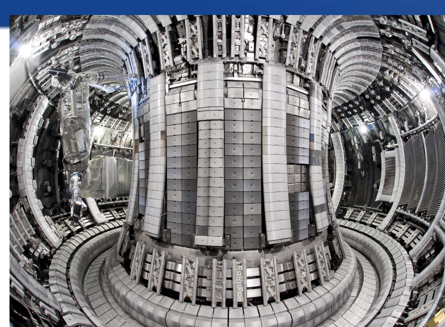
EUROfusion

JET programme in support to ITER and preparation of the 2020 DT campaign

Presented by Xavier LITAUDON on behalf of EUROfusion

Acknowledgments: The JET Task Force and Project Leaders, the JET secondees, the EUROfusion Programme Management Unit, the JET Exploitation Unit and the JET operator

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 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Introduction, Context

- **Europe has elaborated a roadmap to the realisation of fusion energy** [https://www.euro-fusion.org/eurofusion/roadmap]
  - ***'ITER is the key facility and its success is the most important overarching objective of the programme'***
  - 2018: roadmap evolution* in response to revised ITER schedule
- **ITER International Organization**
  - issued a detailed analysis of the risks to ITER operation
  - identified main R&D needs to mitigate those risks in the revised ITER research plan**
- **EUROfusion has seized the opportunity to develop an integrated programme on devices of different sizes**
  - PFC facilities, EU Medium-Size Tokamaks and JET
  - step-ladder approach for extrapolation to ITER and DEMO

[*T. Donné et al. SOFT 2018, ** https://www.iter.org/technical-reports]

JET

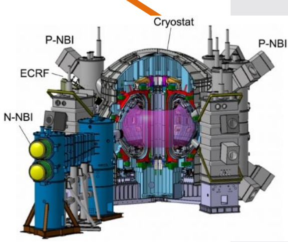
EUROfusion coordinates R&D in fusion research

30 Research Units from 26 EU countries plus Switzerland + Ukraine from Jan. 2017 working together to achieve the goal of the Fusion Roadmap

china eu india japan korea russia usa

FUSION FOR ENERGY

the EU Domestic Agency for ITER: Focus on procurements



JT-60SA (Japan)

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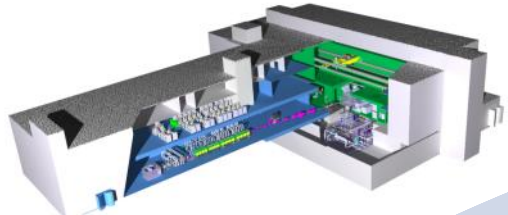
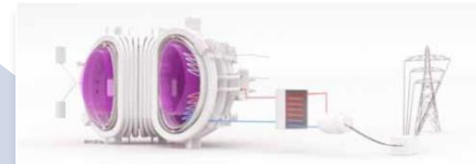
JET

EU step-ladder approach towards ITER and DEMO

Materials under 14 Mev neutrons



Power Plant

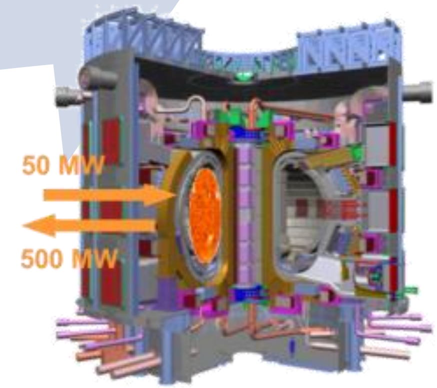


[G. Federici et al. SOFT 2018]

DEMO

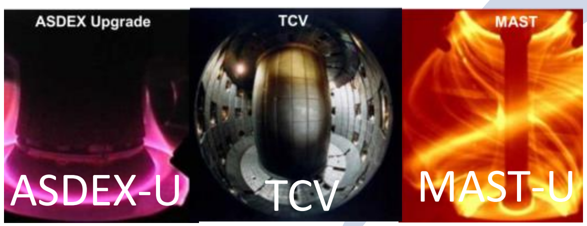
ITER

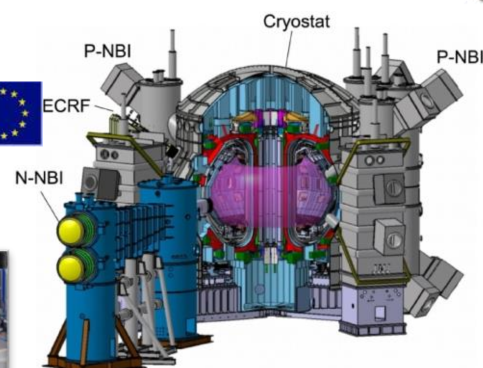
JET



Medium-Size Tokamaks and Plasma Facing Components facilities

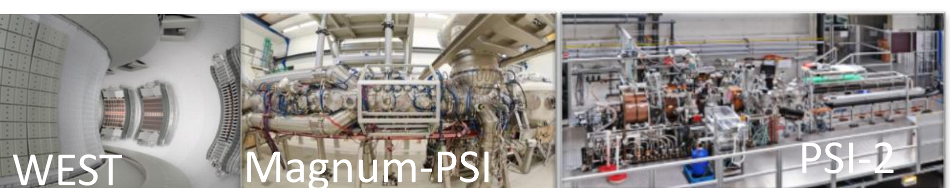
JT-60SA





[B. Bigot et al. SOFT 2018]

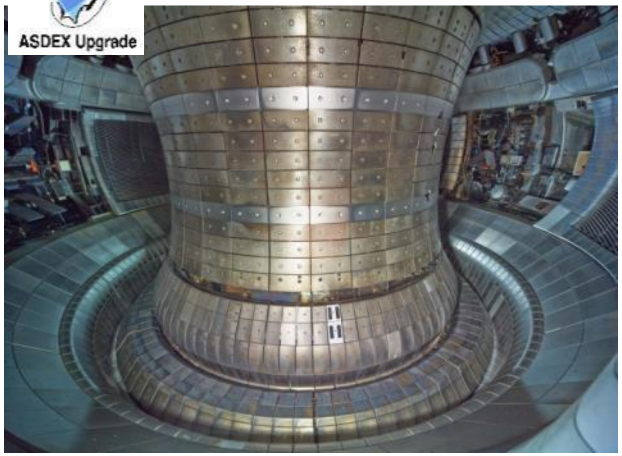
[X. Litaudon et al. SOFT 2018]

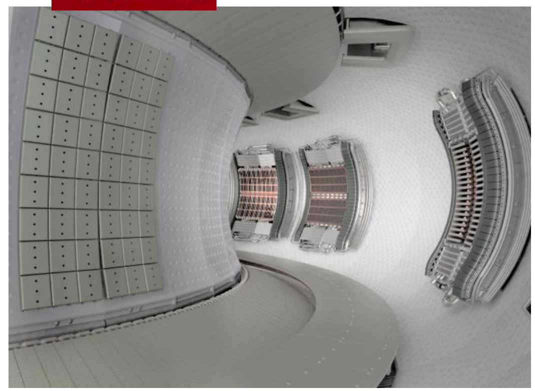


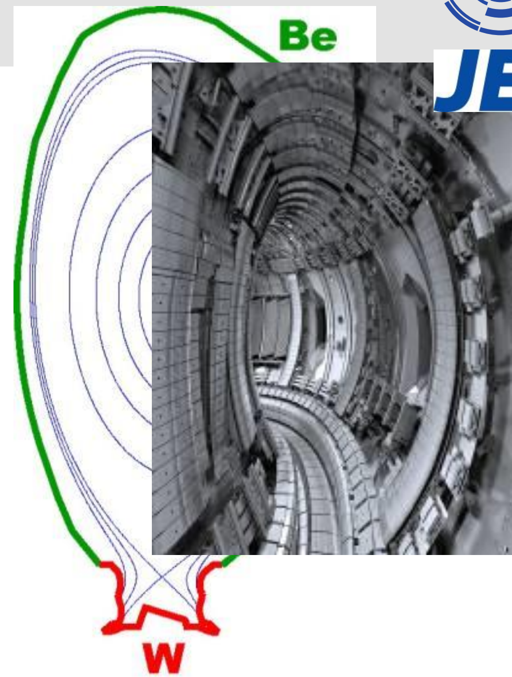
[Y. Kamada et al. SOFT 2018]

[https://www.euro-fusion.org/eurofusion/roadmap]

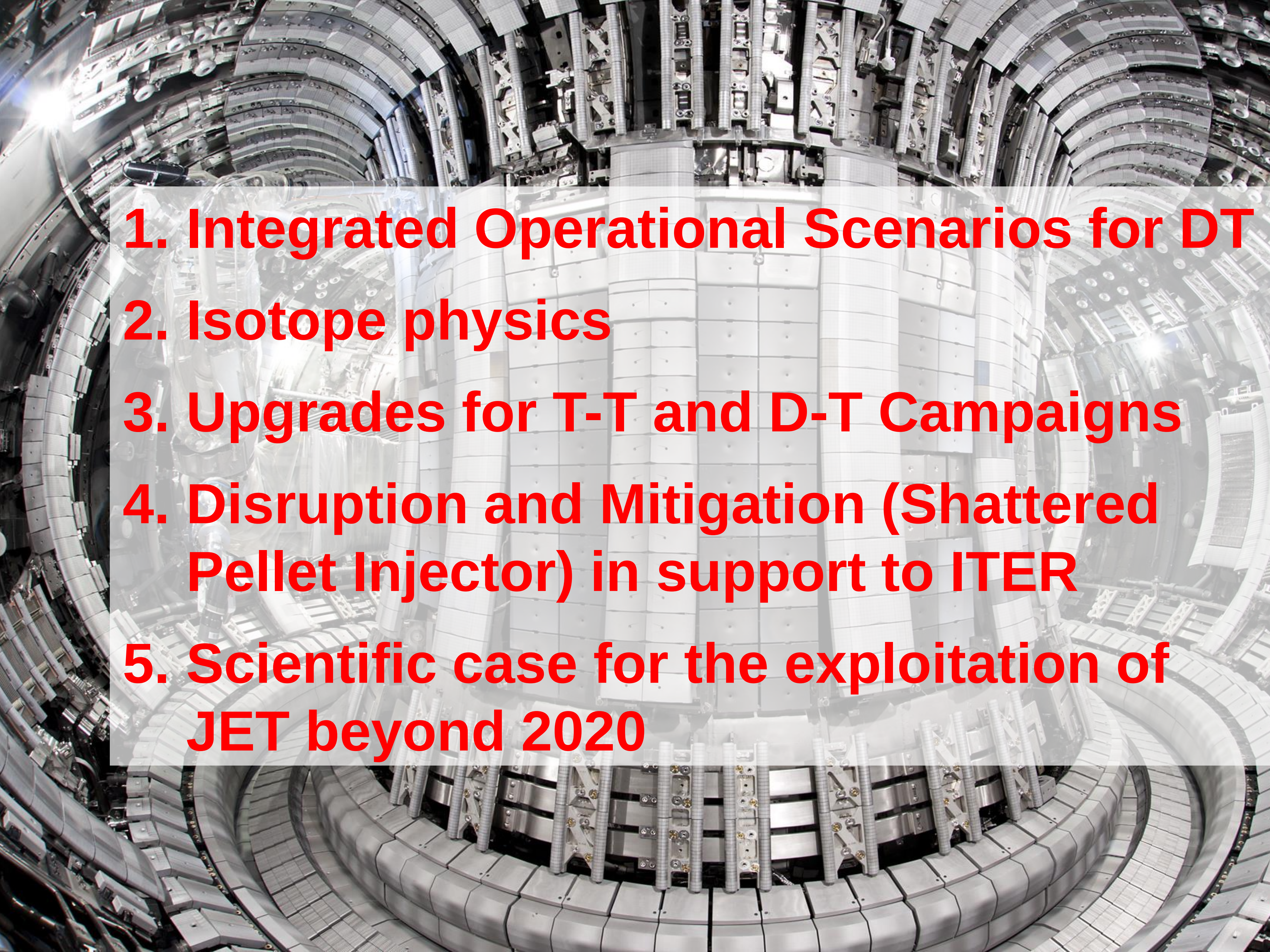
EU Tokamaks with a metallic wall







- **ASDEX Upgrade**
  - **Conversion to all W PFCs complete gradually over 7 years**
  - **ITER pre-fusion Operation Helium campaign, divertor manipulator**
- **Tore Supra→ WEST (2017 First Diverted Plasma)**
  - **Long pulse operation with actively cooled ITER W-monoblocks components including He-campaign (2019/2020)**
- **JET ITER-like Wall (Be wall and W divertor) change in 2011 shutdown**
  - **Preparation of ITER pre-fusion (H-H) and fusion operation with D-D, T-T and D-T scenarios in 2020**



1. **Integrated Operational Scenarios for DT**
2. **Isotope physics**
3. **Upgrades for T-T and D-T Campaigns**
4. **Disruption and Mitigation (Shattered Pellet Injector) in support to ITER**
5. **Scientific case for the exploitation of JET beyond 2020**

Breaking News JET and Brexit !

- **JET operation is guaranteed until the end of 2020 <u>regardless of the Brexit outcome</u>**
- The European Commission and the UK have signed a contract extension that will secure at least €100 Millions from the EU until end of 2020
- Indeed the news brings reassurance to the more than 500 staff who work at the JET site

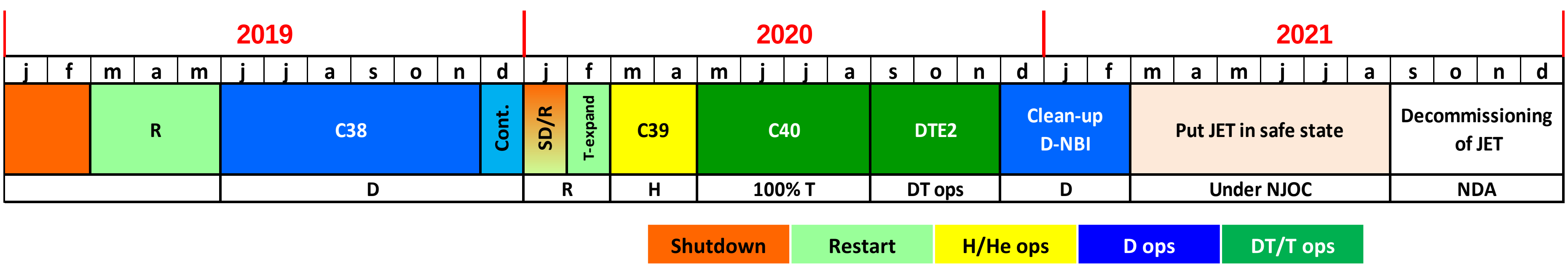
Overview of the JET schedule up to 2020

- **In order to keep the timeline inside of 2020, priority has been given to experiments with the new Shattered Pellet Injector and to DT operation**

- **This is at the cost of a significantly reduced scope for the isotope experiments and of less thinking time between TT and DT**

- **The JET Task Force Leaders have reviewed the programme scope in light of these changes**

JET Schedule until 2020, with Tritium and DT in 2020

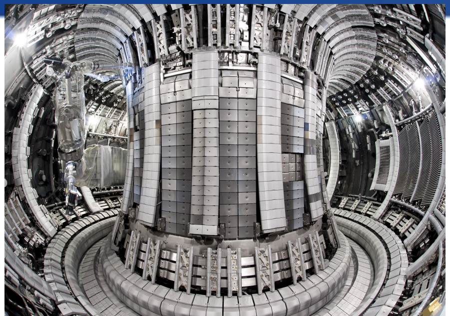


The JET operating contract has been extended to 31 December 2020 and the contract foresees post-operational activities

European Commission
UK Atomic Energy Authority

JET

Integrated Operational Scenario for DT and fusion performance



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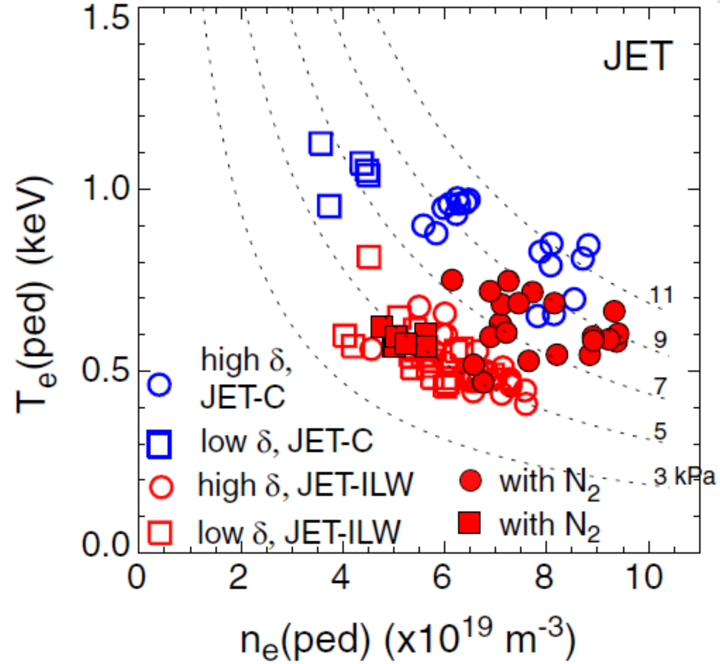
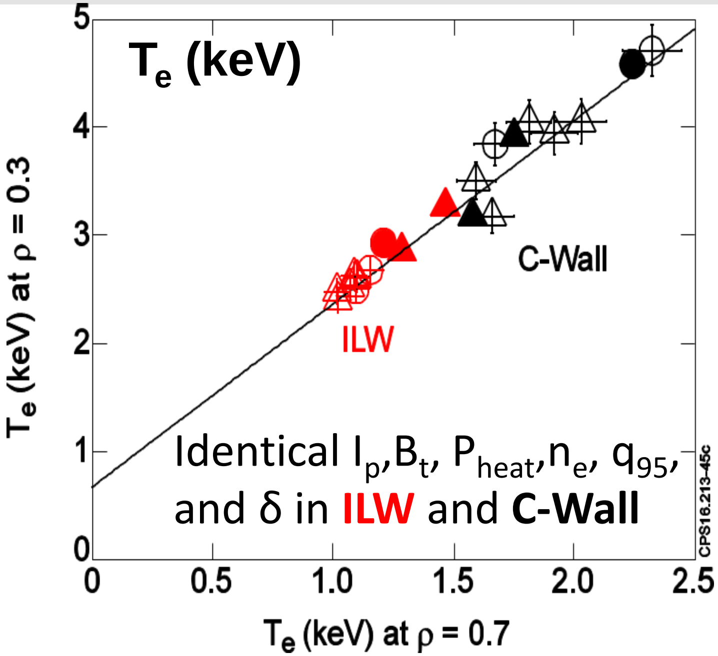
Confinement with JET ITER-Like Wall , ILW



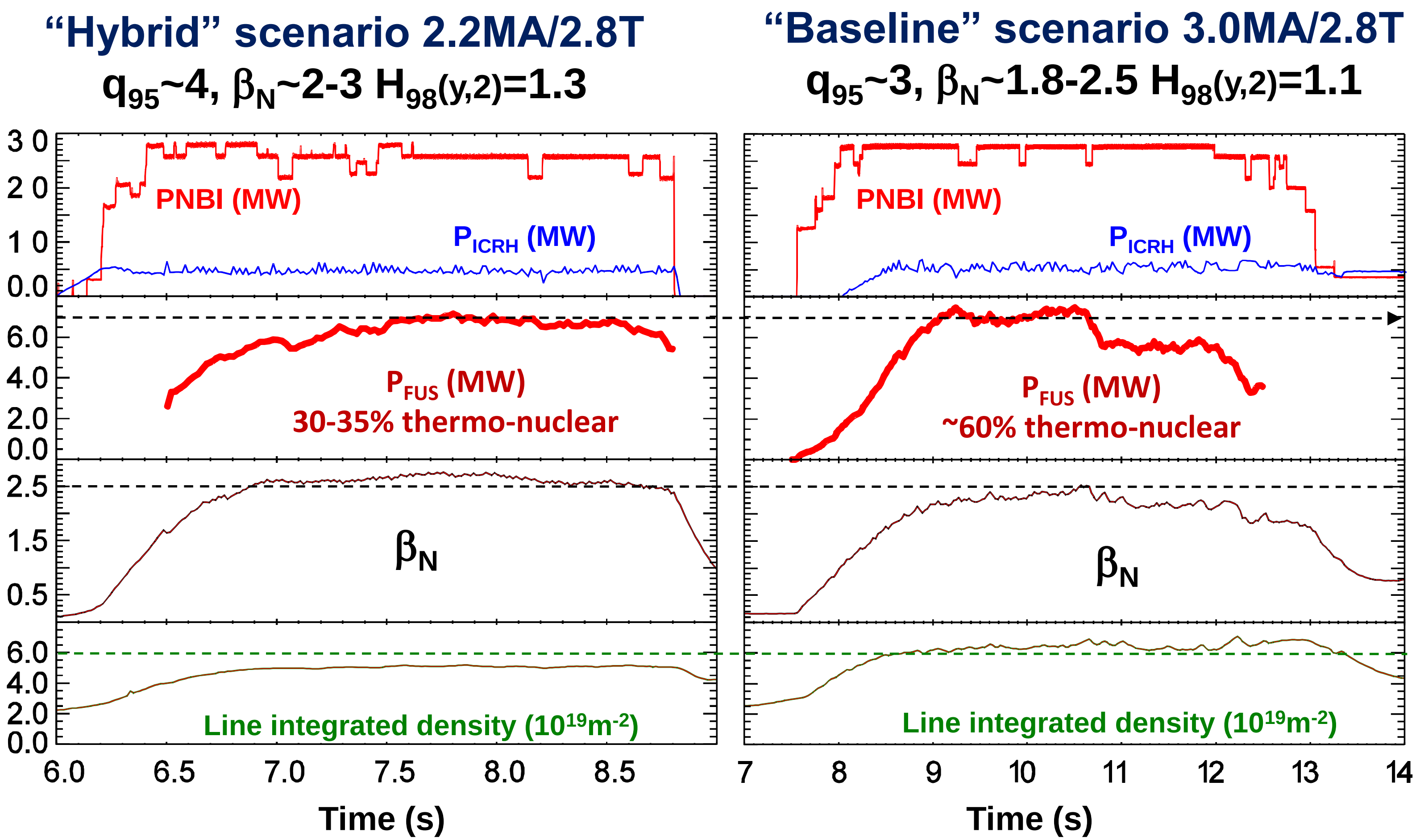
[M. Beurskens et al, PPCF (2013)]



[Hyun-Tae Kim et al, PPCF (2015)]

- **Reduction of Te pedestal, and therefore pedestal/total confinement**
  - high gas fuelling to increase ELM frequency, to avoid core W accumulation
  - N_2 seeding helps partial recovery of pedestal confinement but not possible in DT
- **Core confinement with JET-ILW similar as JET C-Wall**
- **Total confinement recovered at high heating power (2016 campaign)**

Stationary Scenarios for the DT phase achieved ~7-8MW of equivalent P_{FUS}

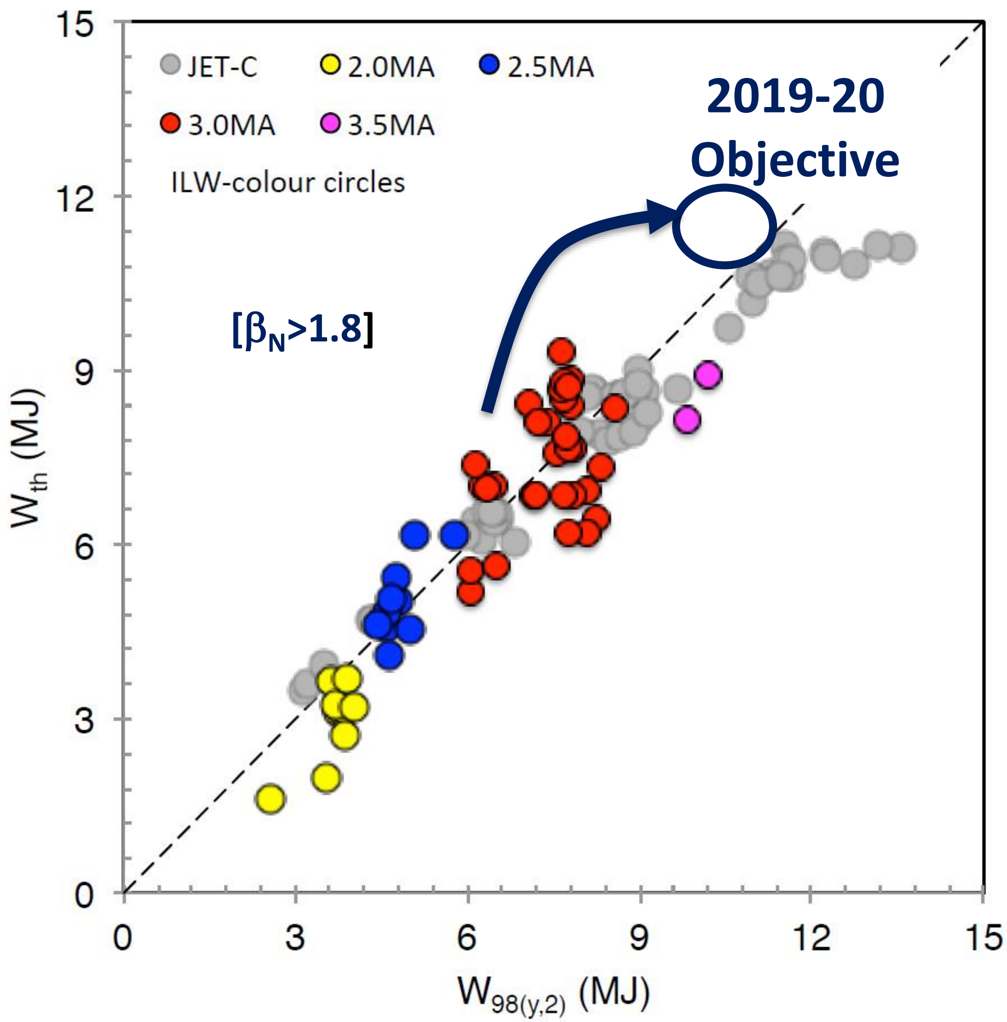


Fusion equivalent power for a 50/50 D/T mix:
7-8MW of fusion power for both scenarios

[E. Joffrin et al., FEC 2018]

ITER operation with JET ITER-Like Wall

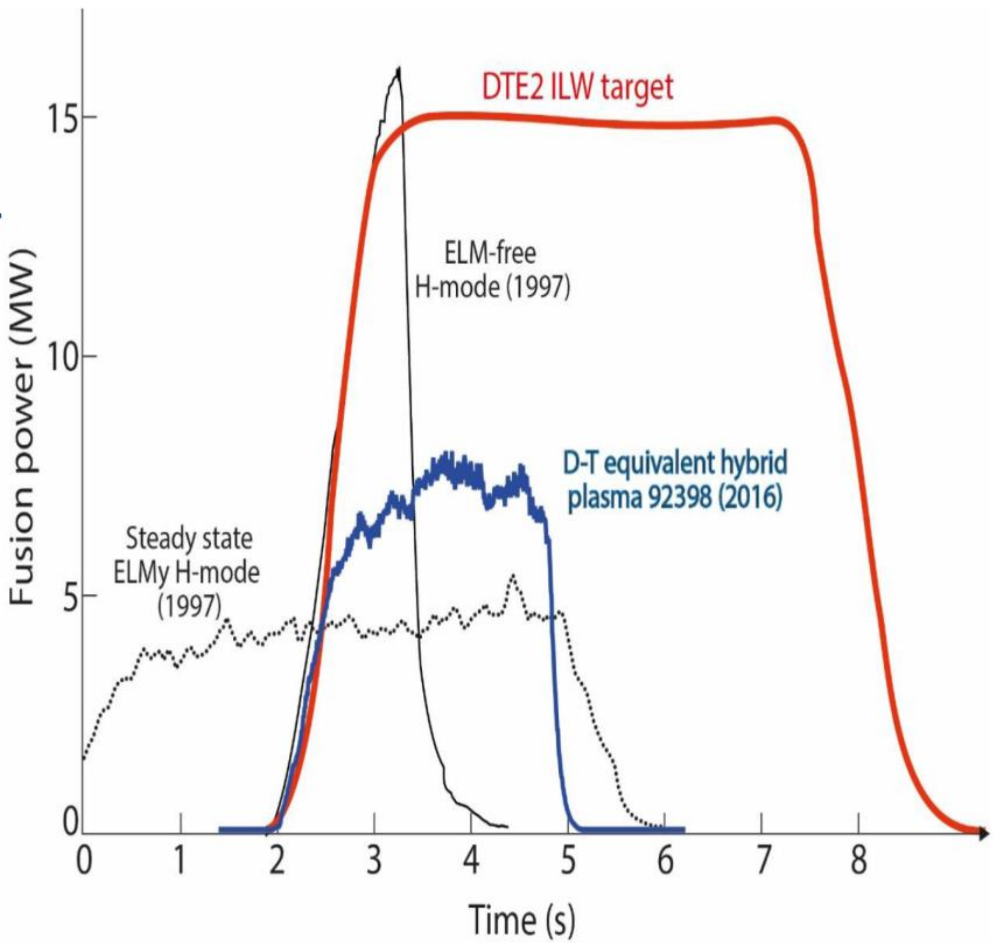
Prepare ITER operation towards Q=10



- **High performance ITER scenarios developed with the ITER-Like wall**
- **Remaining challenges**
  - **Extend to high input power (40 MW), high magnetic field (3.85 T) and high plasma current (4 MA)**
  - **Transfer from D-D to D-T**

[L. Garzotti FEC 2018, I. Nunes *et* al. Nucl. Fusion 2015]

JET tritium, deuterium-tritium operation with ITER Like Wall

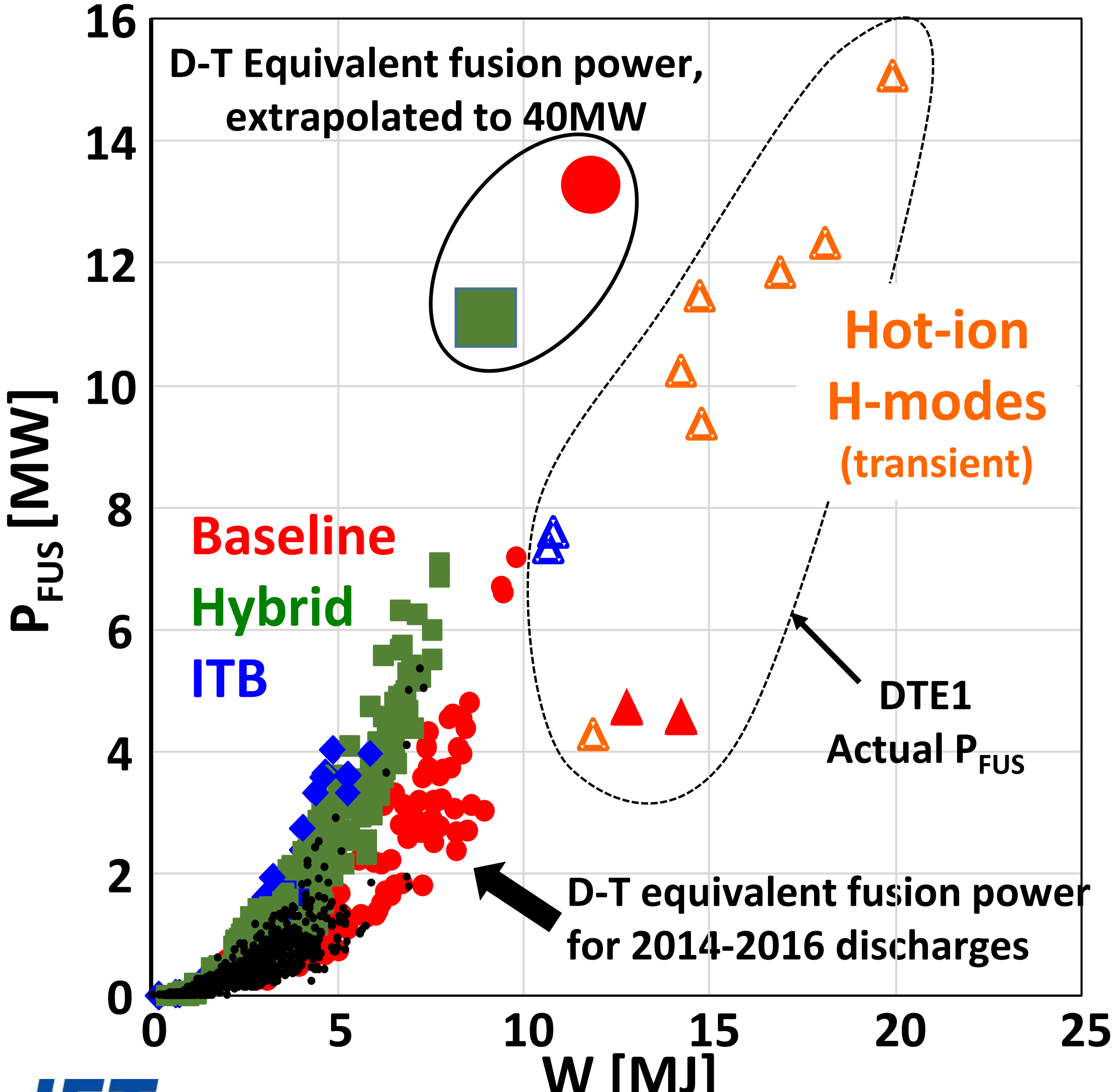


[M. Mantsinen et al. EPS 2017,
E. Joffrin et al. FEC 2018]

- **ITER scenarios and transferability from H-H, D-D, T-T, D-T (Isotope effects)**
- **Plasma Wall Interaction with ITER materials mix in D-T**
- **Tritium cycle**
- **Alpha-particle physics**
- **Fusion technology**

Overview of the DT equivalent fusion power

[E. Joffrin et al., FEC 2018, to appear in Nuc Fusion]



DT equivalent fusion power

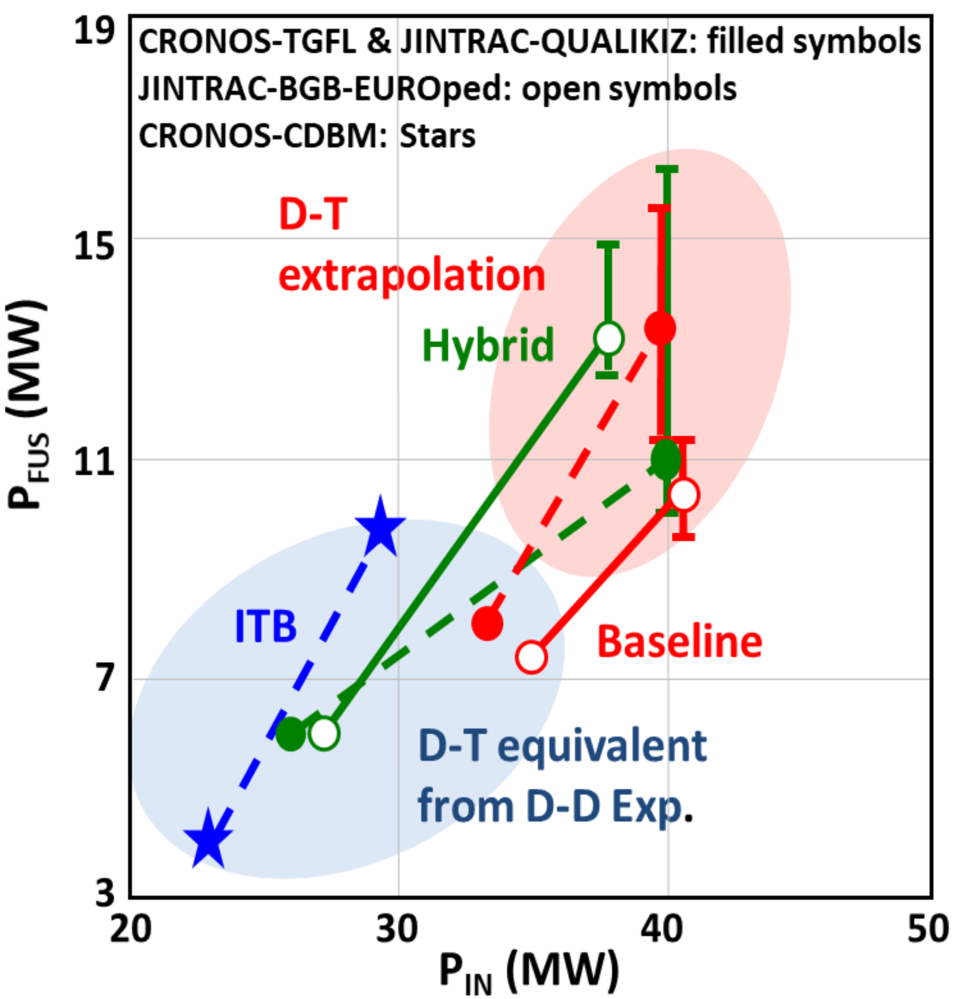
- 50/50 D/T mix with identical plasma profiles
- No isotope effects
- No alpha heating

DT equivalent fusion power reaching similar level as 1997 DTE1 with two stationary scenarios: baseline and hybrid.

Transient ITB scenario for alpha particle driven mode studies (TAE)

JET Prospects for D-T Operation

Prepare stationary ITER D-T operation



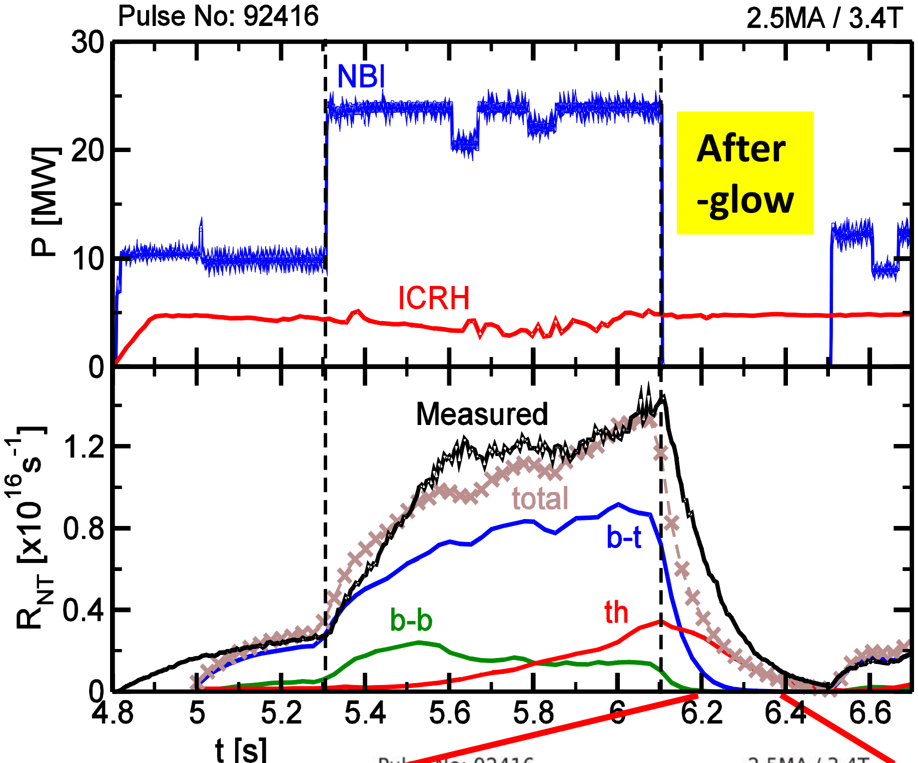
- P_{fus} ~10-16 MW with P_{inj}= 40MW
  - favourable isotope effect (hybrid)
  - P_{fus} uncertainties: bootstrap models, isotope effects, Ip, density at pedestal top, beam energy…
- Auto-consistent modelling with core-pedestal (EUROped)
- Experimental challenges
  - high P_{in} (40 MW), high B (3.85T) and I_p (4 MA) ?
  - Transfer from D-D to D-T ?

[J. Garcia et al IAEA FEC 2018, F. Casson et al. IAEA FEC 2018, S. Saarelma et al. PPCF 2017]

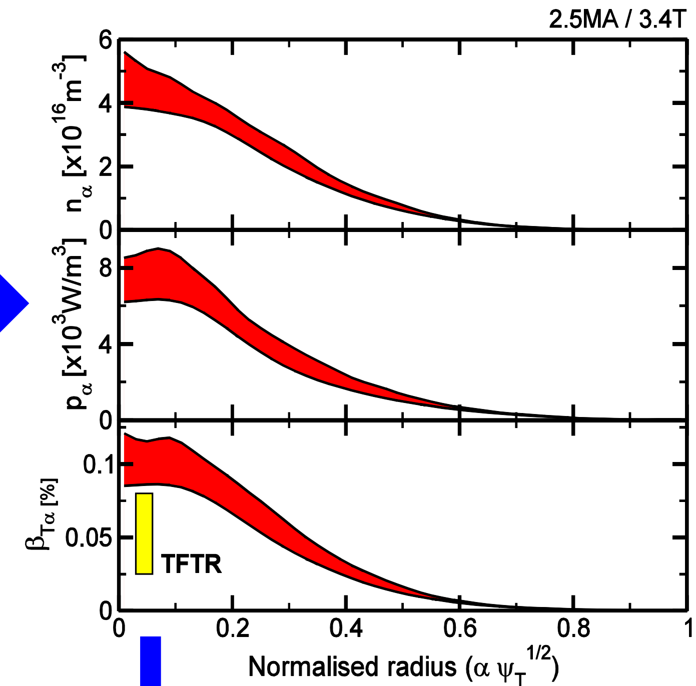
α-driven TAEs studies for JET DT

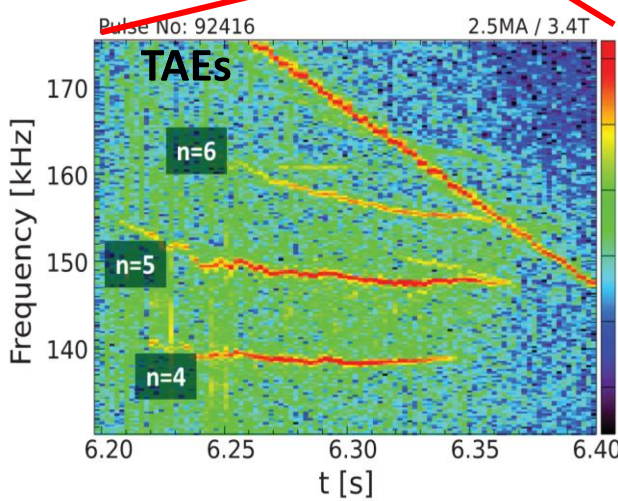
- **No conclusion regarding α-driven TAEs excitation could be drawn from JET DTE1 data [Sharapov NF 1999], unlike from TFTR experiments [Budny NF 1992, Spong NF 1995, Nazikian PRL 1997]**
- **α-driven TAEs studies require afterglow scenario development**
  - **TAE excitation not naturally fulfilled (e.g. NBI damping) in baseline/hybrid scenarios in JET DT plasmas**
- **Afterglow scenario suitable for the observation of α-driven TAE in JET DT campaign developed in deuterium**
  - **ICRH-driven TAEs have been observed [Dumont NF 2018]**
  - **Extrapolation to DT predict β_α (0.08%-0.12%) comparable to TFTR α-driven TAE experiments**
- **Net damping of damped energetic particle modes measured using active TAE antennae and model validation for ITER**
  - **comparison to Gyrokinetic calculation (GTC) [Aslanyan NF 2019] and drift-kinetic code (CASTOR-K) [Nabais NF 58 2018]**

ICRH-driven TAEs consistent with predictions in afterglow D-D scenarios for D-T preparation

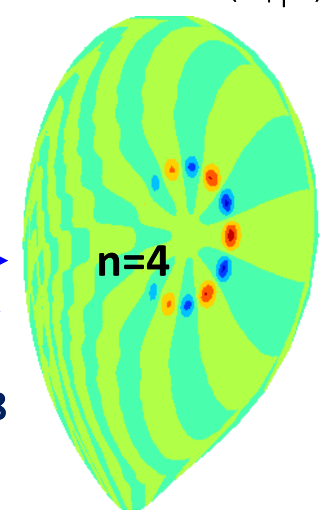


50/50 D-T
Prediction
(TRANSP)





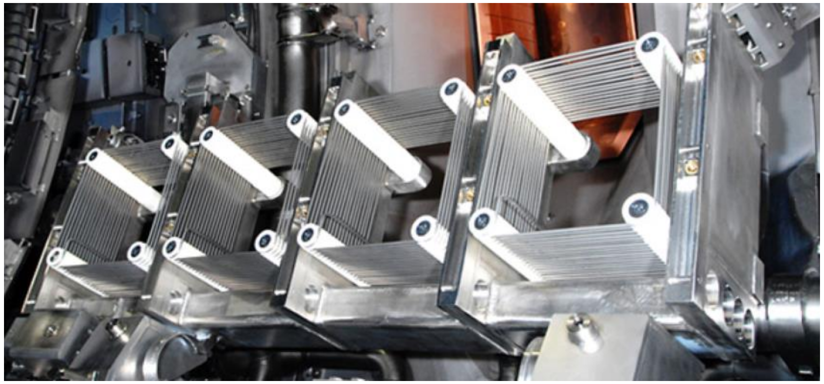
Stability
calculation
(MISHKA)



[R. Dumont, Nuc. Fus. 2018
S. Sharapov, FEC 2018]

TAEs damping rates measurement by dedicated external antennas and simulation

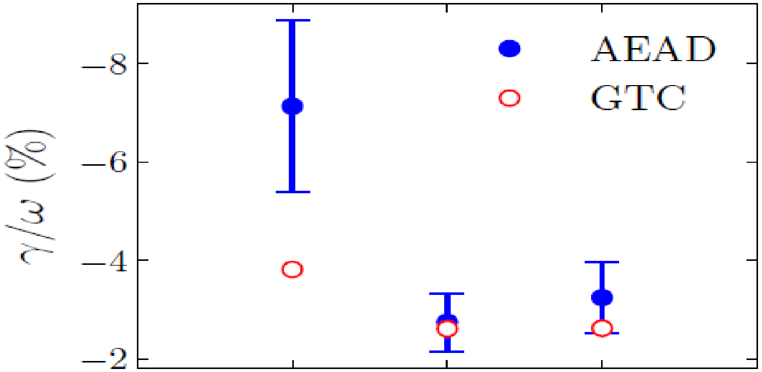
- **Real-time detection of n=0-15 TAEs, damping rate, amplitude and tracking** **[P. Puglia et al., NF 2016]**
  - 8 toroidal antennas
  - 6 antennas driven by individual/upgraded amplifiers (arbitrary phase control)
  - improved plasma coupling with new impedance matching system
  - added frequency range for GAMs, BAEs, RSAEs detection



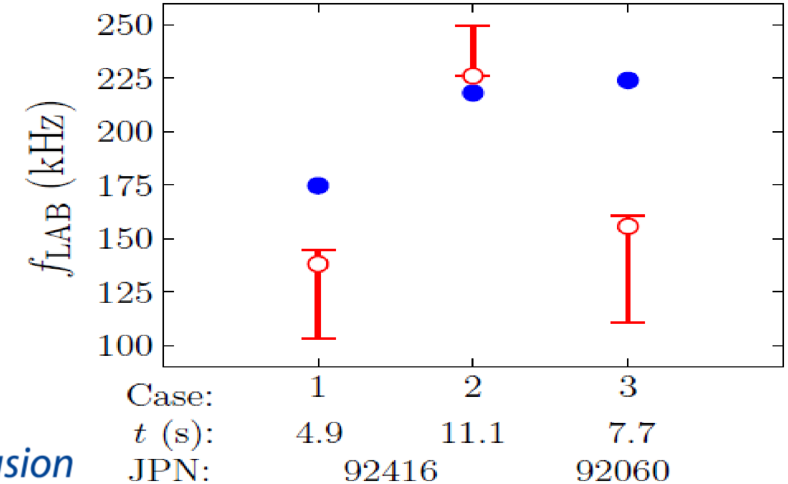
International Collaboration USA, Brazil

JET IFUSP–USP PSFC UC Irvine EUROfusion

- **First comparison between stable TAEs damping rate and frequency measurements (AEAD) with GTC gyrokinetic simulations on JET**



[V. Aslanyan et al, NF 2019]



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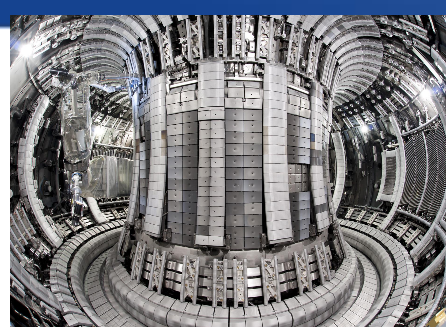
Isotope physics

JET



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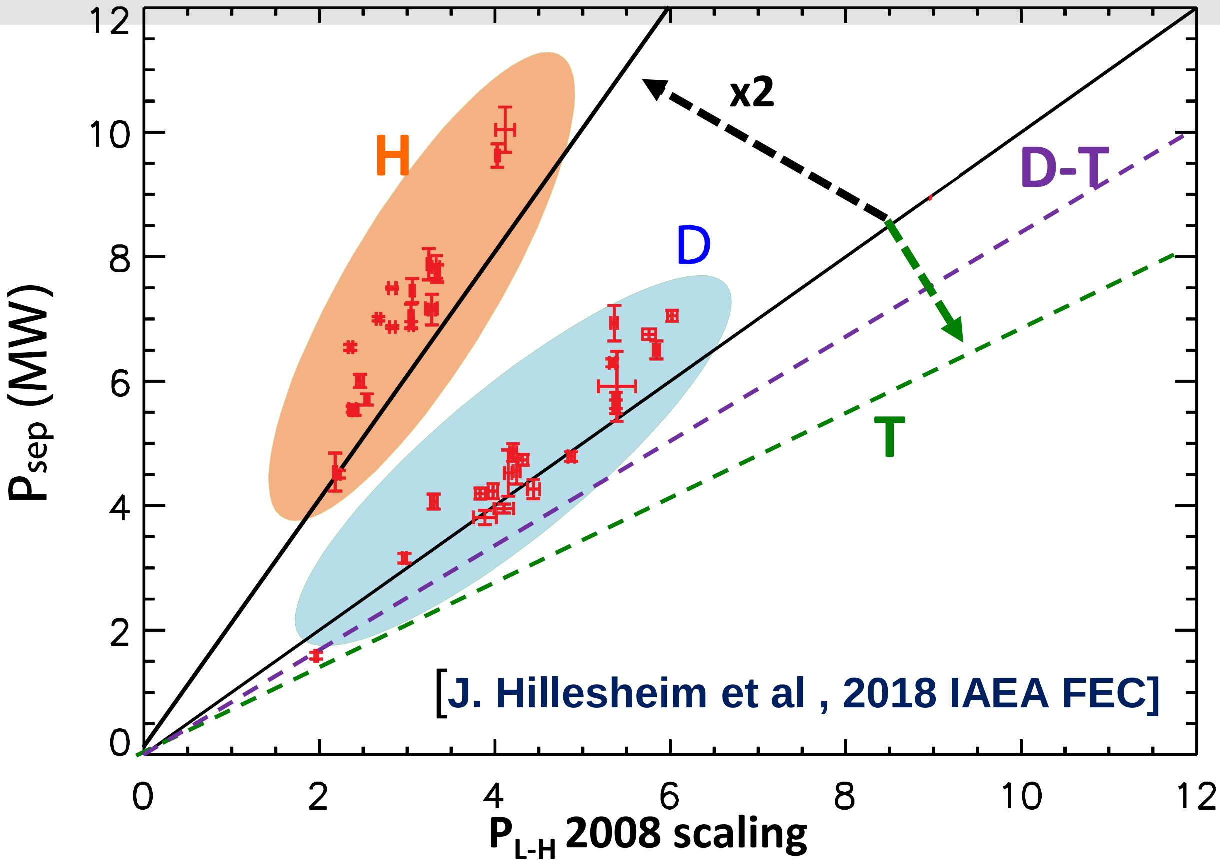
Isotope effects on L-H power threshold

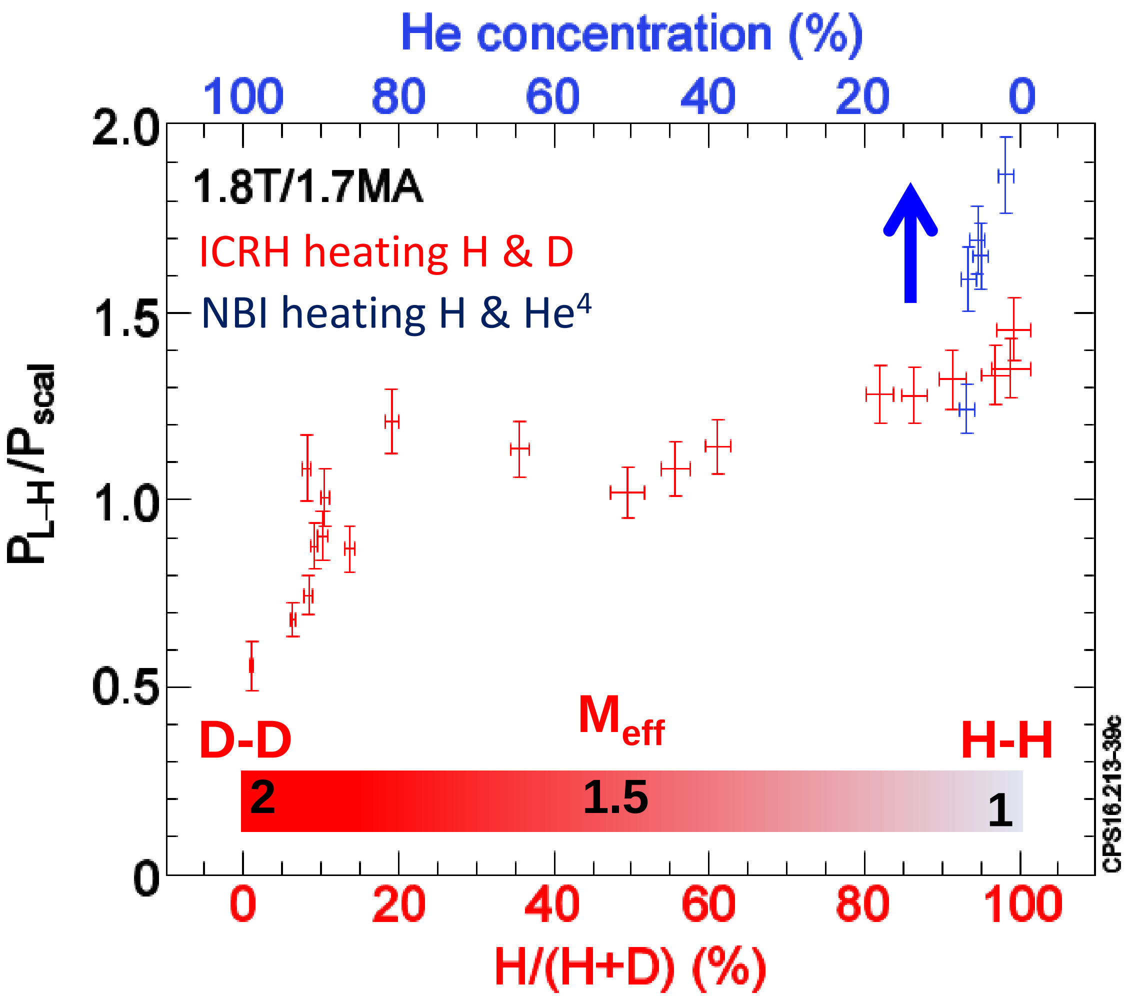


[C. Maggi, PPCF 2017]

- **P_{L-H} threshold ~ 1/A**
  - **P_{L-H} likely to be reduced by 2/3 in T and 1/3 in D-T**
  - **Consistent with past DTE1 results in C [Righi et al. 1999]**
- **Prediction with non-linear fluid turbulence code (HESEL) indicates similar: ~ $1/A^{1.4}$**

ITER Non-Active Operation: H-mode Access

Non-linear mass dependence on L-H power threshold



[Hillesheim et al EPS 2017]

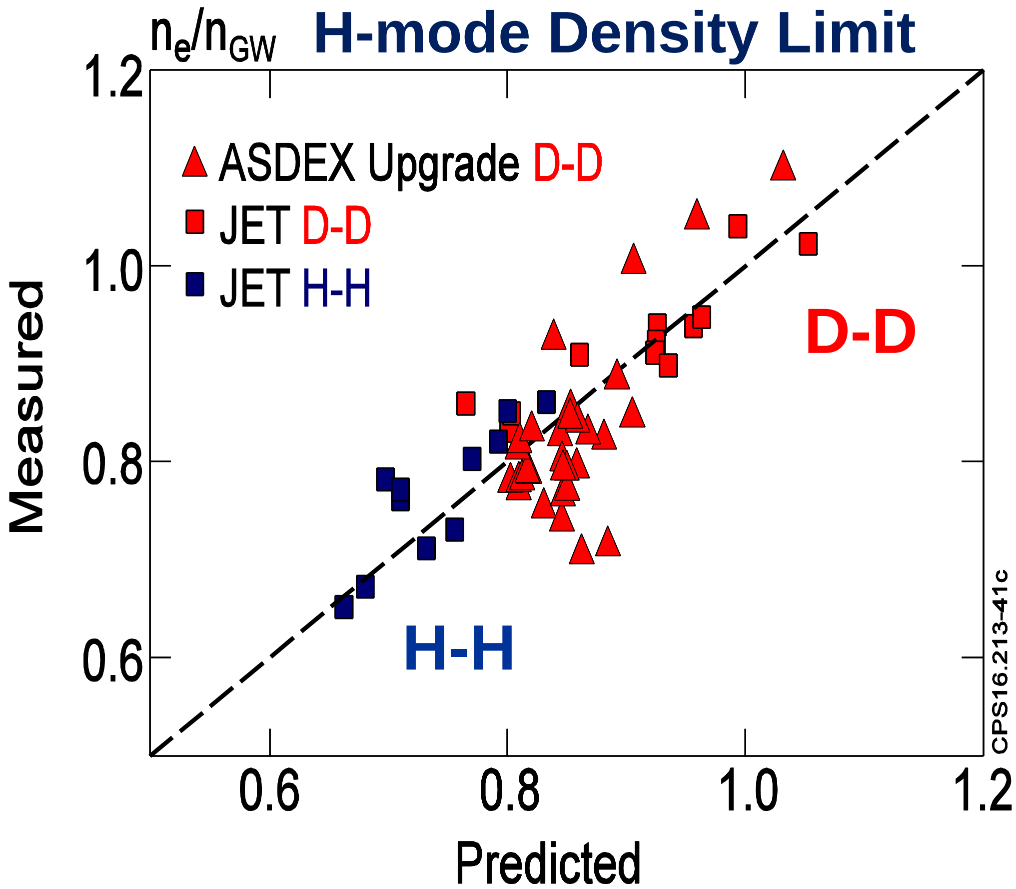
- **Fine mass scan 2→1 via H/(H+D) control**
  - **Large variation at high and low H/(H+D)**
  - **Little variation 0.2<H/(H+D)<0.8**
  - **Trace He quantity in H-plasma:**
    - **Significant P_{L-H} reduction**
  - **Impact on ITER non-active phase to be investigated**
    - **helium campaign ?**

[P_{scal} from ITPA scaling J. Phys. (2008)]

ITER Operation: H-Mode Density Limit

H-mode Density limit consistent with Goldston's prediction

[Goldston J of Nuc Materials 2015]



- **Mass dependence $\propto M^{9/16}$**
- **Weak power dependence**
- **H-mode Density limit**
  - **SOL MHD instability**
- **Wider JET and ITER operational boundaries in T-T and D-T**
  - **When $M_{eff}\uparrow$: $P_{L\text{-}H}\downarrow$ & $n_{DL}/n_{GW}\uparrow$**

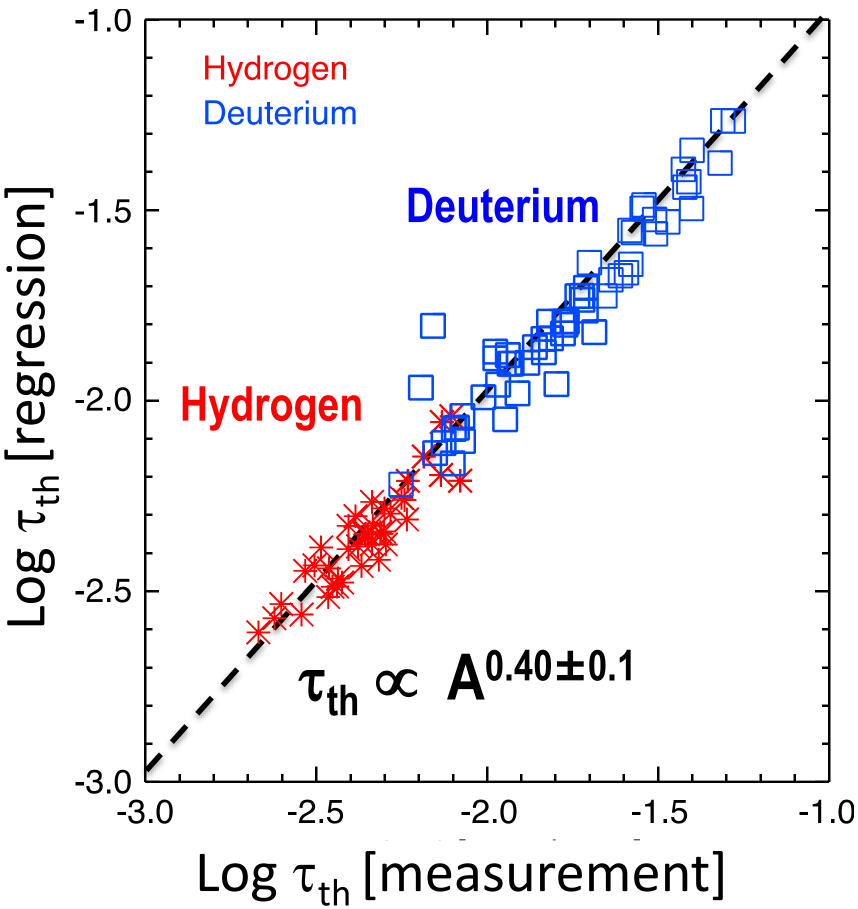
[A. Huber et al. FEC 2016]

[Goldston Nuc. Fus 2012, Eich et al PRL 2011 & Nuc Fus 2013]

Confinement in H-mode operation

H-mode confinement for ITER in H-H, D-D and D-T mix ?

τ_{th} **Thermal Energy confinement time**



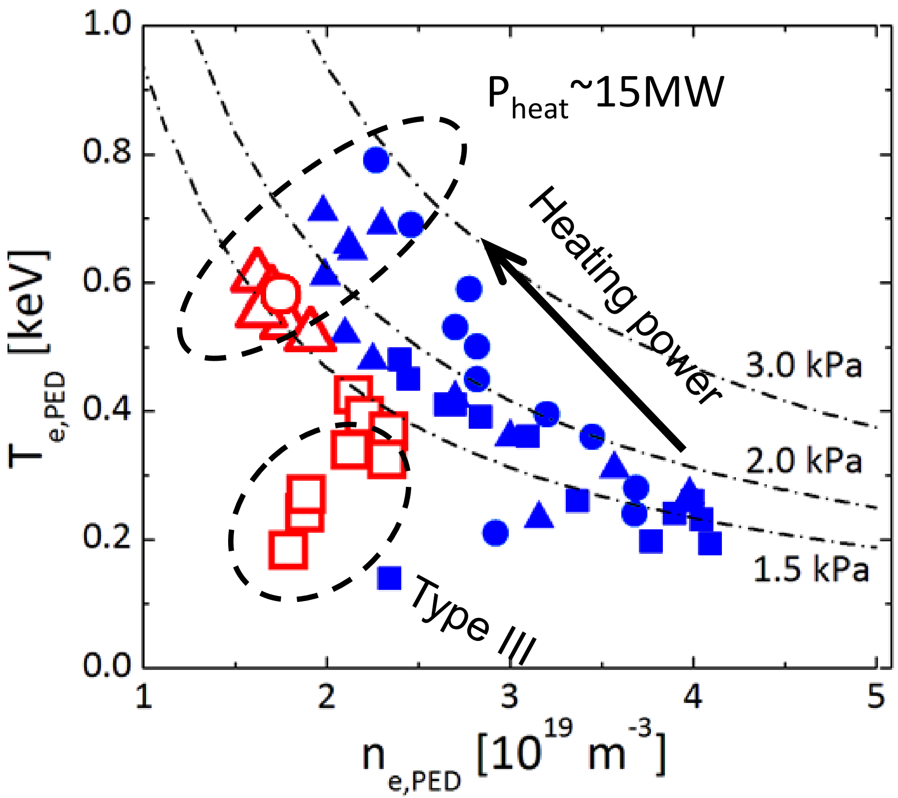
[H. Weisen et al. IAEA FEC 2018, C. Maggi et al. EPS conf. 2017]

- **JET isotope experiments**
- **Confinement**
  - **Favourable mass dependence: $\tau_{th} \propto A^{0.4\pm0.1}$ vs. $A^{0.2}$ in present scaling**
  - **But, lack of density dependence (vs $n^{0.41}$)**
- **Revised confinement scaling with metallic wall for ITER under development (ITPA)**

[M. Maslov & M. Romanelli EPS 2018, G Verdoolaege et al FEC 2018]

JET

Isotope effects on JET pedestal pressure



1.4MA/1.7T
Power and gas scans

H	D	Gas puffing rate
○	●	Γ = 3-4 x 10^{21} e/s
△	▲	Γ = 8-9 x 10^{21} e/s
□	■	Γ = 18 x 10^{21} e/s

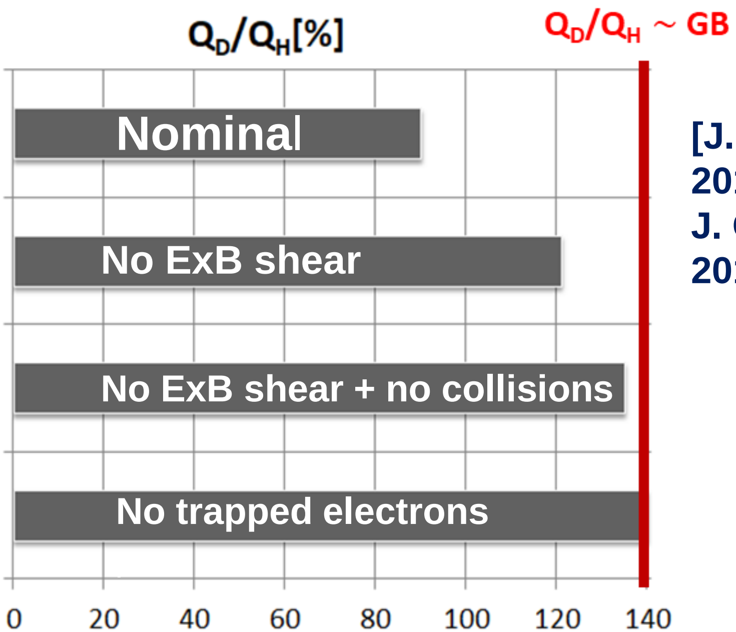
- **Lower pedestal density in H than in D → lower plasma density in H**
- **Larger $p_{e,PED}$ in D than in H at the same heating power**
- **Hydrogen type I pedestals evolve along same isobar at all gas rates**

[C. Maggi 26th ITC Conference, Toki, Japan, December 5th 2017, L Horvath et al. EPS 2017]

Core Isotope effect & first-principle simulations

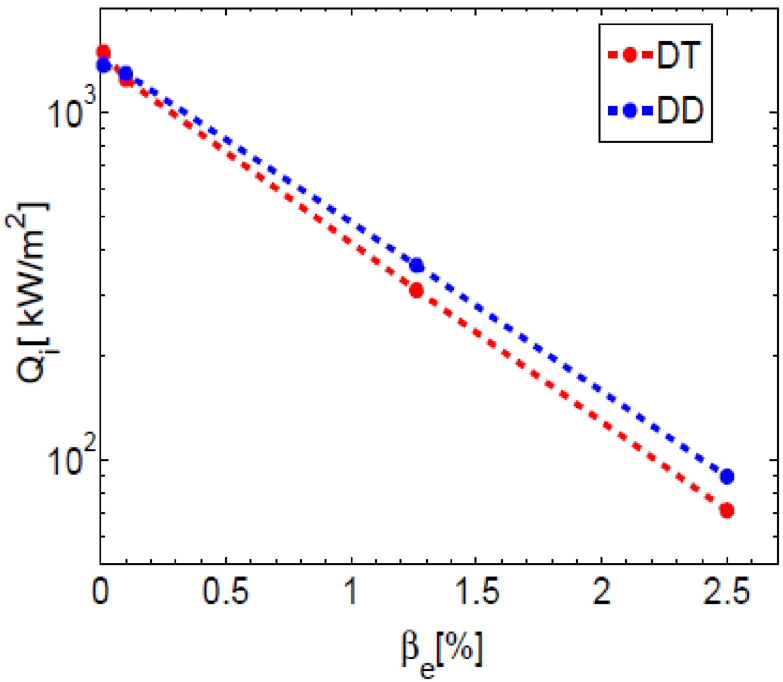
GENE* non-linear local simulations [*Jenko et al., PoP 2000]

- JET H-H vs D-D
  - Deviation from Gyro-Bohm when including ExB shearing, collisionality and electron transport



[J. Garcia et al., PoP 2018,
J. Garcia et al., NF, 2017]

- JET D-D vs D-T Strong isotope effect at high β
  - Non-linear interplay between zonal flows, mass and β



Broad range of JET operational conditions in DD, TT, DT to disentangle the effects in support to ITER

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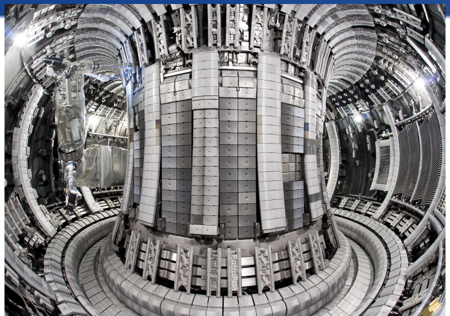
Upgrades for T-T and D-T Campaigns

JET



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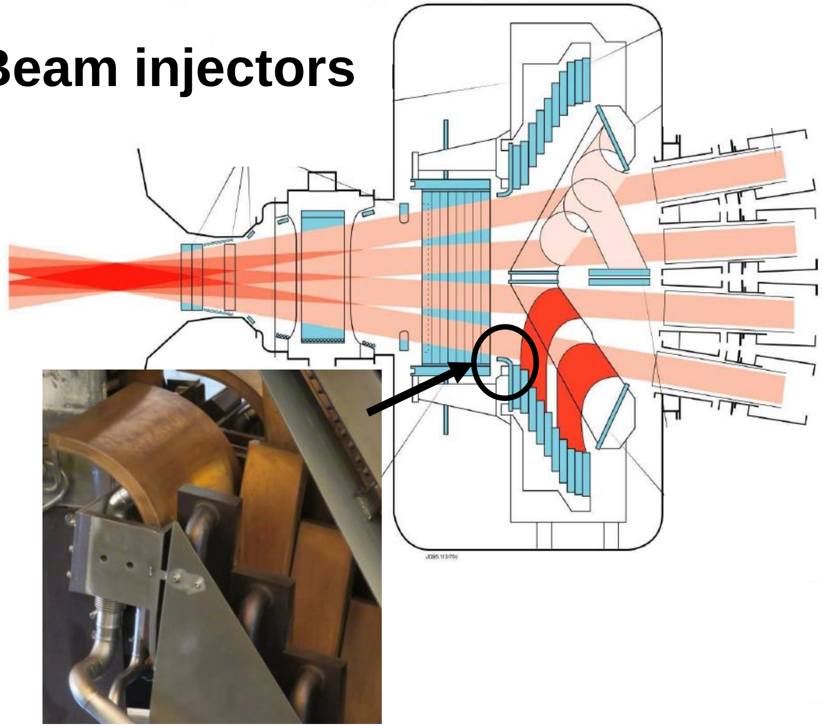
Upgrades for T-T and D-T: NBI and T fuelling

NBI power was limited by one of the ion dumps component cooling capabilities.

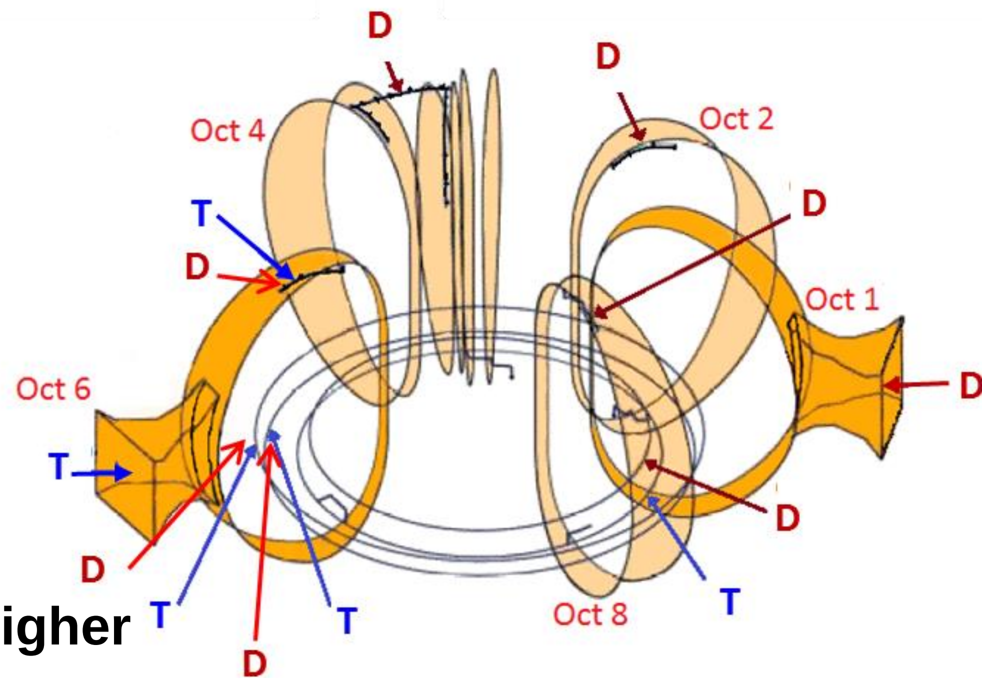
Beam injectors



New plates with optimised cooling: higher the limits to beam voltage and pulse length ➔ 34MW in D-T (21MW in DTE1)

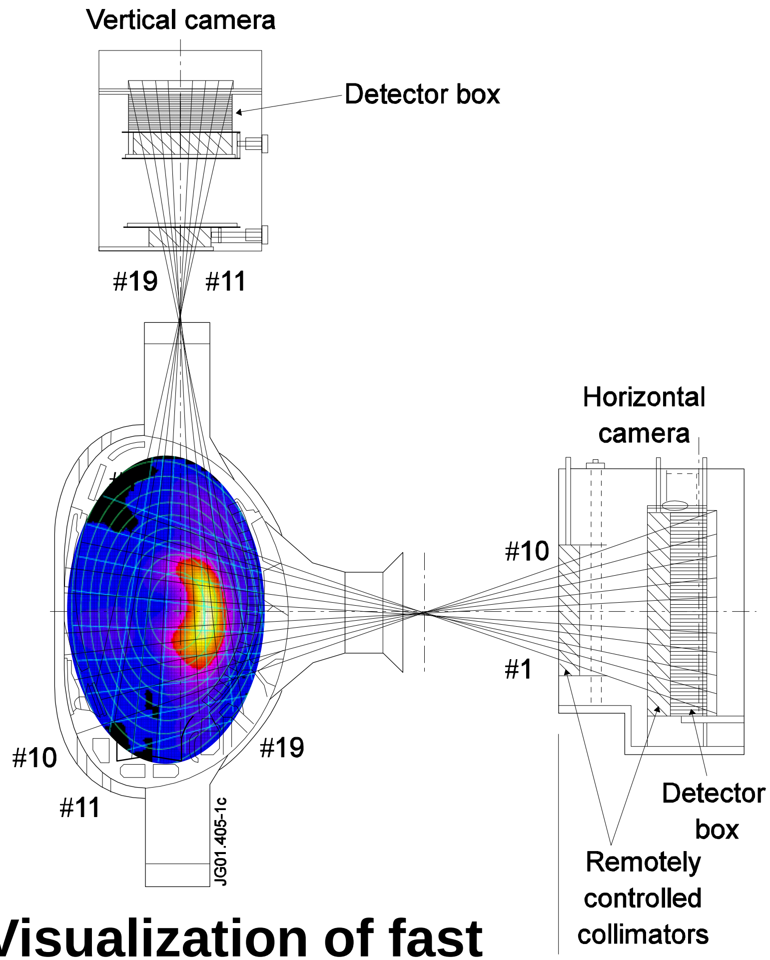
[A. Shepherd et al., SOFT 2016]

5 new tritium gas injection module
(Only one existed in DTE1)



[I. Carvalho et al, SOFT 2016]

New diagnostics for D-T campaign



Visualization of fast particle orbits with gamma ray tomography

Several burning plasma diagnostics ready for the D-T phase.

Charge Exchange (T_i)	OAK RIDGE National Laboratory
TAE antenna	IFUSP–USP PSFC
Neutron Camera	
Vertical Neutron Spectrometer	
γ-Ray Camera	
Horizontal γ-Ray Spectrometer for alpha-Particle Diagnostic	
Upgrade of the scintillator based Fast-Ion Loss Detector (FILD)	

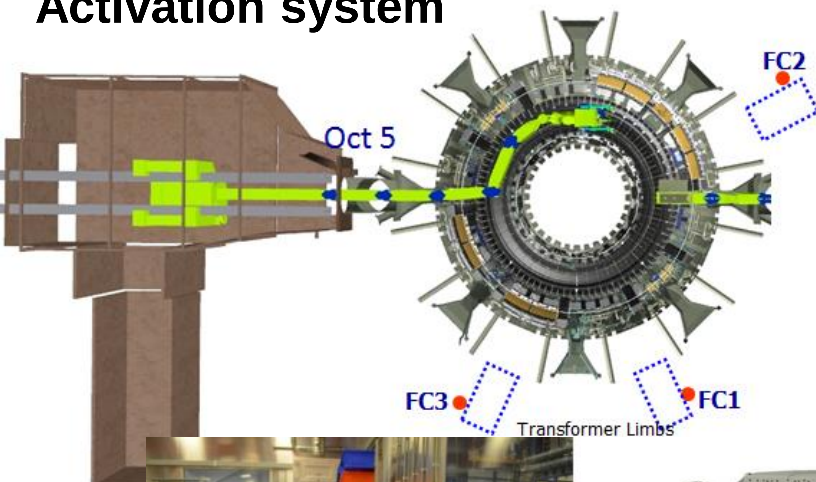
Most diagnostics included synthetically in modelling suites for code validation

[J. Figueiredo et al., 2018 IAEA FEC]

D-T Fusion power measurement for ITER

Accurate measurement of the fusion power for ITER

3 Fission (^{235}U) chambers and 1 Activation system

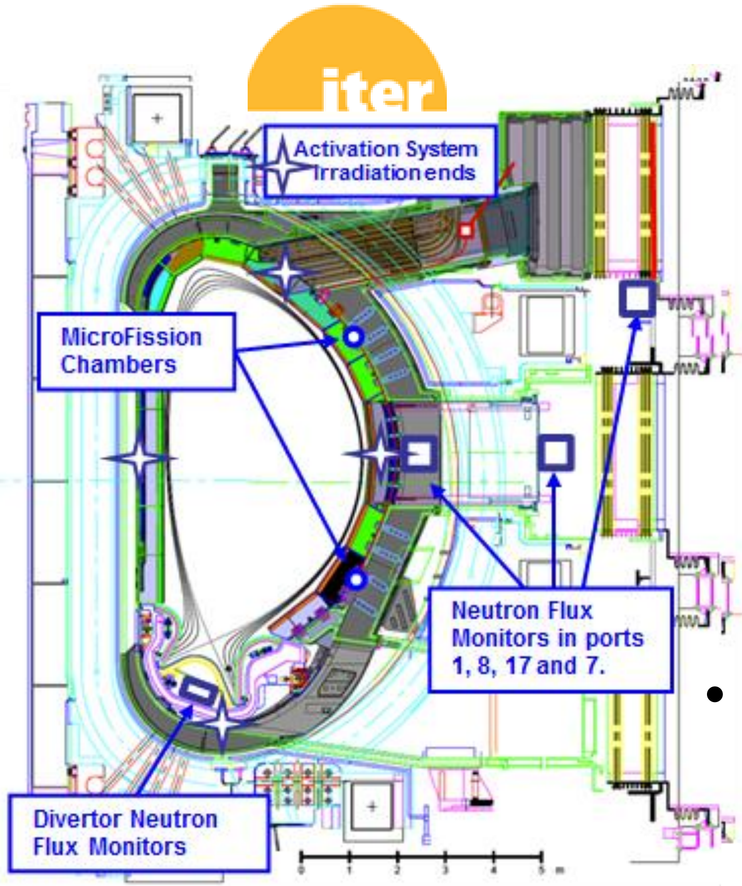


- **Diagnostic calibration using a 14MeV neutron generator inside JET vessel (remote handling)**
  - **9 days, 76h of irradiation in 73 poloidal/toroidal positions**
  - **detailed modelling**
  - **calibration within ±6%**
- **validation of neutronics codes in tokamak environment for ITER**

[P. Batistoni et al. Nuc Fus 2018, S. R. Villari SOFT 2018, E. Laszynska et al. SOFT 2018, T. Vasilopoulou et al. SOFT 2018]

Implications for ITER fusion power measurement within ± 10%

ITER neutron detectors



[V. Krasilnikov Private Com. 2018]

- **JET calibration proves the feasibility of the procedure for ITER**
  - **accurate characterization of 14 MeV neutron generator**
  - **in-vessel operation of full equipment with remote handling system**
  - **high accuracy in limited time**

→ Similar procedure for ITER

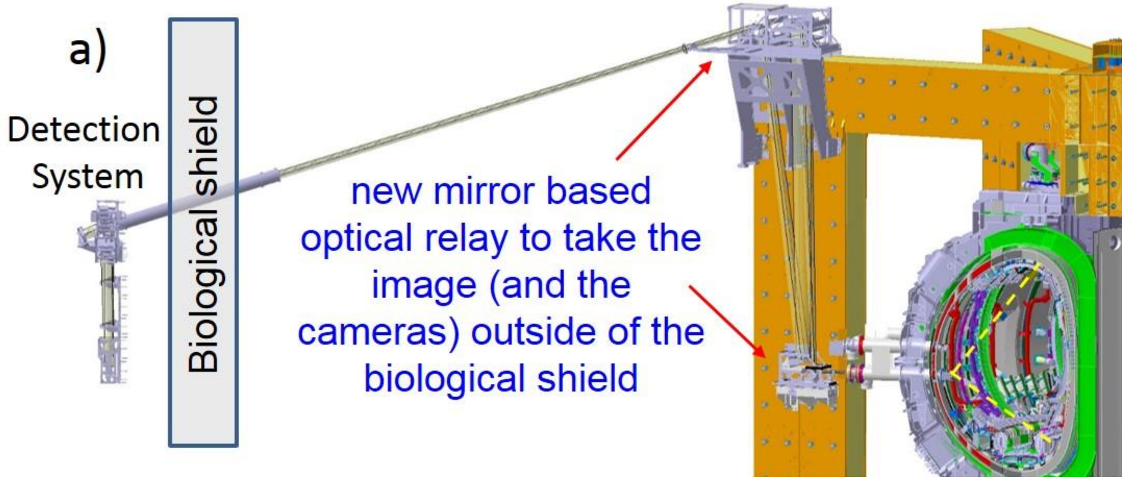
- **Recommendation: on-site test of calibration equipment**

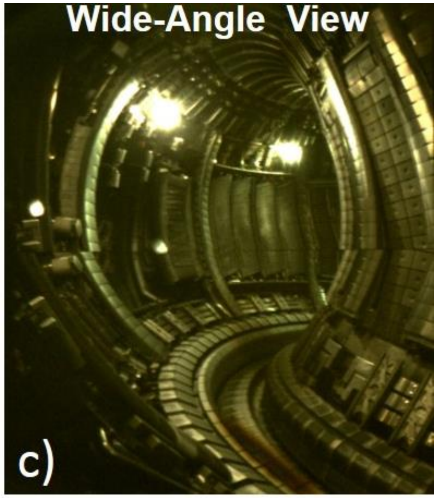
→ on-site neutron facility to operate neutron sources, calibrate detectors, test calibration equipment

[P. Batistoni et al. Nuc Fus 2018]

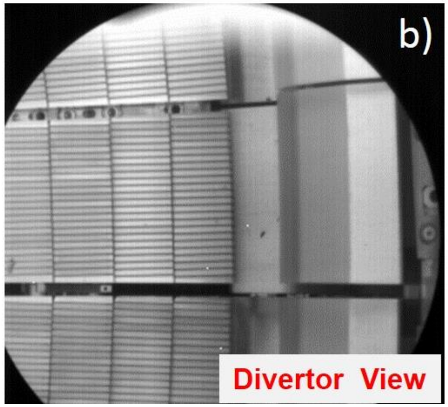
Imaging Machine Protection Systems and Software for D-T operation

Imaging Protection System and Software relevant for ITER





- **Long distance optical relay (~40m long)**
  - **Imaging cameras outside of the biological shield**
  - **Mirror based optical design**
- **Optimised wavelength (near IR 1.25µm):**
  - **Temperature independent W-spectral emissivity**
  - **Reduced sensitivity to surface roughness**
  - **BUT: detection limit ≈ 600˚C**

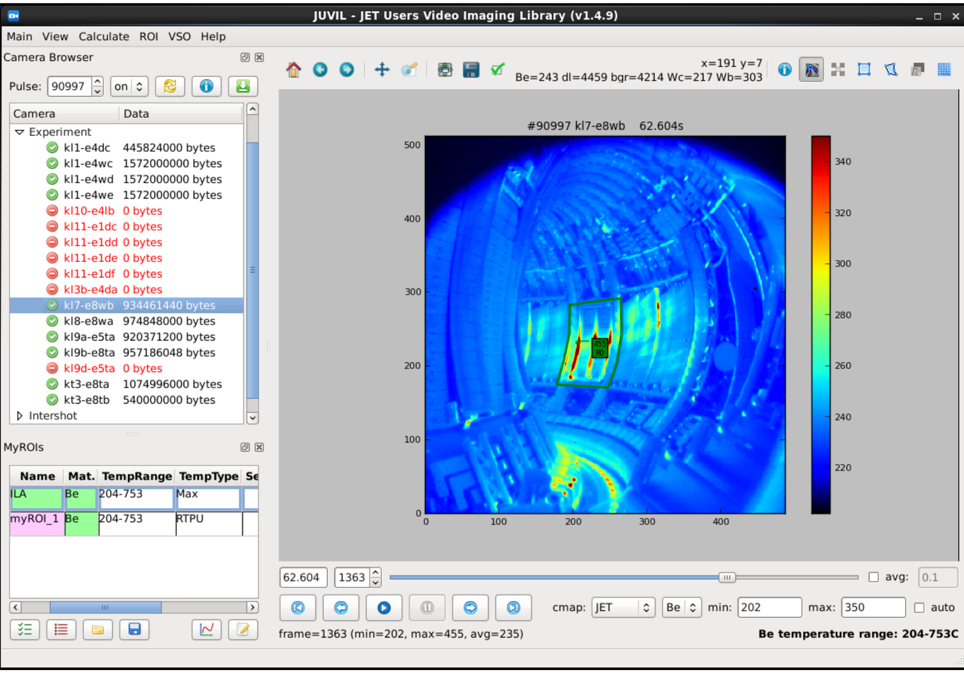


[A. Huber et al. SOFT 2018, Nuc Fus 2018, V. Huber Fus Eng, Des 2017, SOFT , FEC 2018]

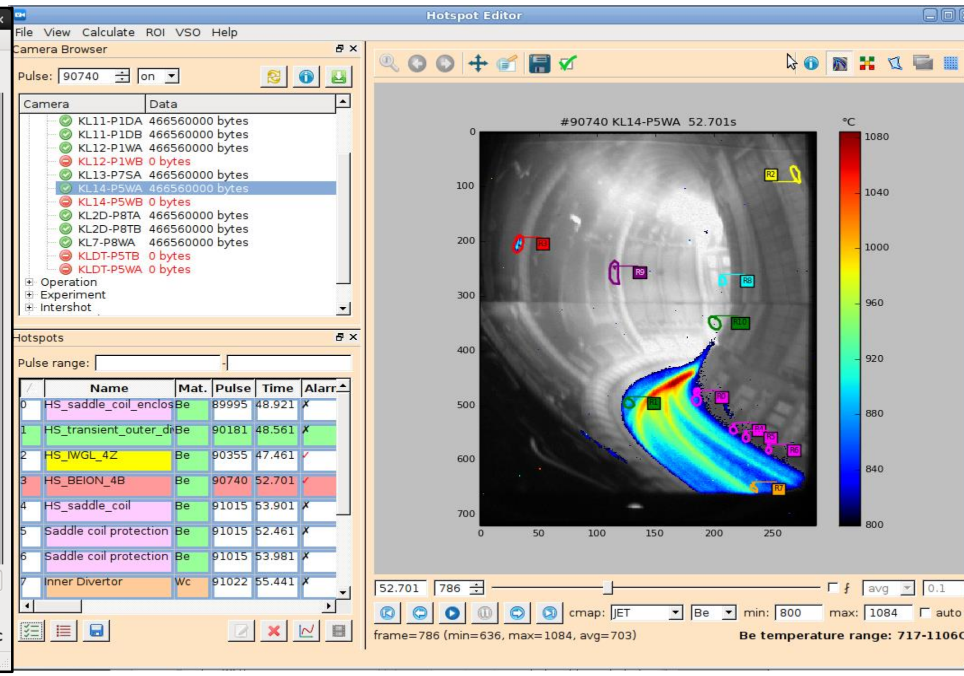
Machine independent imaging software for real time protection and post-analysis

Imaging Protection System and Software relevant for ITER

JUVIL - JET Users Video Imaging Library



Region of Interest and Hot-spots tracking



– **user-friendly, robust platform independent**

– **modular object-oriented framework**

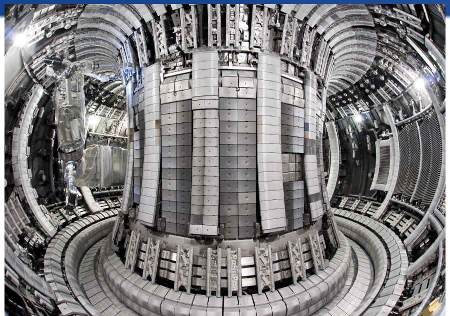
– **hot-spot tracking**

[V. Huber Fus Eng, Des 2017 SOFT , FEC 2018 to appear in Nuc Fus]

EUROfusion

Disruption studies and Shattered Pellet Injector in support to ITER

JET

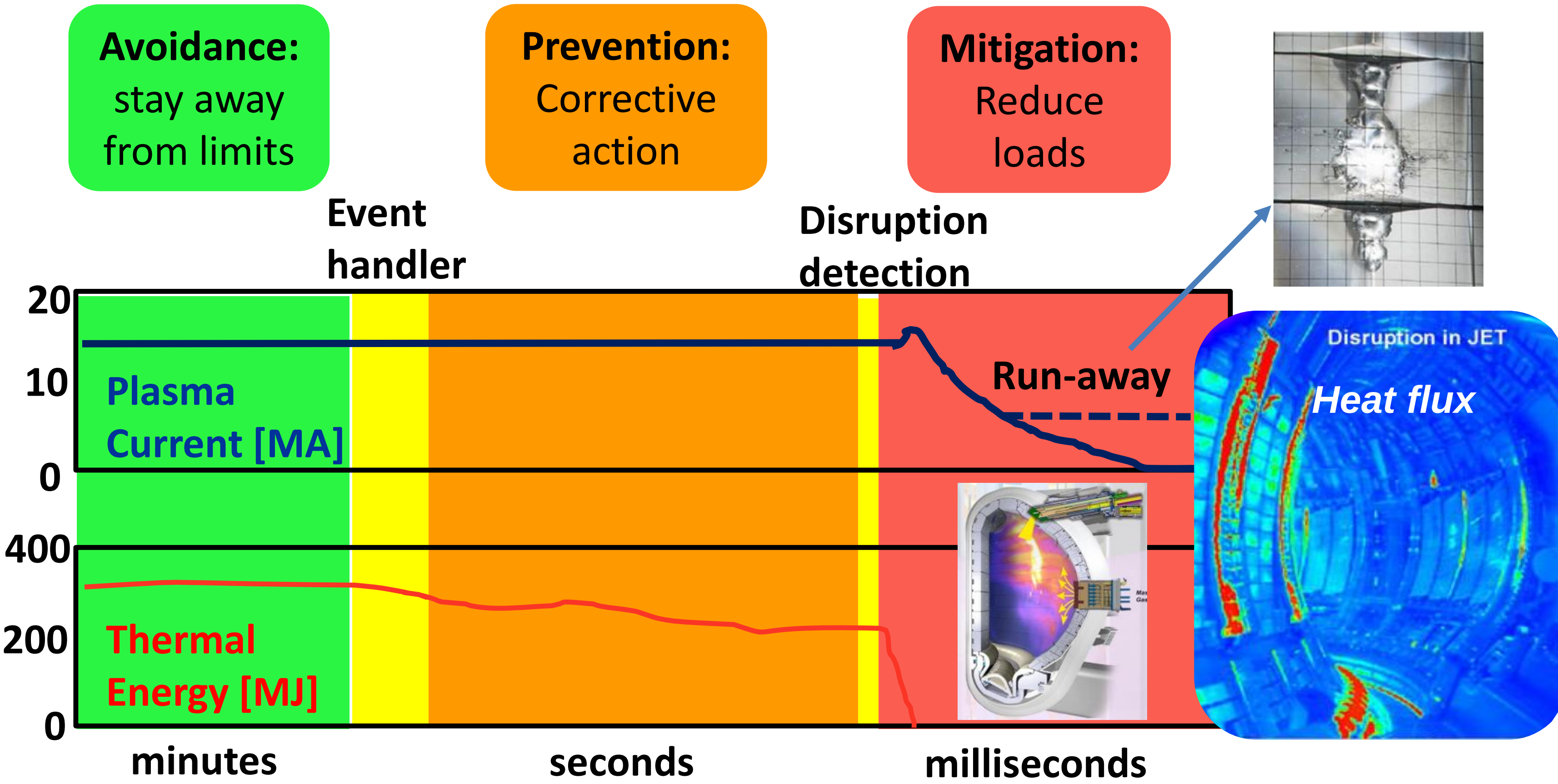


This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Disruption programme in support to ITER

Highest operational risk in ITER Research Plan: ITER can only have very few disruptions at full current (below 5%),

Three layers of defence:

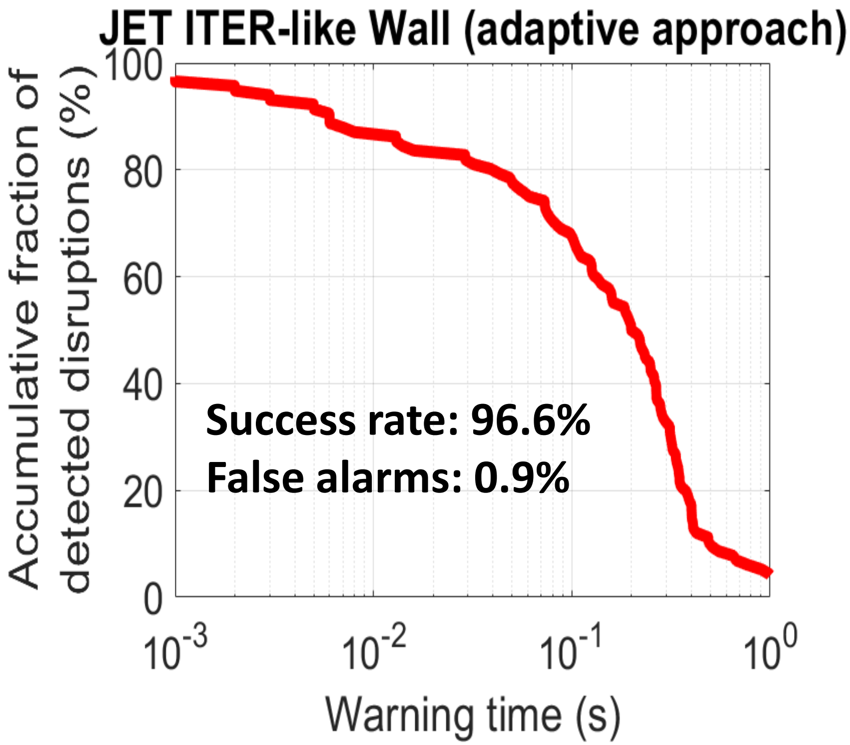


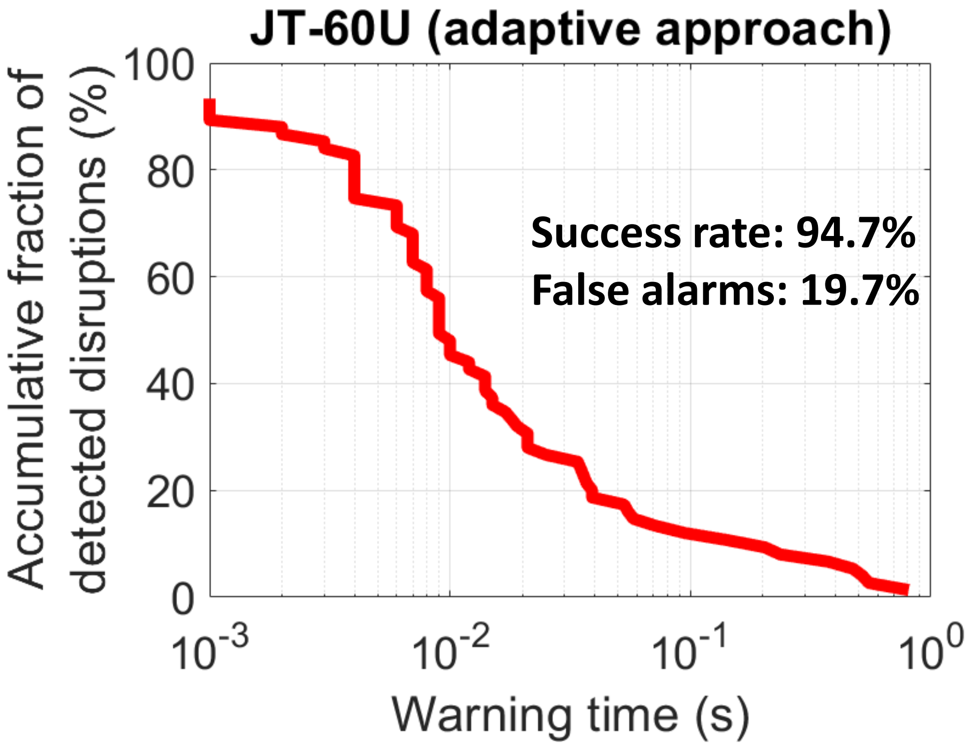
[M. Lehnen et al SOFE 2015]

Machine Learning disruption predictors for ITER

ITER will require “adaptive” predictors ‘from scratch’, i.e. without previous training

- **Multi-machines (AUG, JET, JT-60U) predictors for JT-60SA and ITER using locked mode signals**
  - **other predictors are also using radiative power or MHD signals to increase disruption warning time**



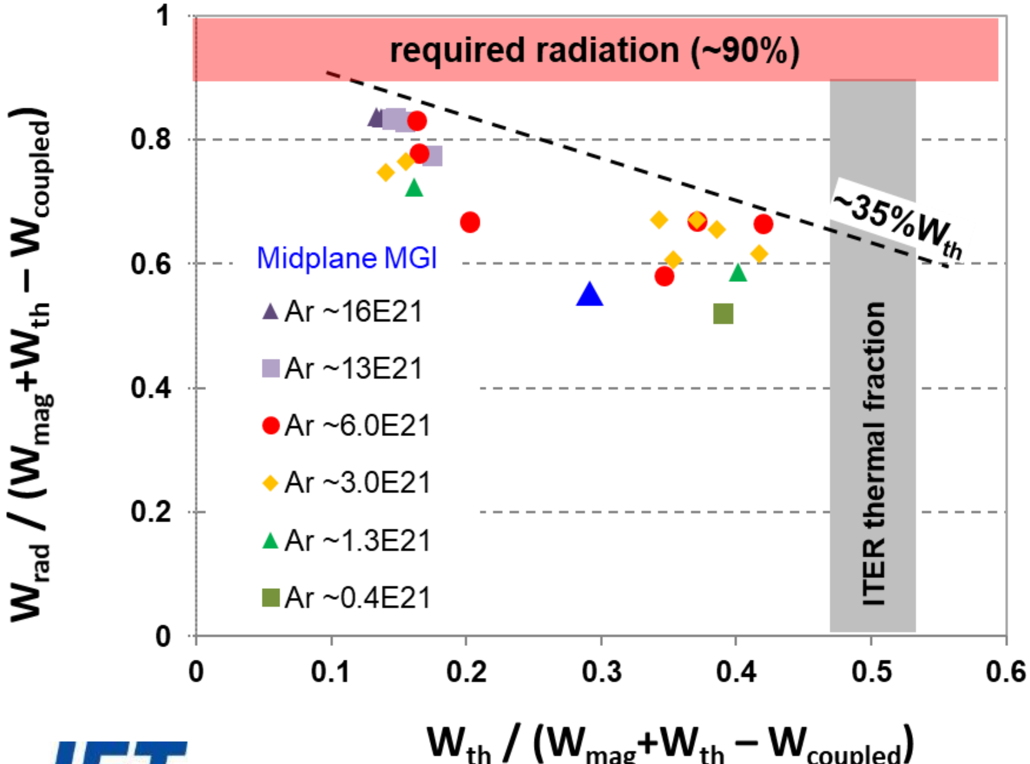


[Vega et al. NF 2018, Vega et al. SOFT 2018 P3.038, Ratta et al. SOFT 2018 Oral 2B]

Disruptions with metallic walls and mitigation

- **Absence of intrinsic impurities (C) → lower radiation**
- **Slower I_p quench → higher halo currents → larger EM forces**
- **Higher thermal loads → melting Be-tiles**
- **3 fast Massive Gas Injection valves to mitigate disruption**

JET Thermal load mitigation mitigation



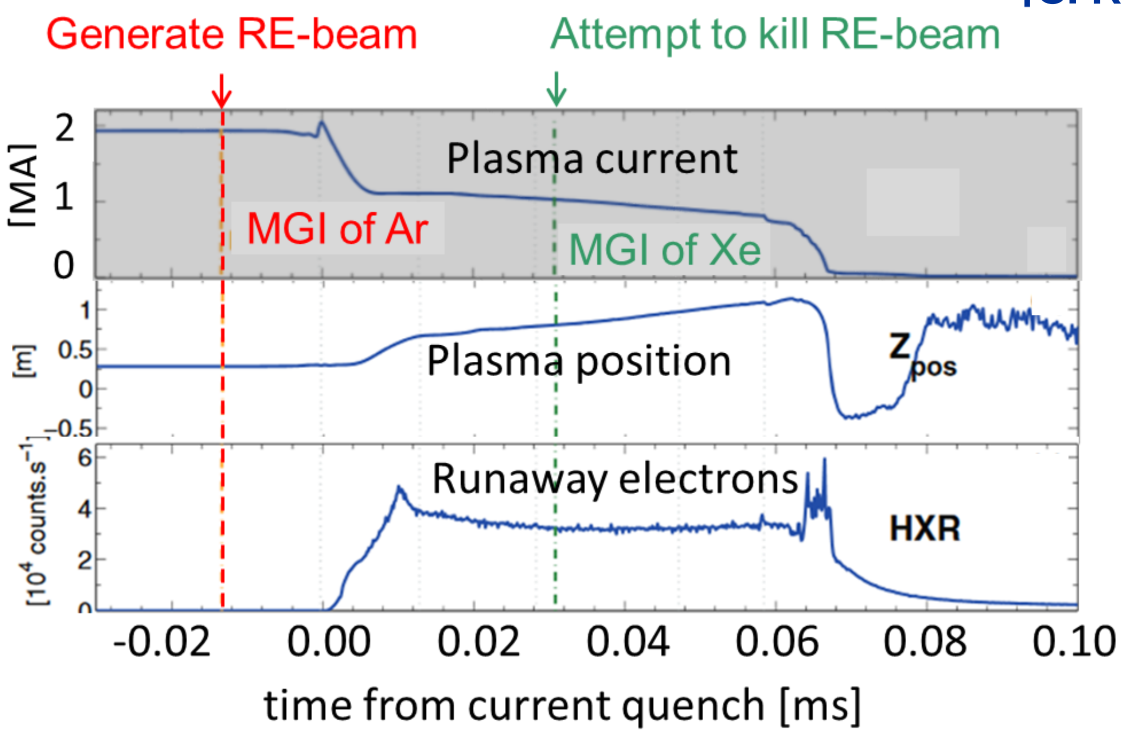
- **ITER:**
  - **90% of energy to be radiated**
  - **Suppression of Runaway Electrons**

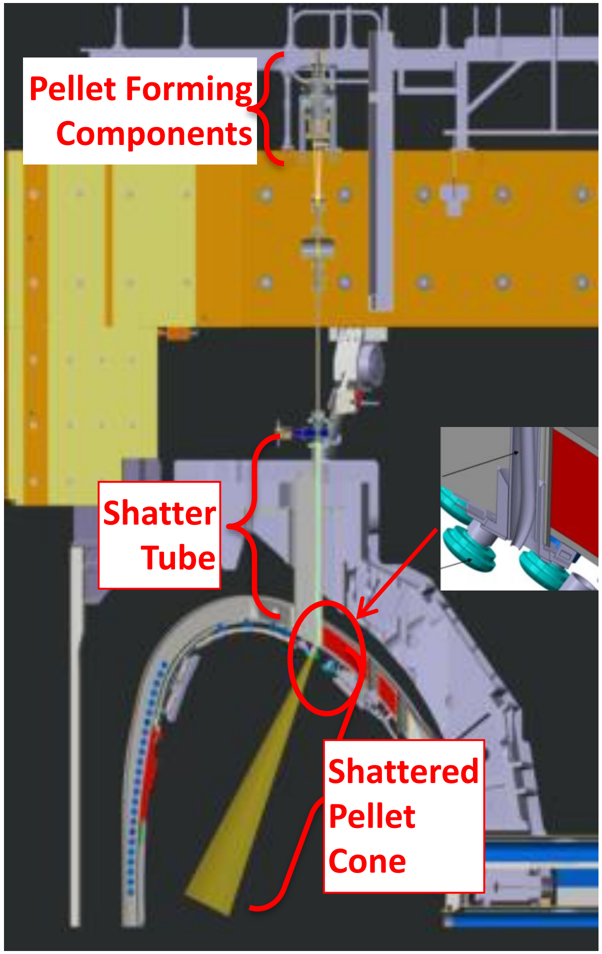
[S. Jachmich et al. PSI 2016]

New Shattered Pellet Injector (SPI) at JET

MGI not as successful as in AUG/DIII-D for RE suppression

[C. Reux *et al*, NF (2015)]





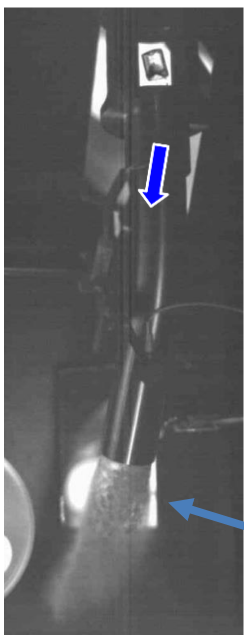
⇨ **New Shattered Pellet Injector installed and to be tested in an international framework**

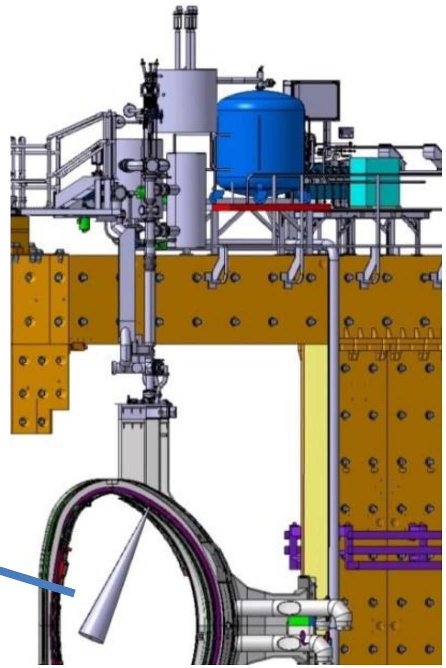
UK Atomic Energy Authority | iter china eu india japan korea russia usa | US iter | U.S. DEPARTMENT OF ENERGY | OAK RIDGE National Laboratory | European Commission | EUROfusion

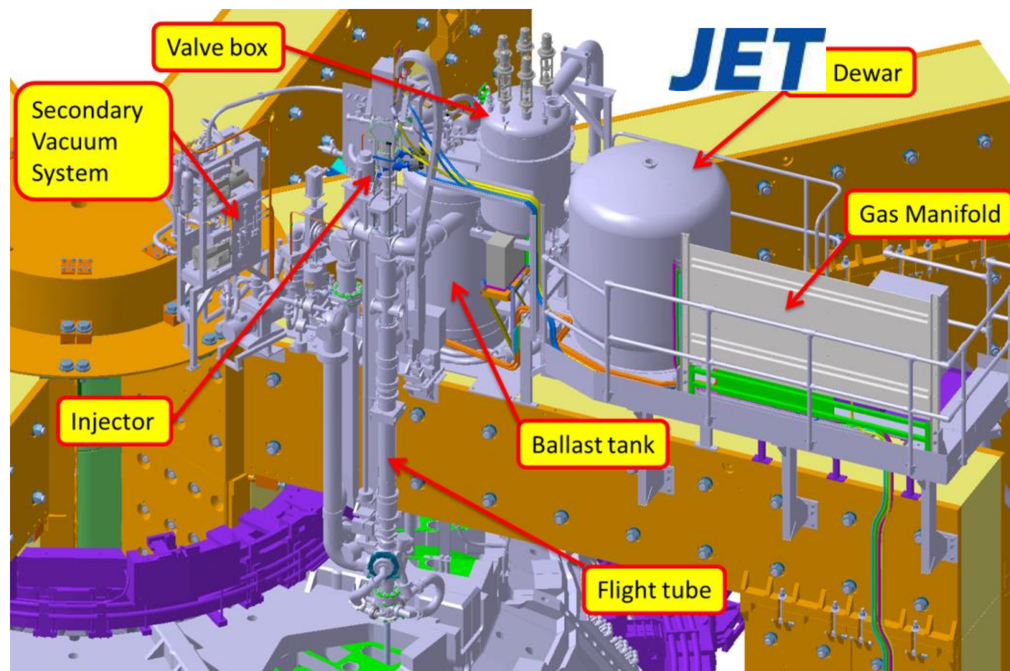
JET

ITER SPI Disruption Mitigation Studies

- **Impact ITER Disruption Mitigation System design and operation:**
  - Thermal load mitigation, Runaway electron dissipation
    - Ne, D_2 and Ar available. Multiple injection possible
  - Disruption Mitigation System operation as on ITER
  - Size scaling and MGI vs SPI: ASDEX-U, DIII-D, KSTAR and JET
  - Extrapolation towards ITER

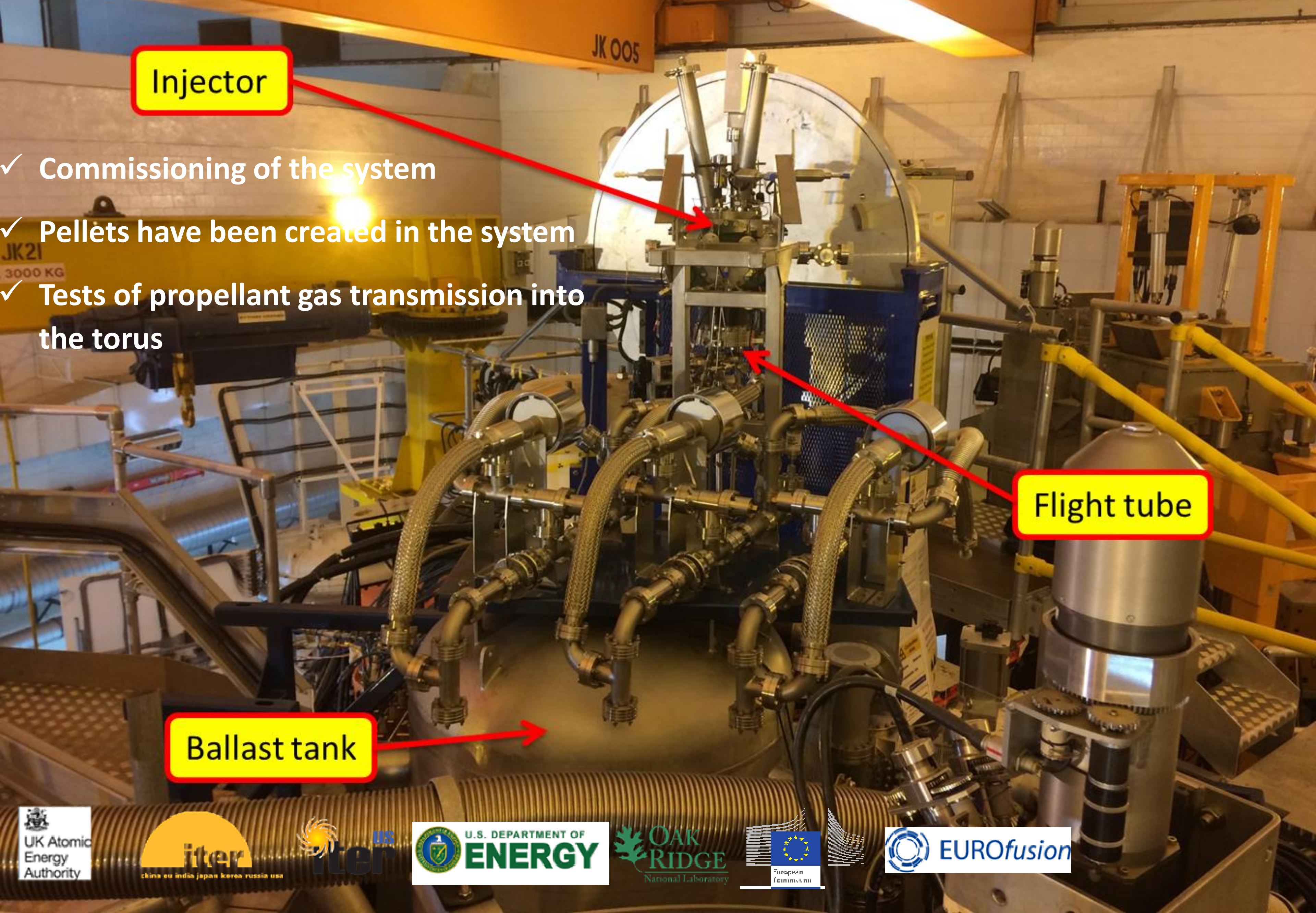






Shattered Pellet Injector on JET for ITER

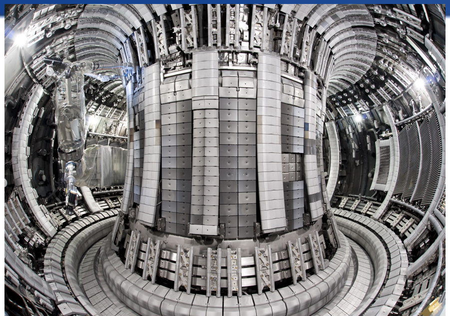
- ✓ Commissioning of the system
- ✓ Pellets have been created in the system
- ✓ Tests of propellant gas transmission into the torus



EUROfusion

Scientific case for the exploitation of JET beyond 2020

JET



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Background

- **JET has unique capabilities for supporting ITER**
  - Tritium operation
  - ITER first wall materials
- **Following discussions with the ITER Organisation, high priority programmatic deliverables have been elaborated where further JET operation can make unique and essential/important contributions to the ITER project in parallel with the MST programme.**
- **Deliverables contribute to ITER along one or more of the four defined criteria:**
  - Reduce risk and optimise the ITER research plan duration
  - Cost savings for ITER
  - Key technology demonstration to enable operational licensing
  - Improving the performance of ITER, perhaps even above Q=10

JET

Boundary Conditions

- **Completion of a significant DT campaign by the end of 2024**
- **T and DT operation before 2020**
- **Focus on ITER priority (technology and operation) where JET bring a unique contribution**
- **Enhancements to be available before 2023 DT experiment and driven by the agreed scientific scope**
- **Individual international collaborations**
- **Refurbishment as required for reliable operation as recently assessed by an independent panel**
  - ***"From these data presented, there is no obvious sign that the JET facilities, as a whole, are reaching their 'end of life' within the extended science case anticipating an operation up to 2024/2025"***
- **Decision to commit resources beyond conceptual design by mid-2019 at the latest with the exception of the RH refurbishments to begin early 2019**

ITER priority and DEMO specific issues

- **JET programme remains focused on two main pillars:**
  - (i) specific preparation for the JET DT experiments
  - (ii) direct support to ITER priority items: key ITER systems, technology and operation
- **As a consequence of the programmatic choices and the limited time available, DEMO-specific items have received a much lower priority**
- **JET programme remains open to opportunity pending exploratory work within the EUROfusion MST**
  - a very limited amount of time available for an additional physics programme, which is flexible by nature, will be kept

Deliverables, which motivate and largely define the JET post 2020 programme [1/2]

- **All deliverables are important for ITER with JET giving information that cannot be obtained elsewhere**
- **Deliverables underlined have been identified by IO as essential for ITER project and only obtainable by JET**
- **Test and improve key ITER systems and technology**
  - **Test ITER's disruption mitigation system**:
    - **multiple shattered pellet injectors (SPI)**
  - **Test ITER's tritium monitoring and removal systems and techniques:**
    - **laser induced desorption system (LIDS) for T monitoring;**
    - **laser induced breakdown spectroscopy (LIBS) for in-situ T inventory;**
    - **in situ T surface inventory characterisation and removal techniques**
  - **Test key remote handling processes for ITER:**
    - **expose single crystal mirrors relevant to ITER in JET**
    - test and de-risk key remote handling technologies for ITER
  - **Test key diagnostics for ITER:**
    - back scattering TOF neutron spectrometer
    - two-colour Infrared cameras in Be/W

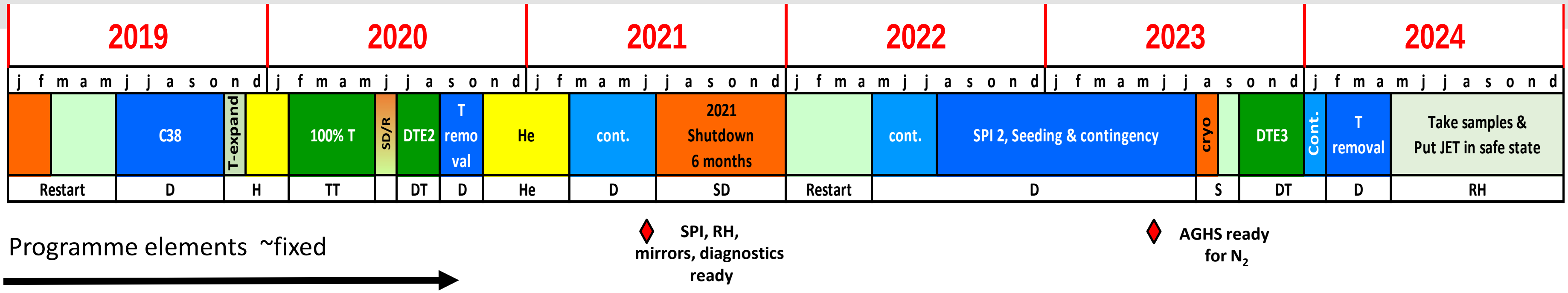
Deliverables, which motivate and largely define the JET post 2020 programme [2/2]

- **Test and optimise key elements of ITER's strategy for operation with the Be/W wall**
  - Assess low wall temperature ops. to predict and optimise ITER conditioning cycle
  - Establish, compare N and Ne-seeded scenarios for ITER seeding gas selection
  - Assess ammonia production and clean-up for ITER N-seeded scenarios
  - Measure dust migration from tokamak to maintenance equipment for ITER's hot cell design
- **Preparation of ITER integrated Operation with low disruptivity**
- **Preparation of ITER Pre-fusion Power Operation**
  - characterise He H-modes and their extrapolation to D and DT plasma
  - document transferability of ITER–like ELM control techniques from Helium to D
  - Characterise Plasma-wall interaction in Helium
  - assess ICRH heating schemes in helium
- **Test & optimise key elements of ITER Fusion Power Operation:**
  - demonstrate real-time DT isotope control in integrated operation
  - advanced ICRH schemes for DT
  - AE stability in H/He/DT plasma & instabilities in DT

Essential JET enhancements to support the programme

- **Second shattered pellet injector**
- **ITER relevant Laser Induced Desorption Spectroscopy (LIDS) and Laser Induced Breakdown Spectroscopy (LIBS)**
- **Diagnostics enhancements**
  - **direct tests of ITER prototypes**
    - **two-colour Infrared cameras in Be/W**
    - **14 MeV Time-Of-Flight Neutron Spectrometer**
  - **essential for the exploitation of the SPI for ITER**
    - **5 Wide angle bolometry, Fast camera**
  - **essential to exploit edge physics, divertor and PWI for ITER**
    - **Refurbishment of the Langmuir probe array**
    - **"Black" calibration target tiles on inner wall for IR (energy balance)**
    - **Divertor IR and/or Visible Spectroscopy (power load studies + LIBS/LIDS)**
    - **Soft X-ray enhancement for impurity transport**
- **Test of ITER mirrors**
- **Active Gas Handling System**
- **Real-Time Control enhancements**
- **Remote Maintenance for ITER**

Time schedule beyond 2020



- **Schedule built around two DT campaigns in 2020 and 2023-4**
  - ensure the overall scope of DT operation would be maintained and supplemented with the new deliverables
- **Optimise the operational time while minimising the shutdown in 2021**
  - mainly to install a second SPI
- **Shutdown in 2021 and DTE3 in 2023 cannot be moved earlier for new hardware, Remote Handling, vessel activation levels, AGHS readiness**
- **All the high level deliverables to be achieved by 2024**
- **Schedule with 12 months contingency elaborated assuming strong programmatic prioritisation but keeping ITER essential priority items**

Conclusion

- **JET operation is secure up to 2020 independent of Brexit negociation !**
- **Significant preparation of unique T-T and DT campaigns with the ITER-like wall (2020)**
  - Results confirm the prospect of a successful DT campaign with reliable high heating power and an extended set of diagnostics
- **Commissioning, operation and efficacy of Shattered Pellet Injectors in 2019 in direct support to ITER**
- **Preparation of Horizon EUROPE (2021-2027)**
  - Strong focus to support ITER operation
  - Proposal for a JET programme up to 2024 pending funding and agreement are reached…
  - Strengthen the EUROfusion–Theory and Advanced Simulation Coordination programme
  - Increase DEMO R&D and finalizing DEMO conceptual design

Thank you for your attention on behalf of the EUROfusion JET contributors

- Austrian Academy of Sciences — **AUSTRIA**
- Ecole Royale Militaire Laboratory for Plasma Physics — **BELGIUM**
- Bulgarian Academy of Sciences — **BULGARIA**
- Ruđer Bošković Institute — **CROATIA**
- University of Cyprus — **CYPRUS**
- Institute of Plasma Physics Academy of Sciences of the Czech Republic — **CZECH REPUBLIC**
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- CCFE Culham Centre for Fusion Energy — **UNITED KINGDOM**
- KIPT — **UKRAINE**