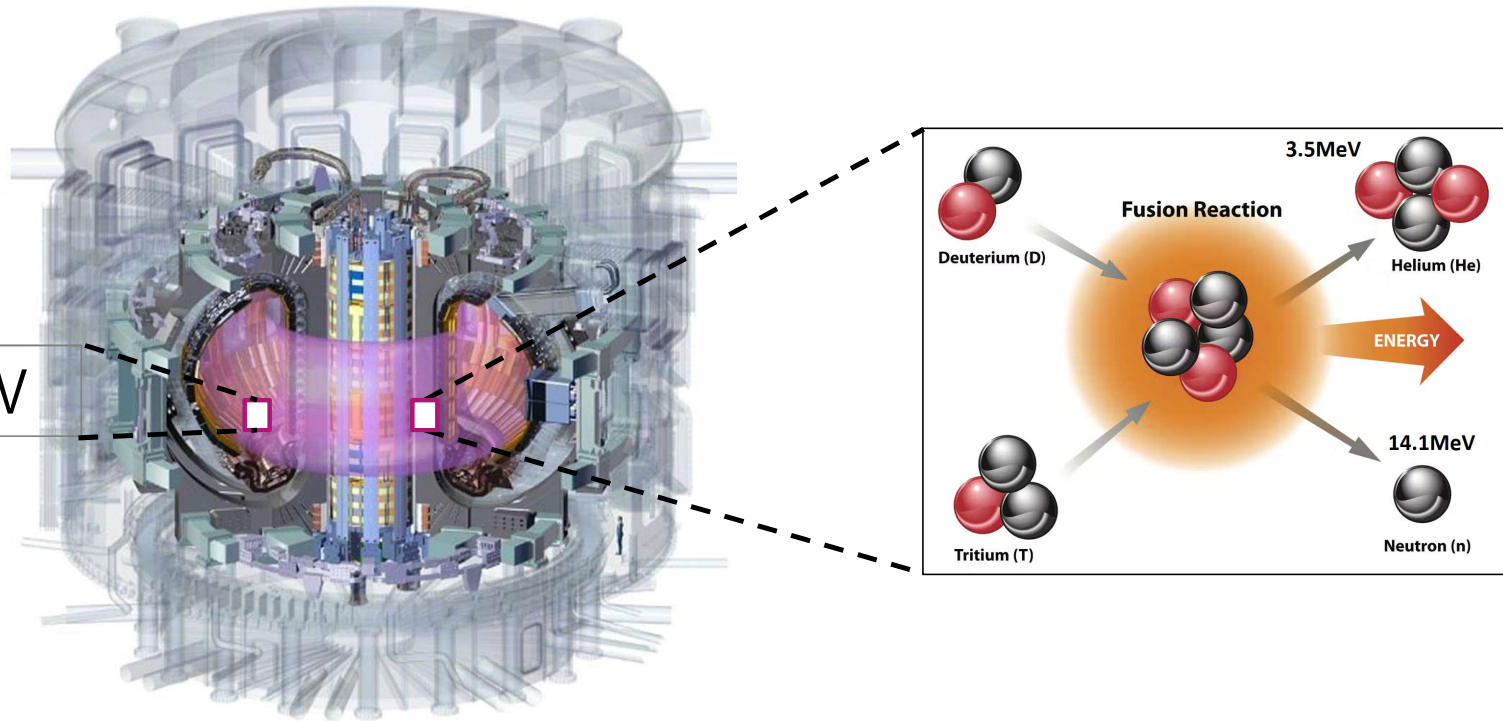
Outline



1. Why DTE2 at JET?
2. Fusion production world record
3. Physics studies in support of DT
4. Conclusions

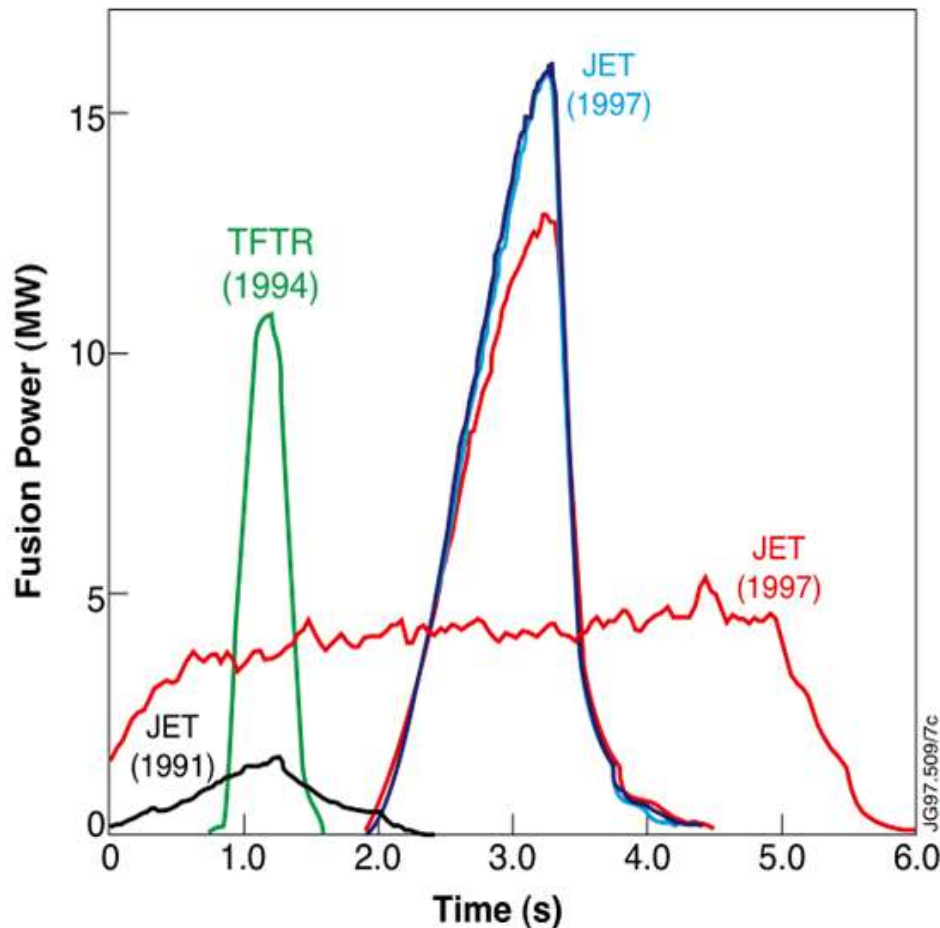


DT plasmas: key pillar for fusion energy production by plasmas



- Fusion produced **3.5MeV alpha particles** → **self heating of plasmas** through collisions
- What we actually know about DT plasmas?

D-T in Magnetic Confinement Fusion before 2021

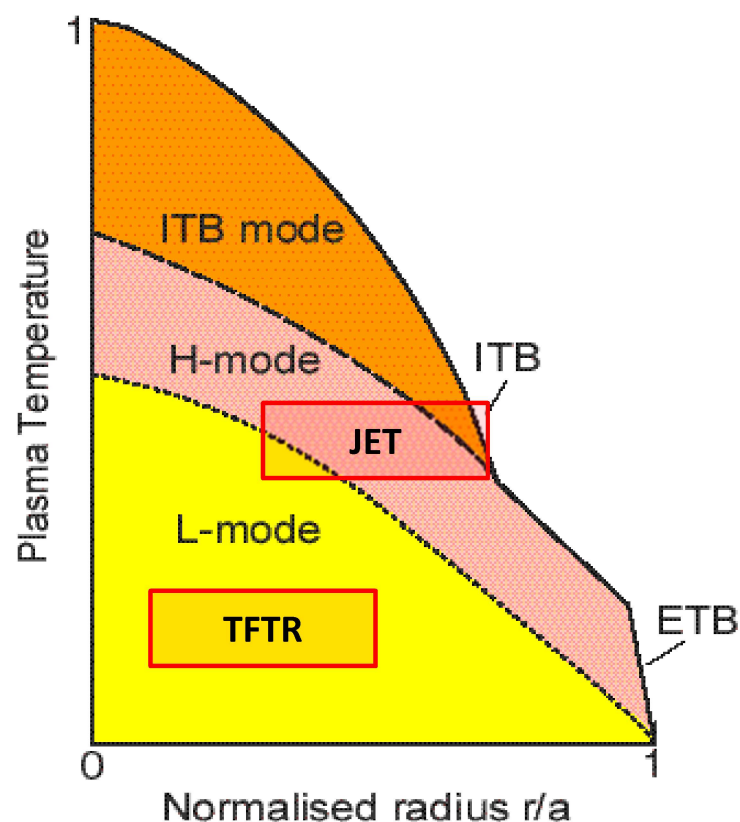


DT experiments were carried out in
1991 (PTE - JET)
1994-96 (TFTR – Princeton USA)
and 1997 (DTE1 on JET)

Clearly demonstrating:

- D-T Fusion production (14MeV neutrons)
- plasma physics effects linked to use of D-T mixture (*isotope effects*)

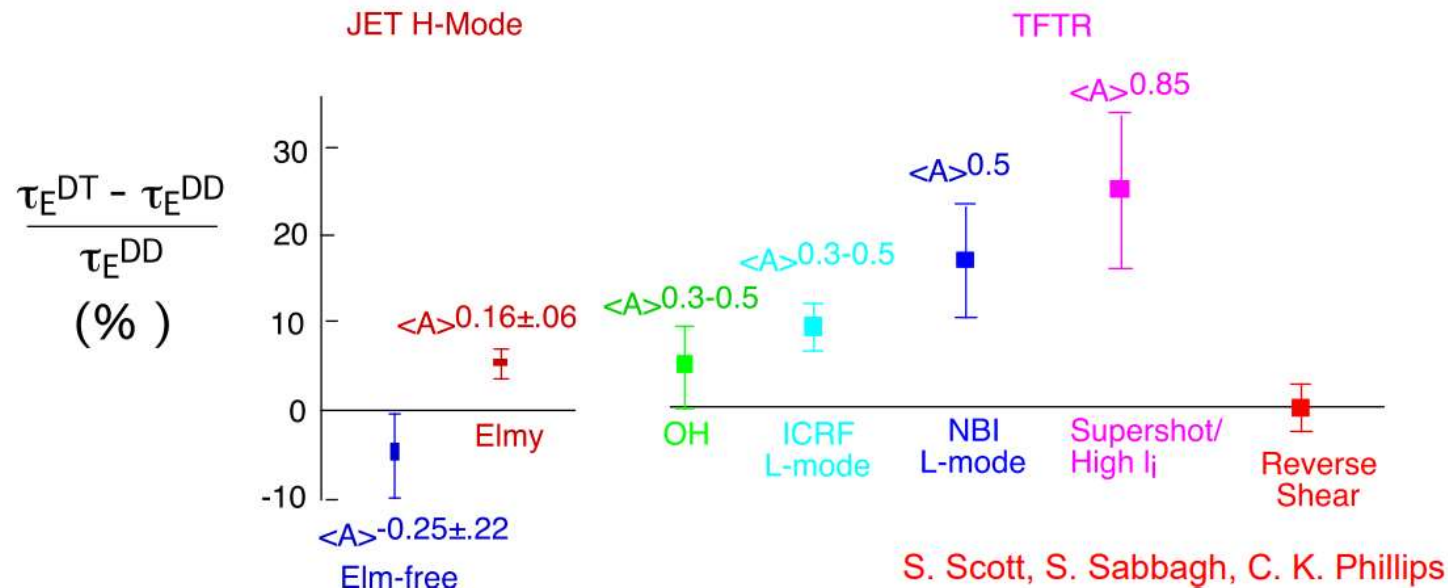
JET and TFTR aimed at different plasma regimes



A variety of tokamak operational scenarios exists

- **L-mode**: low performance, pulsed operation, no need for profile control
- **H-mode**: higher performance, pulsed operation, MHD control needed → **Main ITER Operation**
- **Advanced modes**: higher performance, steady state, needs profile control

DD vs DT plasmas energy confinement time

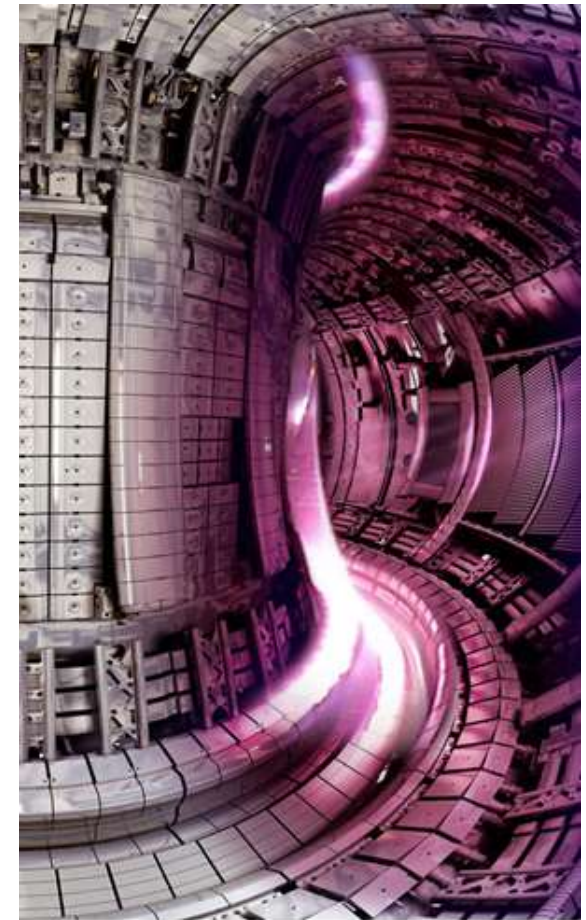


- JET vs TFTR confinement time: *the complete zoo*
- *ITER projection uses:* $\langle A \rangle^{0.2}$
- Are these results definitive and conclusive for ITER?



DTE1: first DT operation at JET, *unsolved issues*

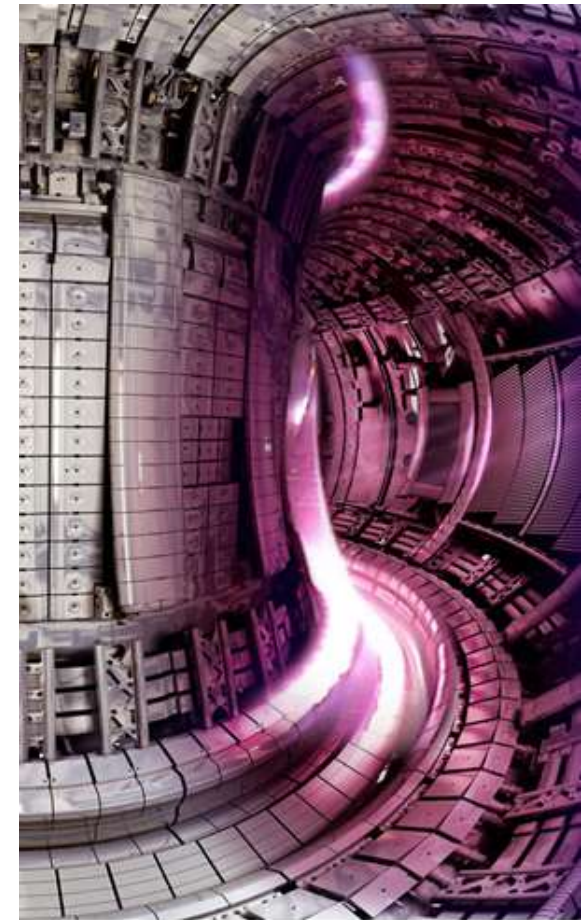
- DTE1 record fusion power plasmas were obtained in plasma conditions less relevant to ITER:
 - very low density
 - $T_i \gg T_e$
 - transient regime





DTE1: first DT operation at JET, *unsolved issues*

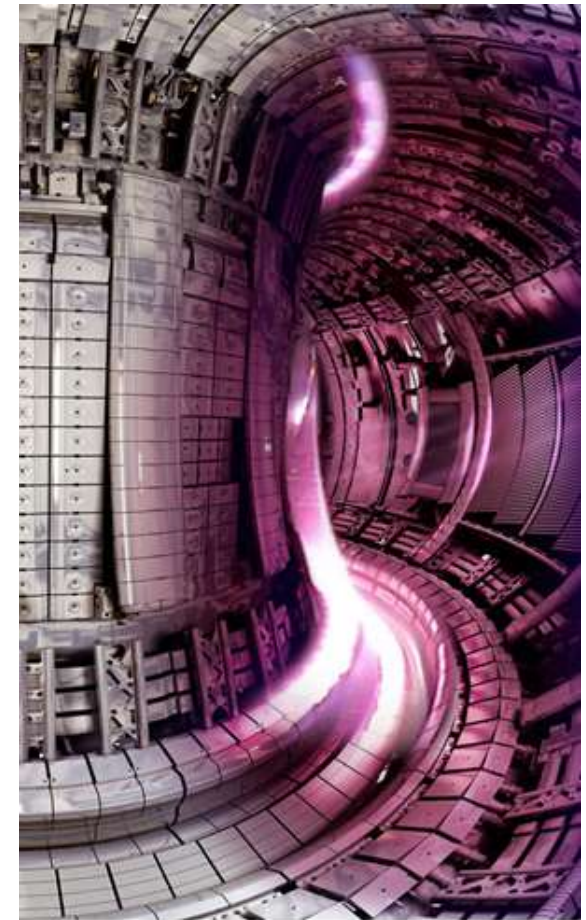
- DTE1 record fusion power plasmas were obtained in plasma conditions less relevant to ITER:
 - very low density
 - $T_i \gg T_e$
 - transient regime
- H-mode plasmas obtained at low power (no high beta plasmas)





DTE1: first DT operation at JET, *unsolved issues*

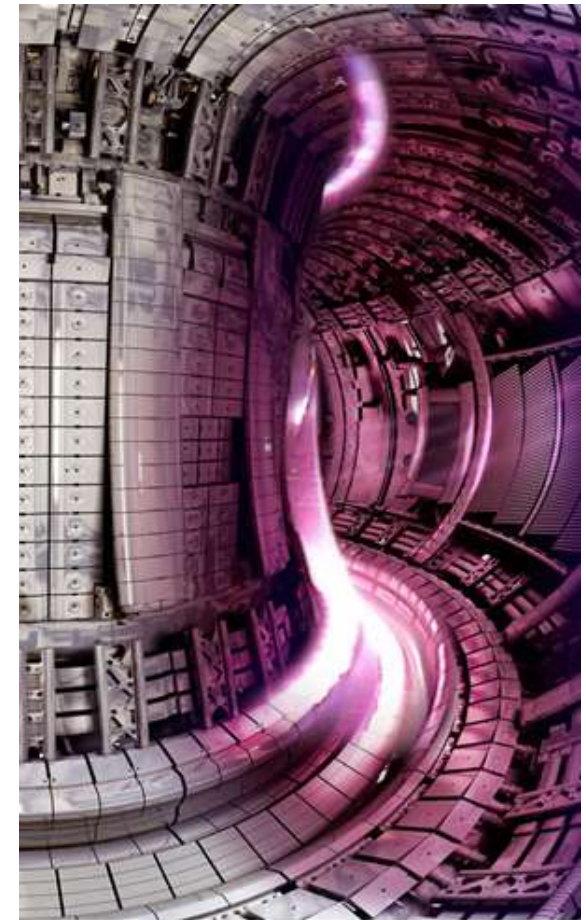
- DTE1 record fusion power plasmas were obtained in plasma conditions less relevant to ITER:
 - very low density
 - $T_i \gg T_e$
 - transient regime
- H-mode plasmas obtained at low power (no high beta plasmas)
- Plasmas obtained in C-wall (high T retention)



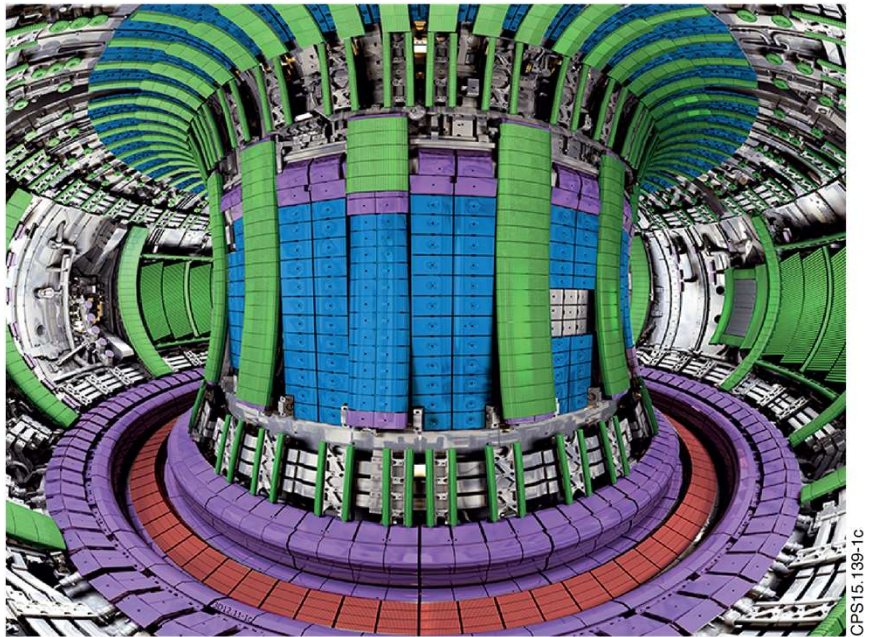


DTE1: first DT operation at JET, *unsolved issues*

- DTE1 record fusion power plasmas were obtained in plasma conditions less relevant to ITER:
 - very low density
 - $T_i \gg T_e$
 - transient regime
- H-mode plasmas obtained at low power (no high beta plasmas)
- Plasmas obtained in C-wall (high T retention)
- Alpha particle effects weak and difficult to understand

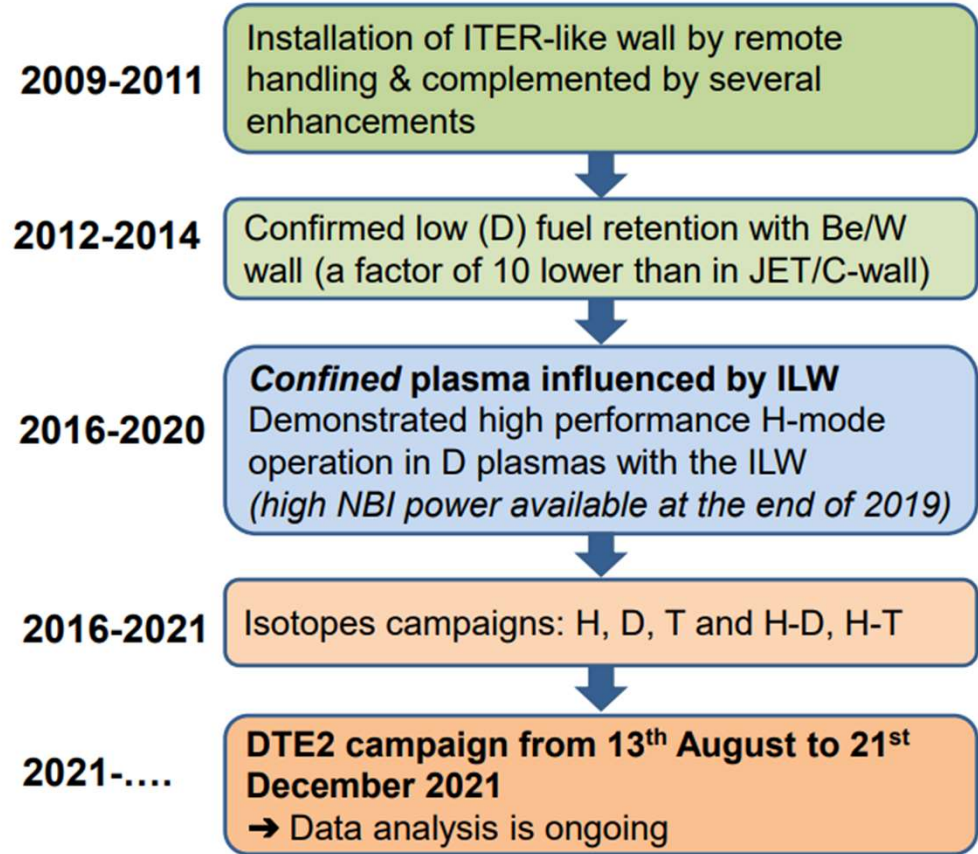


DTE2: Towards ITER relevant plasmas in DT

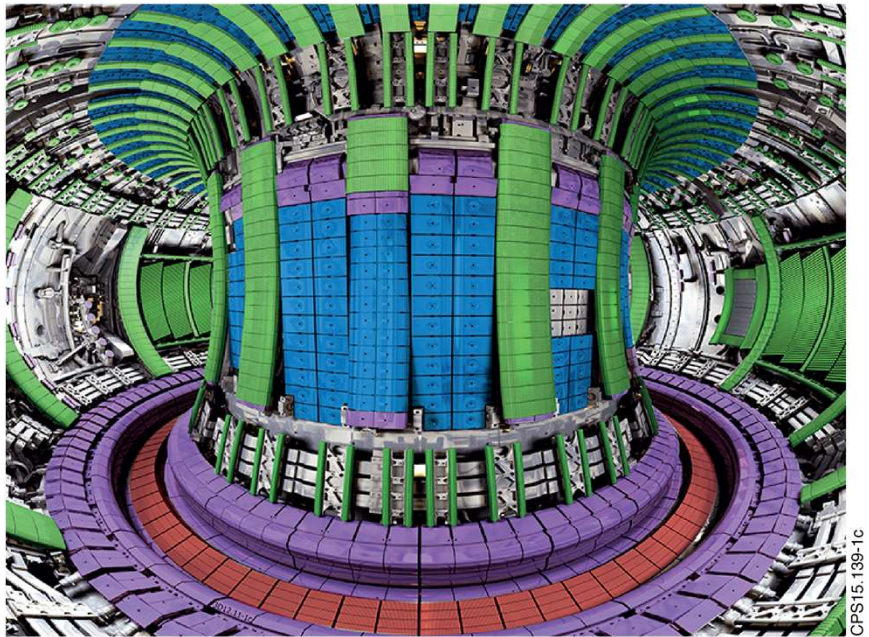


- Bulk Be PFCs
- Be-coated inconel PFCs
- Bulk W
- W-coated CFC PFCs

CPS15.139-1c



DTE2: Towards ITER relevant plasmas in DT



■ Bulk Be PFCs ■ Be-coated Inconel PFCs
■ Bulk W ■ W-coated CFC PFCs

CPS15.139-1c

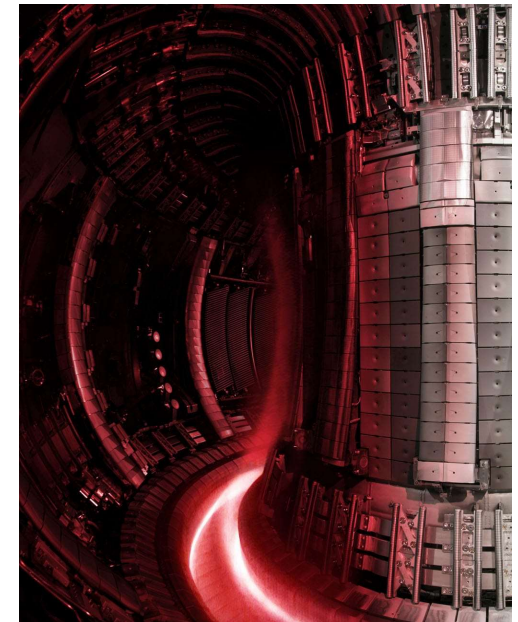
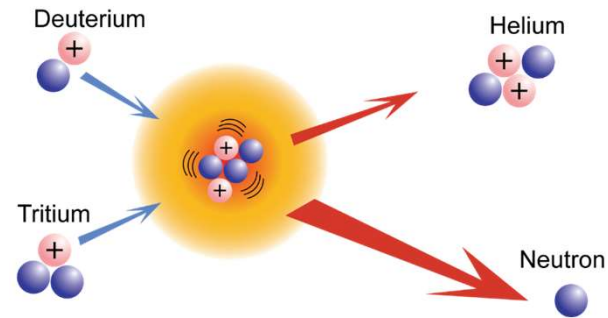
Improved capabilities compared to DTE1:

- ITER relevant wall&divertor
- Diagnostic capabilities
- More heating power
- Disruption prediction and mitigation/control
- RT control schemes
- Sophisticated Modelling

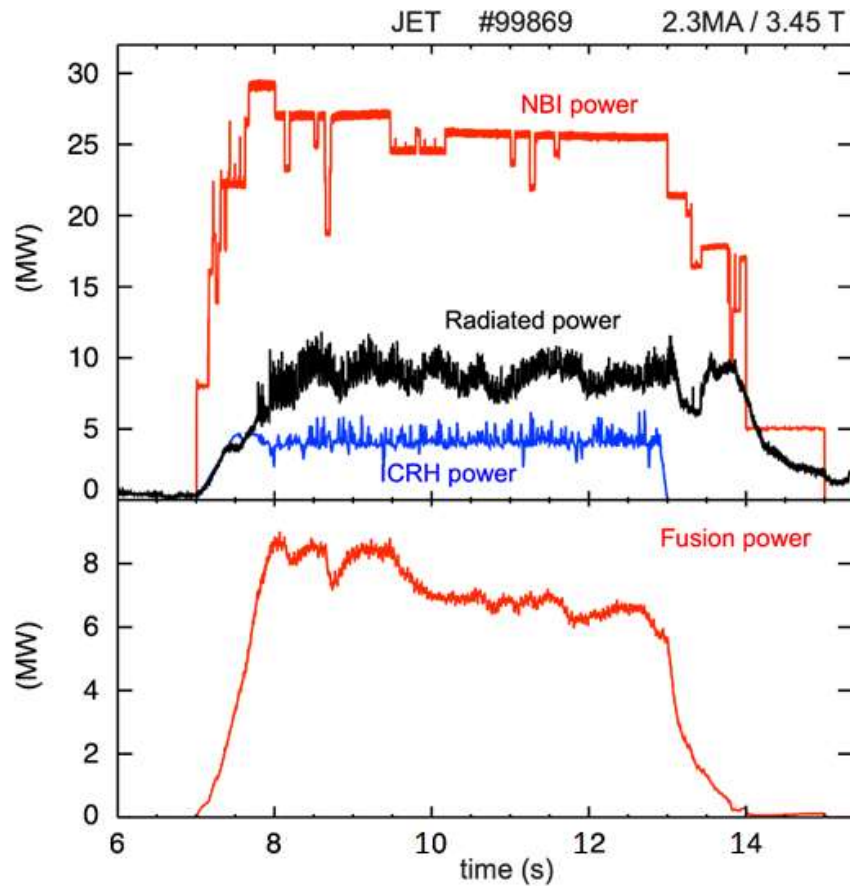
Outline



1. Why DTE2 at JET?
2. Fusion production world record
3. Physics studies in support of DT
4. Conclusions



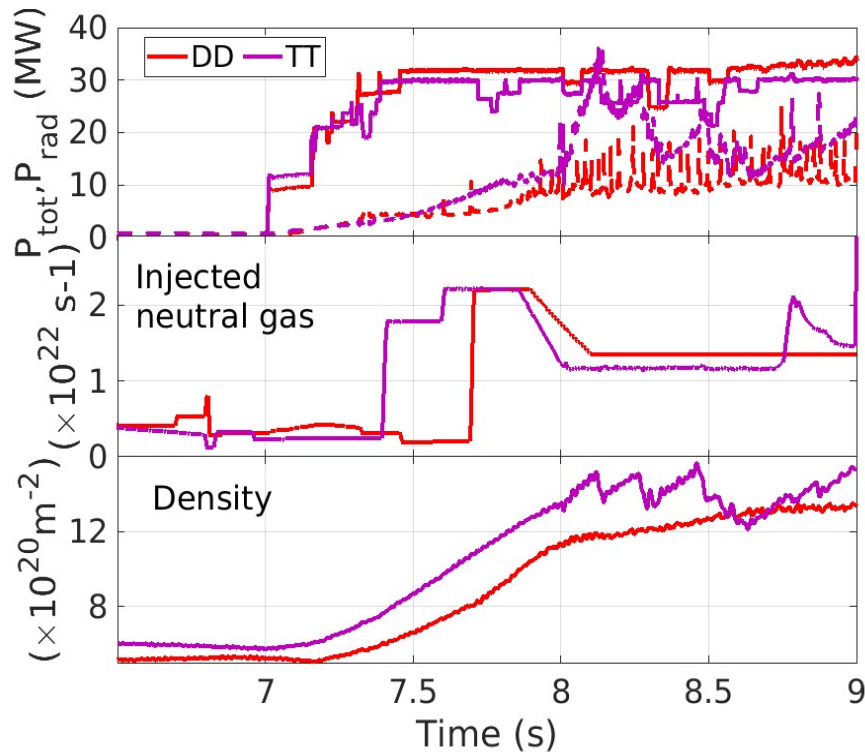
High beta H-mode plasma in 50-50 D-T



[C. Challis EPS2022]

- 'Hybrid' scenario plasmas operate at **medium current** and **high β** :
 - ✓ $2.2\text{MA} \leq I_p \leq 2.5\text{MA}$, $B_t = 3.45\text{T}$
- One of the candidate scenarios for ITER
- Had never been tested with T or D-T fuel before
- **High fusion power obtained but highly sensitive to input power**

Impurity behaviour in DD vs TT: significant differences



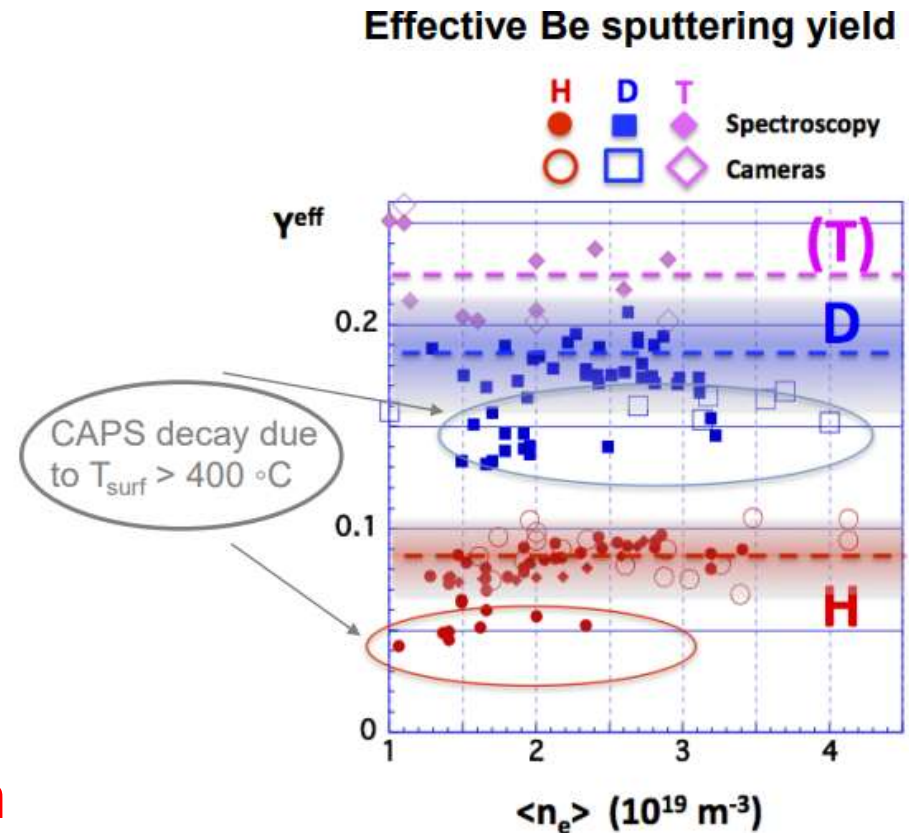
[C. Challis EPS2022]

- Risk of plasma pollution with metallic wall
- DD scenarios highly resilient to high Z pollution [Mailloux NF22] [Field submitted]
- Repeat of DD recipes in TT became challenging
- Transferability of DD recipes to TT and DT might not be straightforward

Measured tokamak Be and W erosion by T and DT fuel

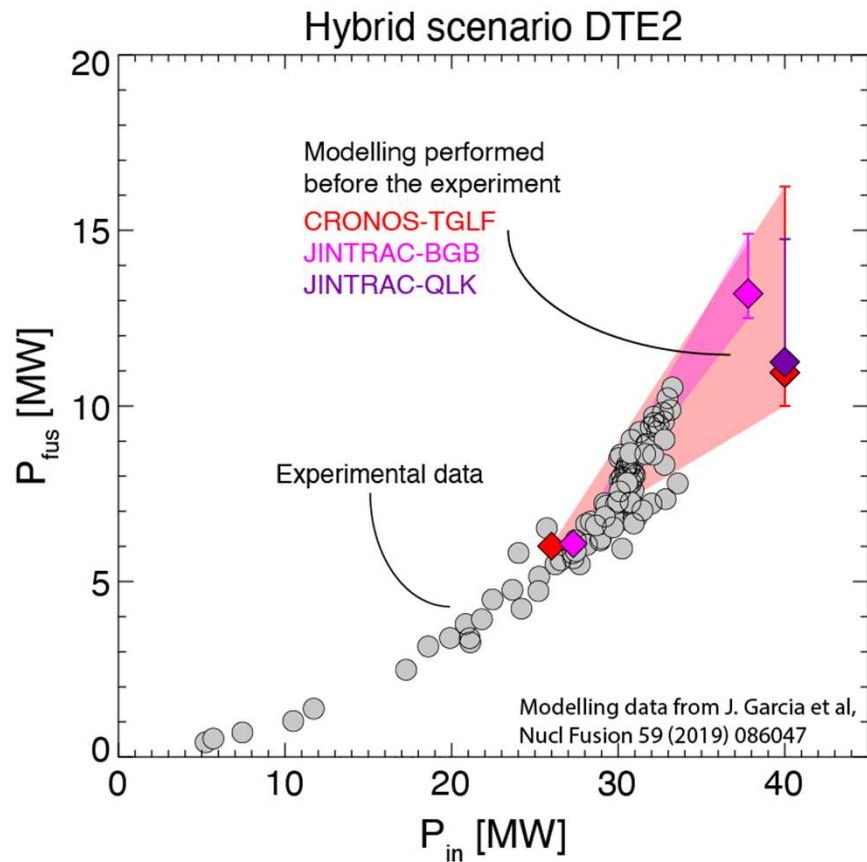


- Erosion of plasma-facing components by tritium → Be, W can pollute and cool plasma
- Observations:
 - Be gross erosion increases with isotope mass
 - Contribution of hydrogen isotopes to total W erosion increases strongly with mass
- Improved predictions of Be and W erosion in ITER



[E de la Cal et al., *subm NF*]
[D Borodin et al., *PSI 2022*]

D-T fusion power confirms modelling predictions

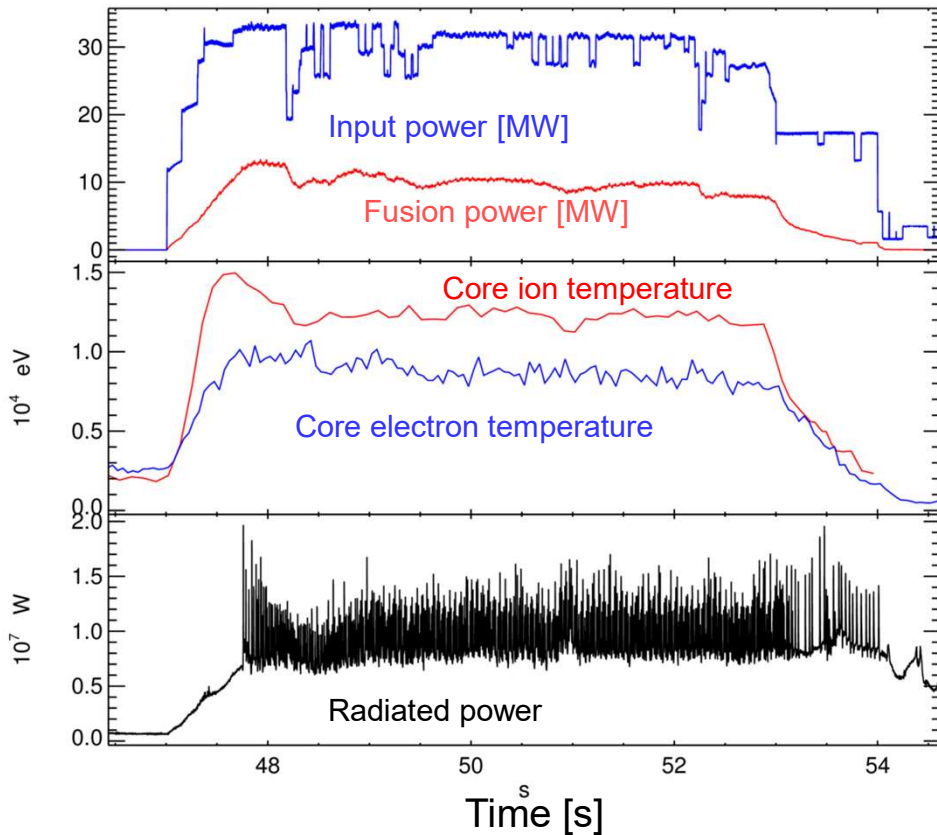


- Strong **predict first modelling** performed since 2010
- **D-T fusion power achieved is in broader agreement with predictions**
- Simplified models can be improved with new DT data.
- **Essential for ITER** and future reactors predictions.

H-mode scenario with optimized non-thermal fusion power



15%D - 85%T plasma with D-NBI (2.5MA/3.86T)

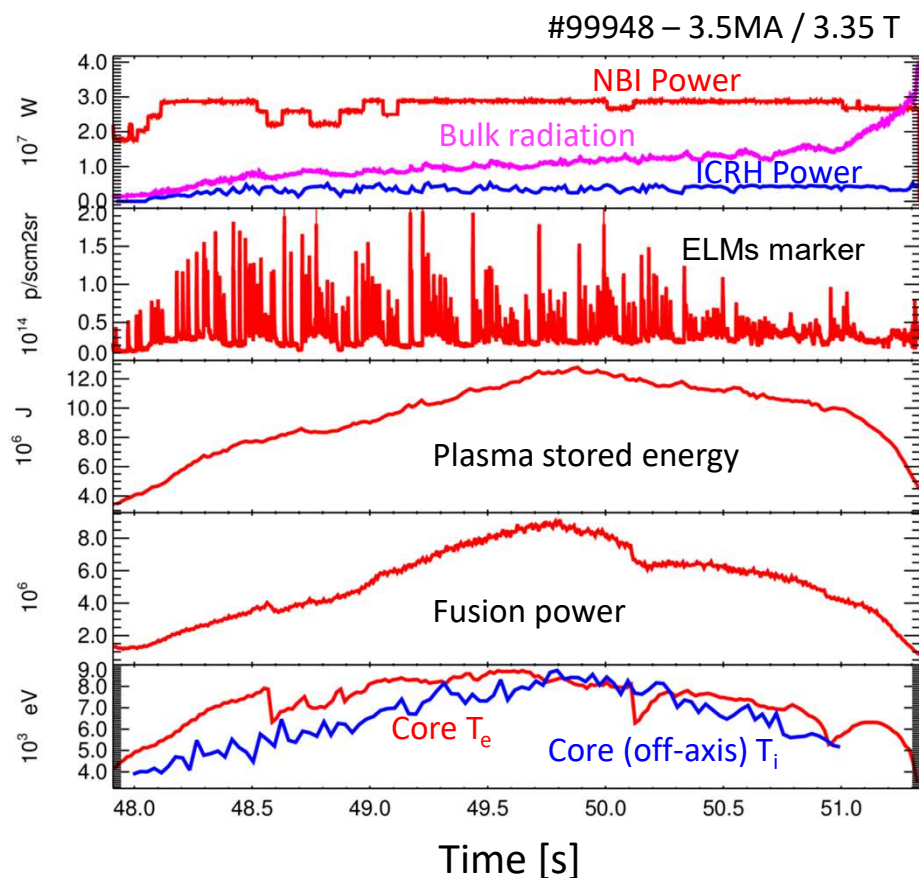


- Plasma composition: 15%D - 85%T
- Max Deuterium NBI heating
- Record steady fusion energy: $E_{\text{fus}} = 59\text{MJ}$
- Non-thermal fusion production dominant

[M. Maslov]

First ever tested on JET or anywhere else

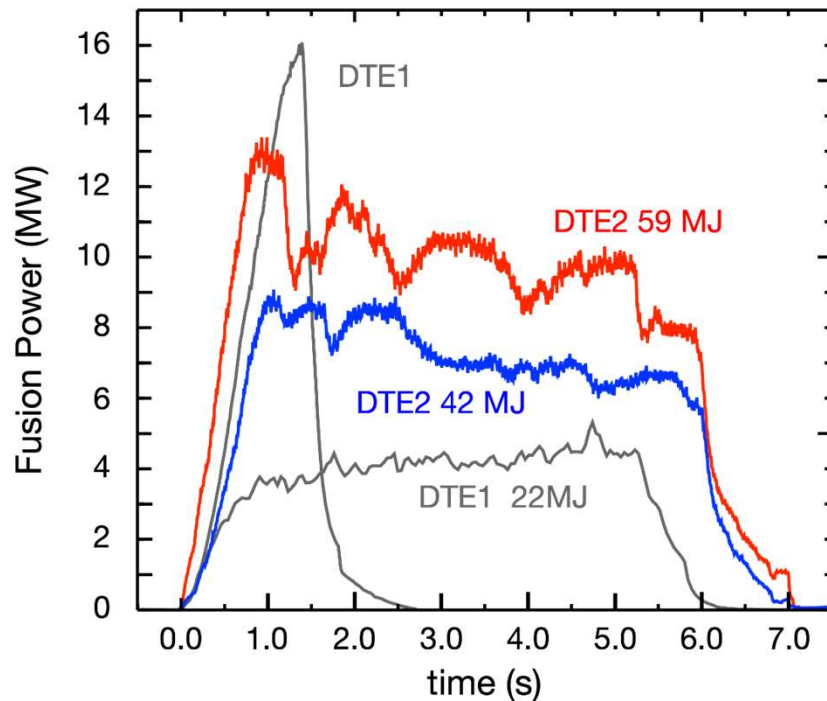
H-mode baseline scenario plasma in 50-50 D-T



[D. van Eester RF topical 2022]

- ‘Baseline’ scenario plasmas operate at **high current** and **medium β** :
 - ✓ $I_p=3.5\text{MA}$, $B_t=3.35\text{T}$
- High confinement stationary plasmas obtained in DD [Mailloux NF 22] [Garcia POP 22]
- **In DT, stopped by too high radiation**
- Under investigation → important to understand for ITER

World fusion energy record obtained in DTE2



- High fusion power plasmas performed in **D-T for the first time with Be/W wall**
- **Confirming predictions** of plasma behaviour
- Confirms expectations for **stationary high fusion power plasmas in ITER**
- Showing the **challenge to transfer operation from DD to DT**

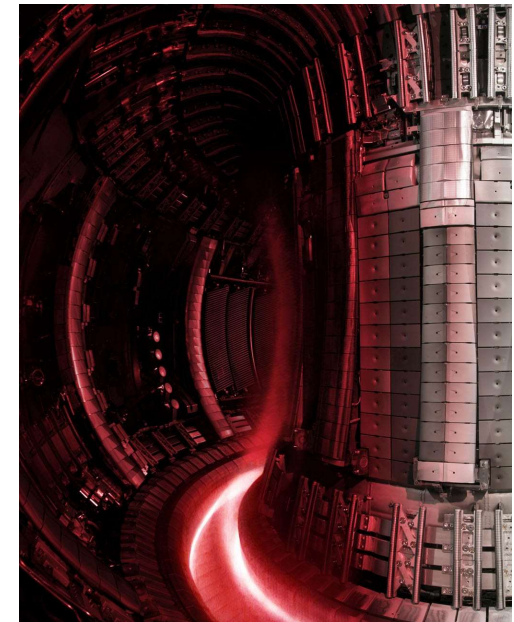
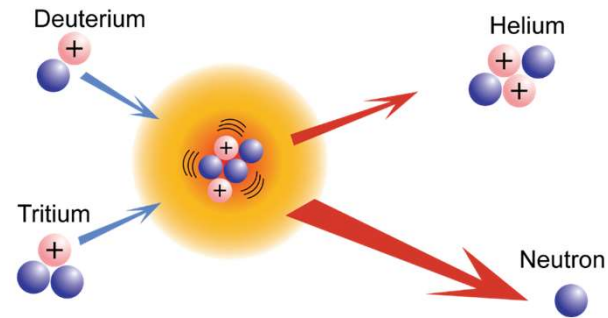
#99869 (2.3MA/3.45T) with ~50/50 DT NBI and plasma

#99971 (2.5MA/3.86T) with D-NBI in T-rich plasma

Outline



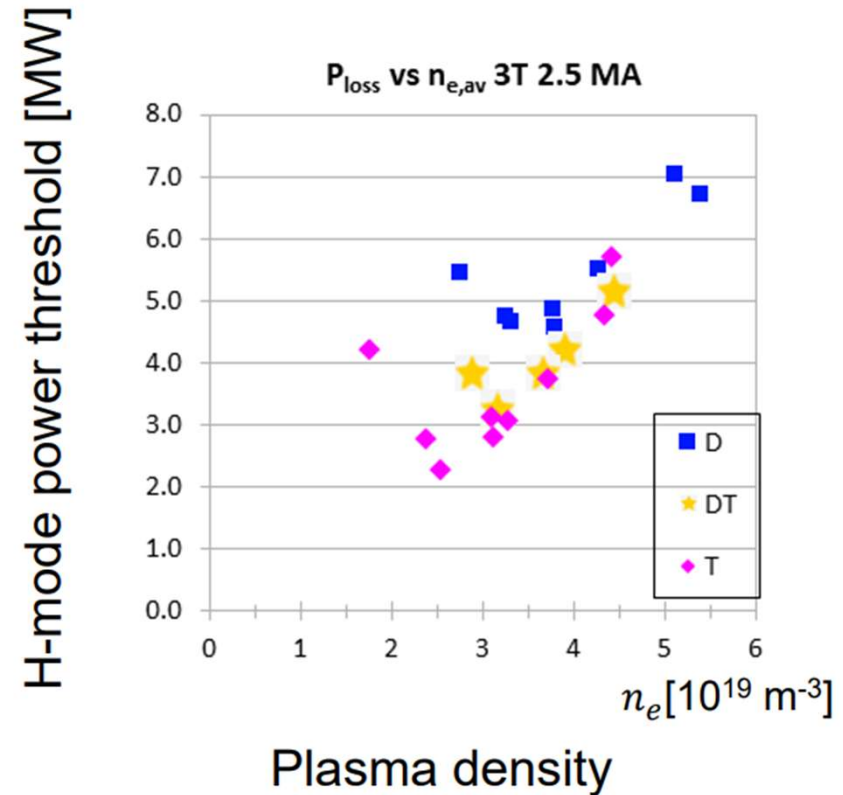
1. Why DTE2 at JET?
2. Fusion production world record
3. Physics studies in support of DT
4. Conclusions



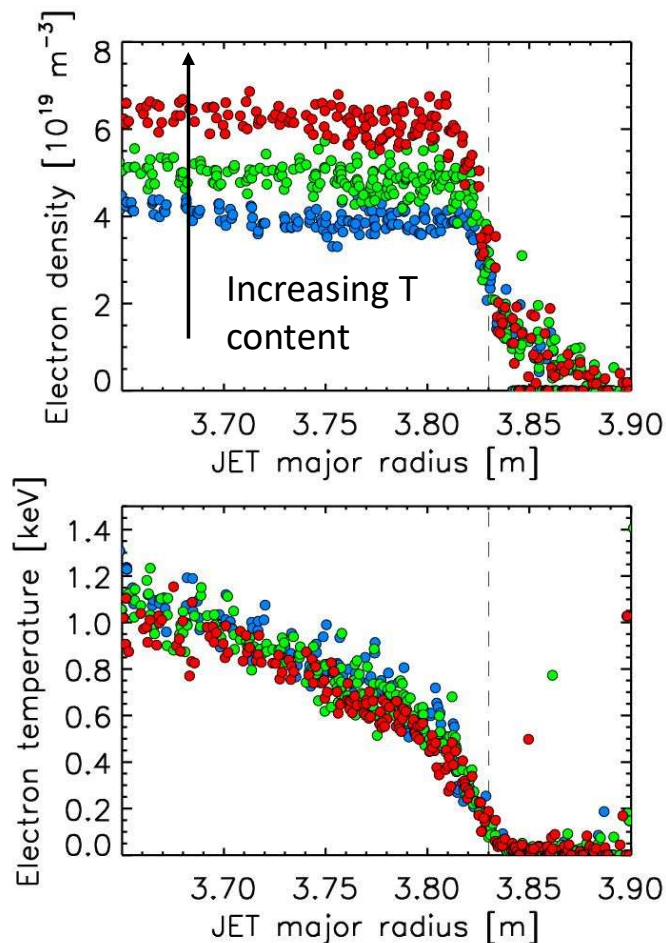
Impact of fuel mass on L-H transition



- L-H transition studies are essential to ITER
- $n_{e,\min}$ and P_{L-H} are different in H, D and H+D mixtures at JET [Maggi PPCF18]
- Similar trend found in D vs T plasmas → Lower P_{L-H} for T [Solano NF22]
- DT plasmas are found between D and T



Variation of H-mode pedestal structure with D-T fuel mix



- Increased pedestal density from H to D

[CF Maggi et al., PPCF 2018]

[L Horvath et al., NF 2021]

[P Schneider et al., NF 2022]

- Changes on transport characteristics

[Horvath NF21]

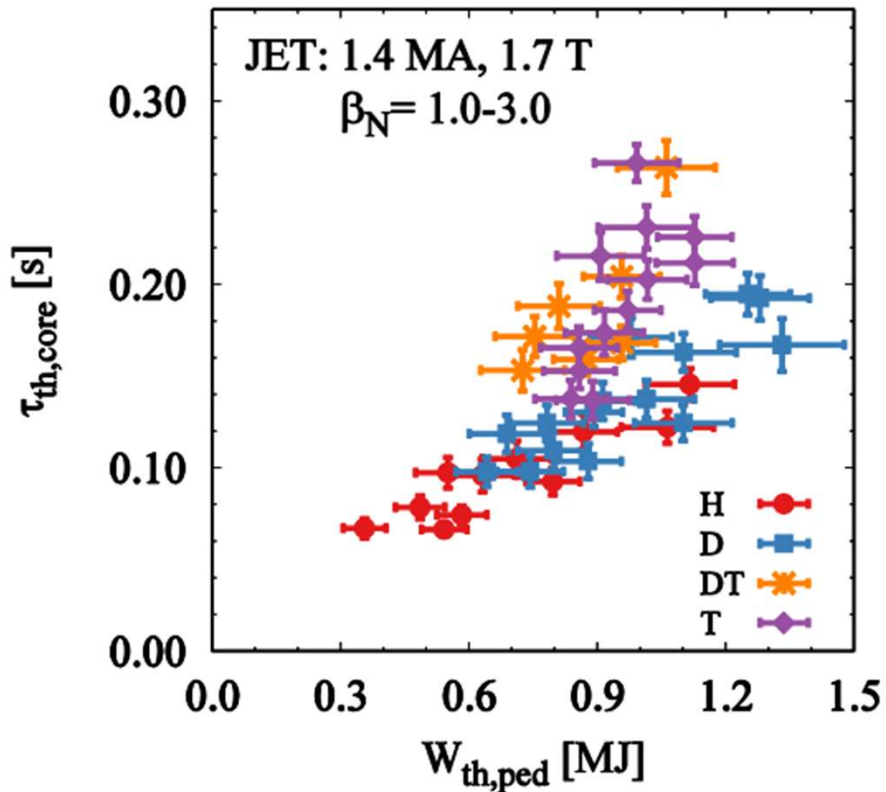
- Pedestal density also increases in D \rightarrow T

- Crucial data for improving ITER predictions

Controlled D-T fuel mix scan at constant β_N
(obtained with feedback control on injected power)

[L Frassinetti et al.]

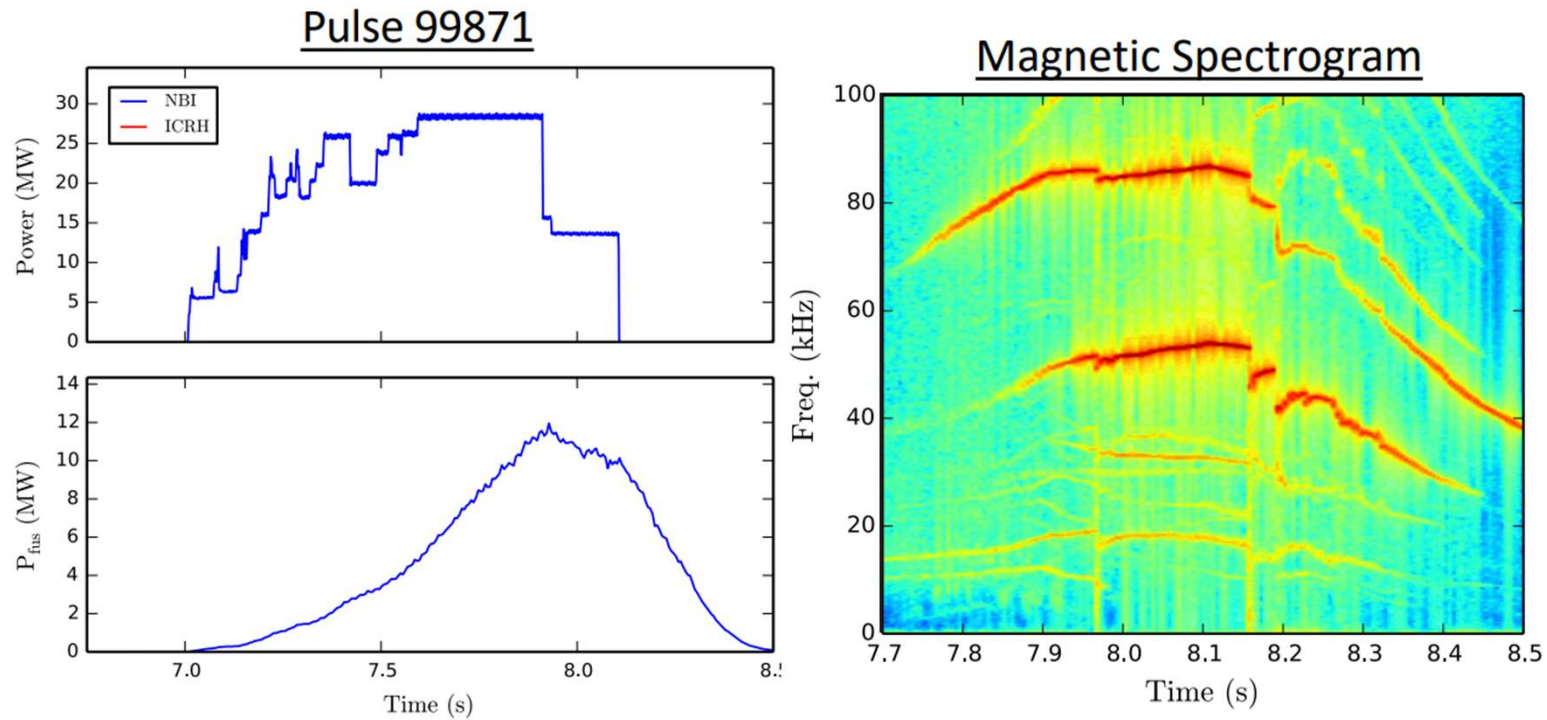
Core energy confinement



- T and DT plasmas show higher core energy confinement than D and H
- Notably at high input power
- In agreement with previous theoretical studies
- Heat transport reduced in D \rightarrow T with:
 - Rotation [\[Garcia NF17\]](#)
 - Beta [\[Casson NF20\]](#)
 - Collisionality [\[Mariani NF21\]](#)

P. Schneider AAPPs conference 2021

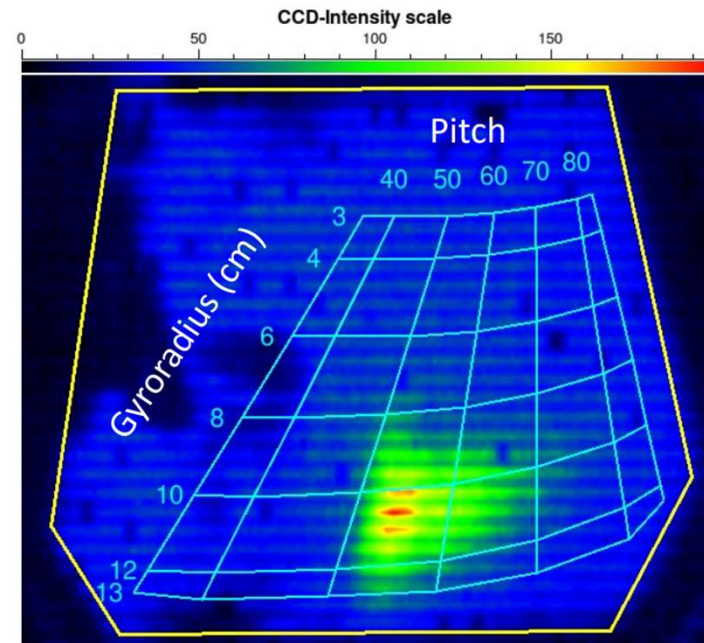
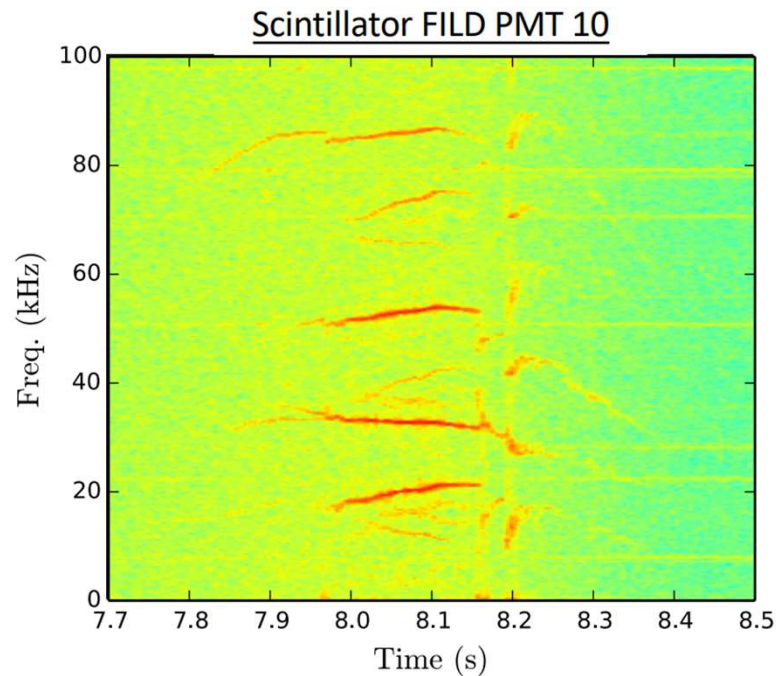
Alpha particle loses and MHD activity



P. Bonfigli
MF1-I3

- MHD activity destabilized in high fusion power plasmas

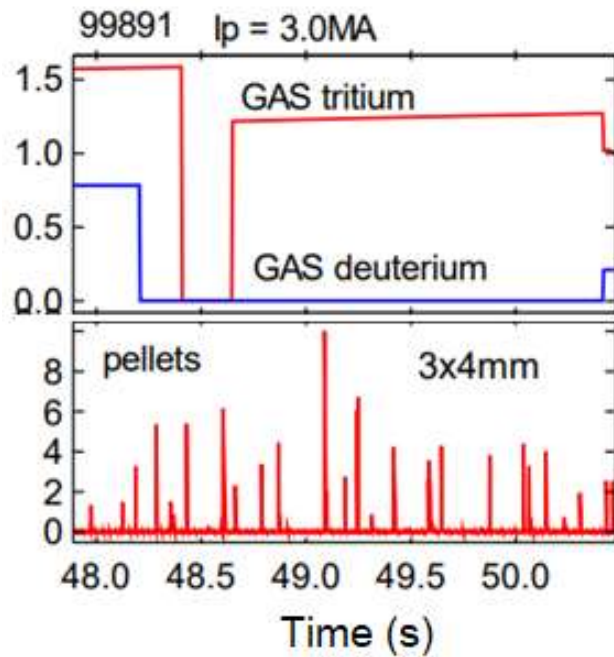
Alpha particle loses and MHD activity



P. Bonfiglio
MF1-I3

- MHD activity destabilized in high fusion power plasmas
- FILD diagnostic: **0.5%-2% alphas lost in MHD events**

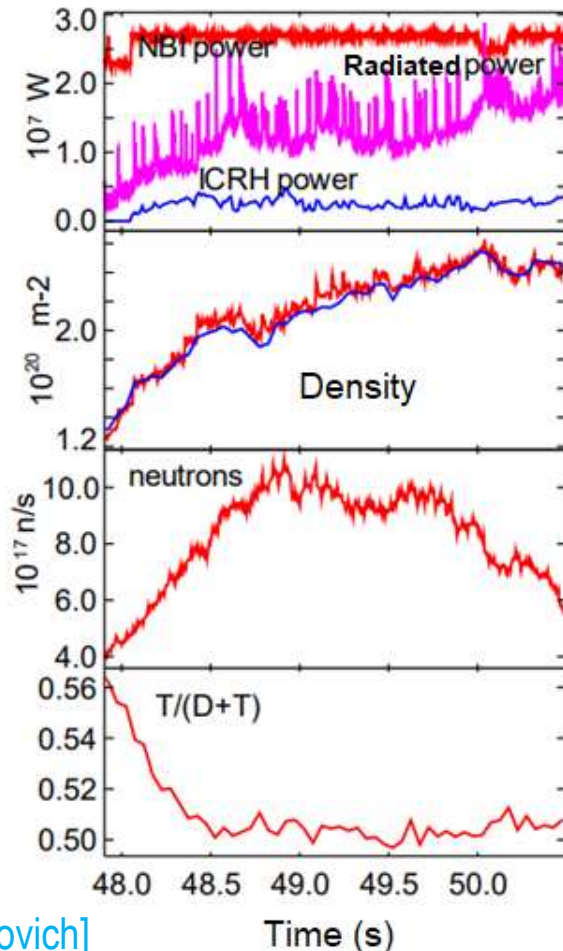
D-T mixture control



[M. Valovich]

- Different D-T plasma fueling tested
 - Neutral Gas Injection
 - Pellets
- Can the 50-50% DT mixture be controlled?

D-T mixture control



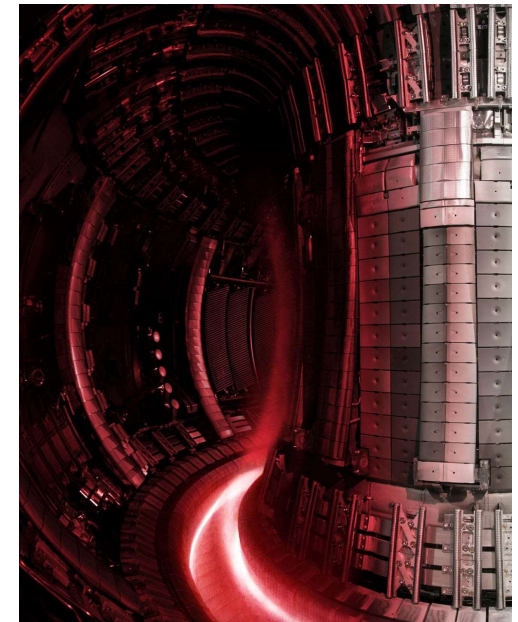
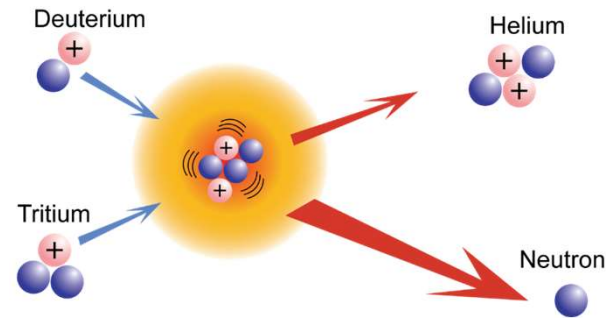
[M. Valovich]

- Different D-T plasma fueling tested
 - Neutral Gas Injection
 - Pellets
- Can the 50-50% DT mixture be controlled?
- 50-50% mix achieved and controlled by adjusting pellet frequency
- High neutron level show potential 50-50% mixture in the core → being analyzed
- **Essential information for ITER**

Outline



1. Why DTE2 at JET?
2. Fusion production world record
3. Physics studies in support of DT
4. Conclusions



JET DTE2 experiments bring fusion energy closer



- Exploiting JET's unique set of capabilities: T handling, ITER-like wall, size, heating & diagnostics enhancements:
 - JET D-T experiments have demonstrated highest ever fusion energy production
 - In conditions closest to ITER as we can with any fusion facility in the world
 - Providing a new set of physics results in DT
 - Confirming modelling predictions for the fusion power, giving confidence for predictions of ITER and future reactors
 - Will help accelerate ITER research plan (risk mitigator for ITER)
- While doing so, we have also trained a new generation of scientists, engineers and technicians, transferring unique knowledge and skills to ITER

List of JET-DT related talks



- S. Mazzi “On the beneficial role of fast ions on microturbulence: from current experiments towards ITER” PL.32
- D. Matveev “Isotope removal and outgassing in JET-ILW” PL.38
- P. Bonfiglio “DT-Alpha Particle Loss Measurements in the JET DTE2 Campaign” MF1-I3
- E. Lerche “Development of a hybrid plasma scenario for D-T experiments in JET-ILW” MF1-I4