# Fusion Energy: Advancing the European Roadmap

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Acknowledgements to the Roadmap revision group:
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EPFL

EUROfusion

École polytechnique fédérale de Lausanne

EUROfusion

EUROfusion integrates R&D in fusion science and technology

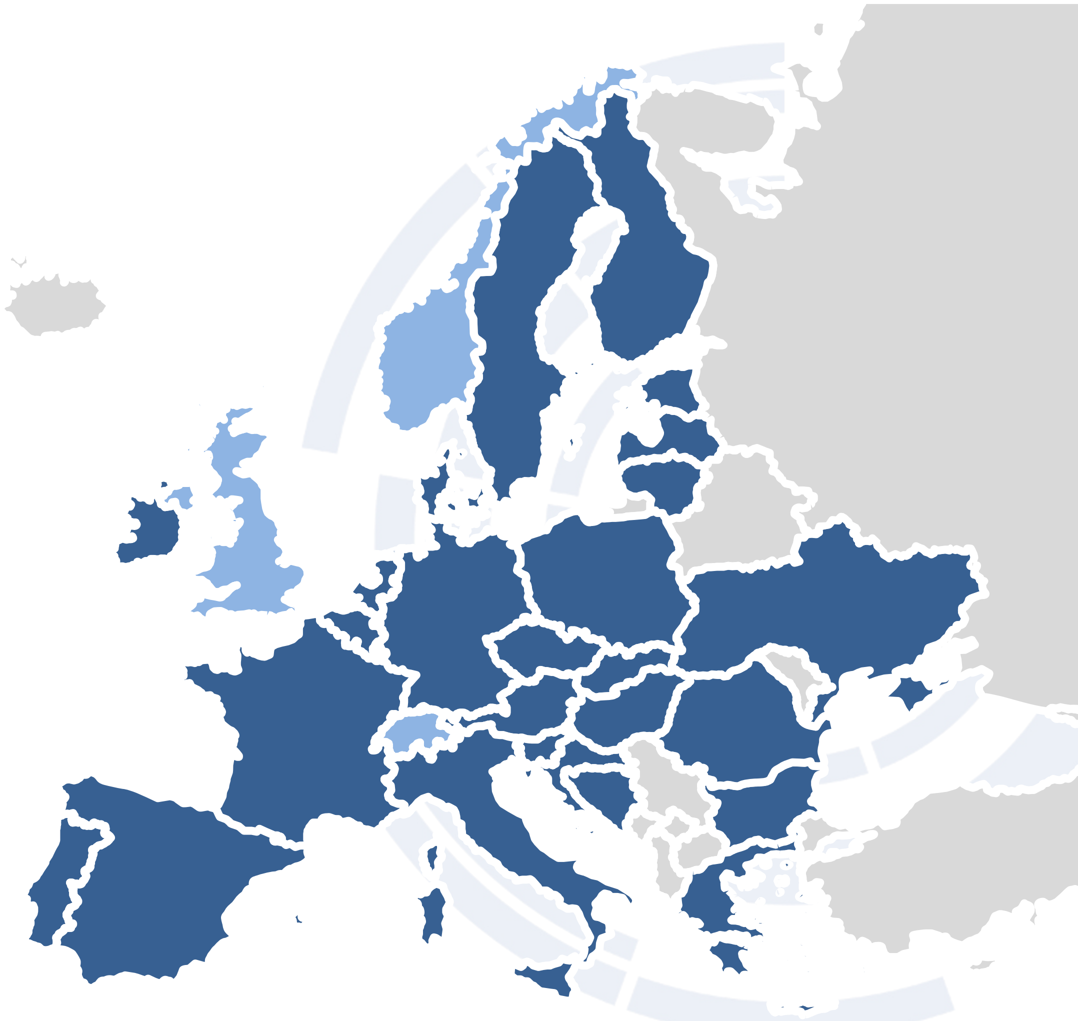
**29** Countries

**31** Research Institutions

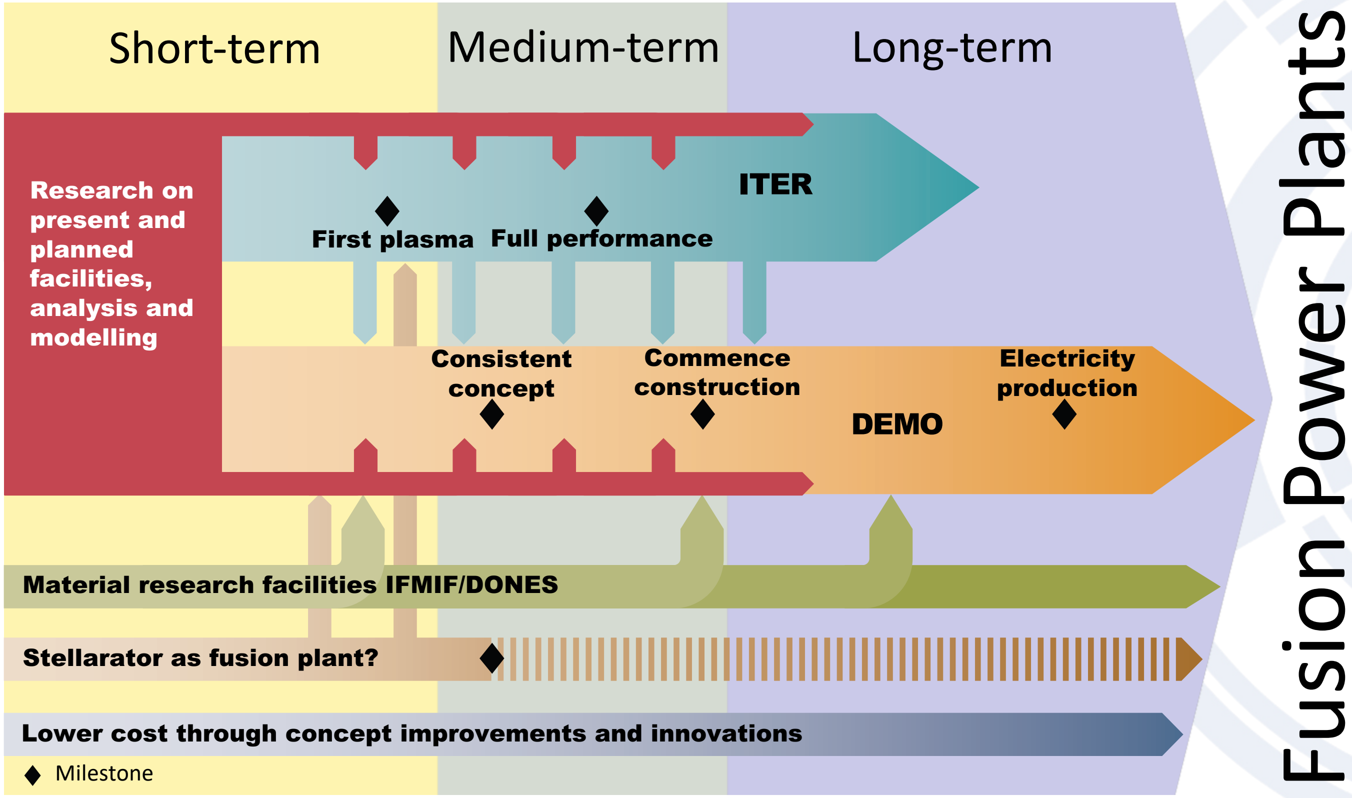
**164** Universities

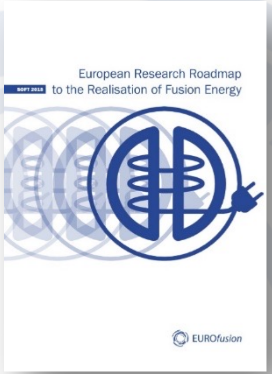
**800** MSc and PhD students

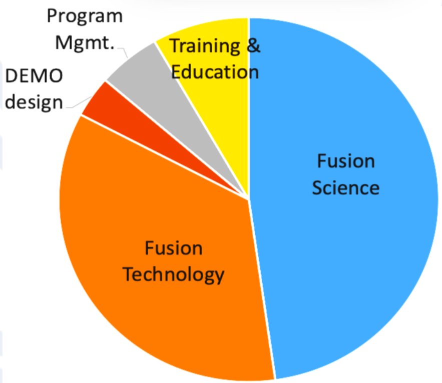
**4000** Fusion Researchers & Support Staff



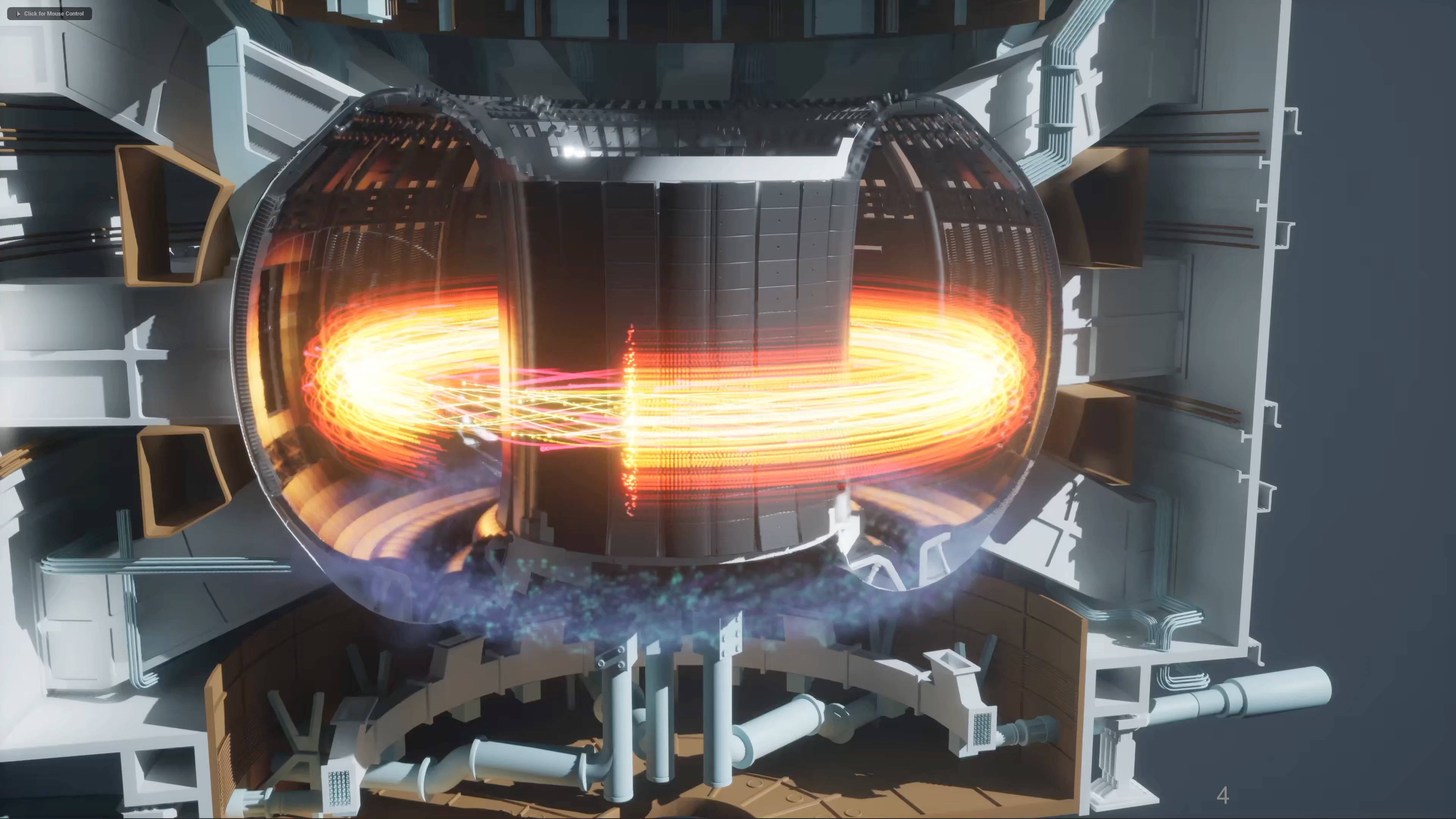
# R&D program follows European Fusion Roadmap




Present resource allocation


Click for Mouse Control

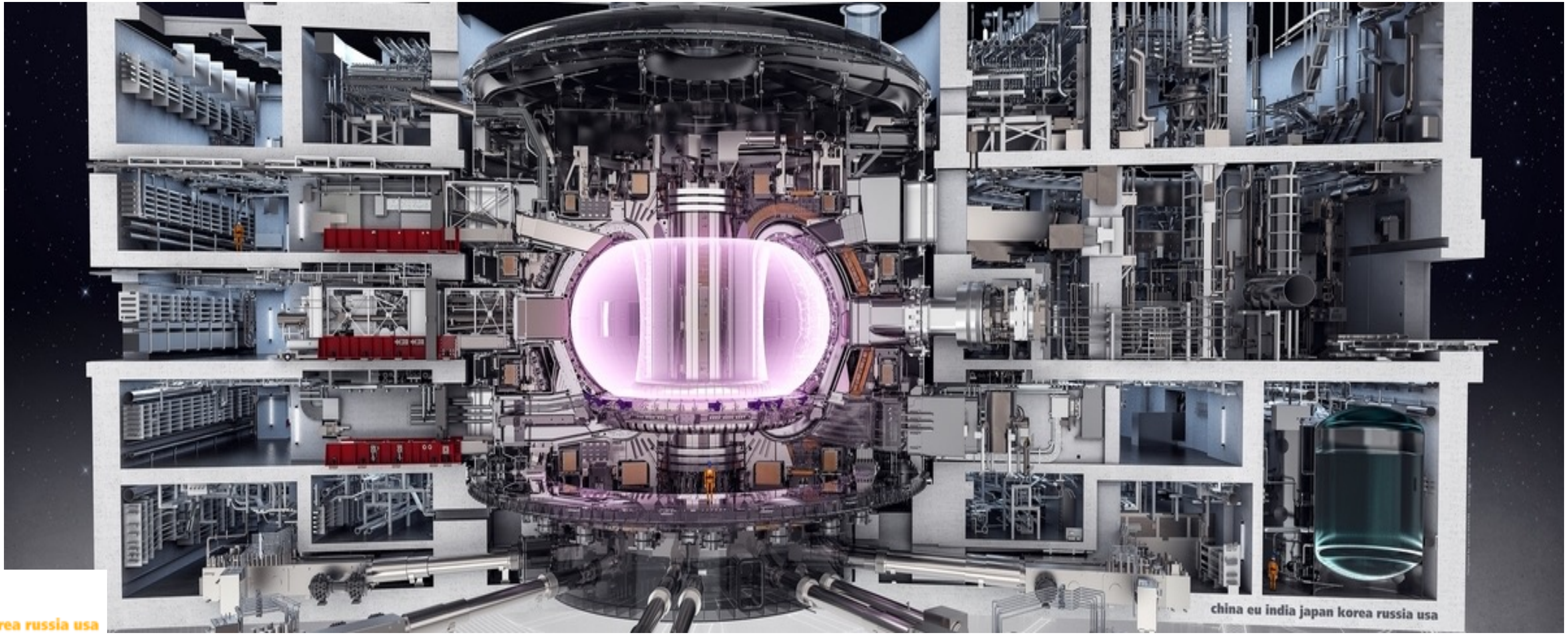
ITER

Scientific and technological feasibility of fusion

Q =10: first *burning* plasma

$P_{fusion}$= 500MW for ~500s

Under construction in the south of France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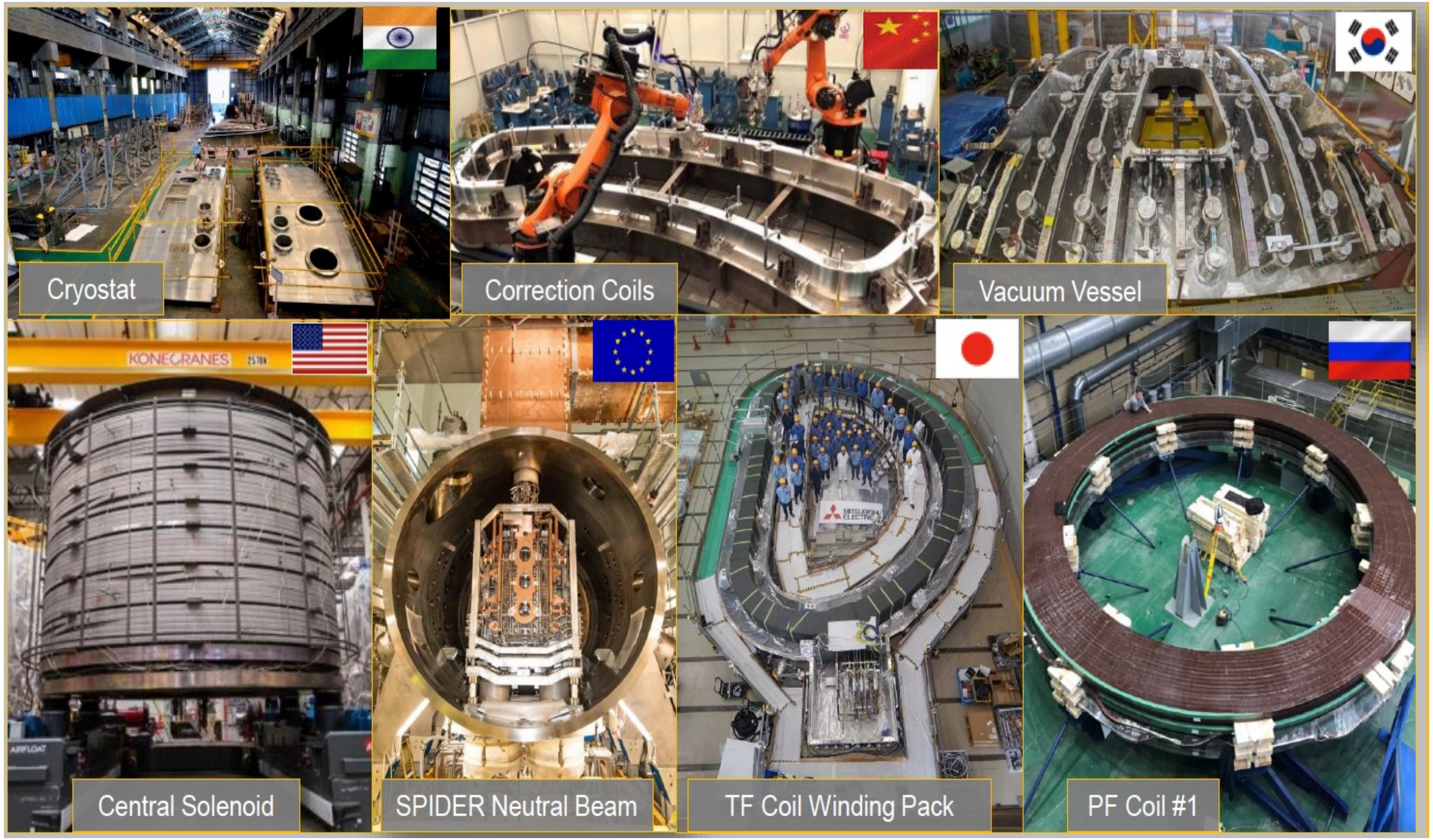
# ITER site

iter china eu india japan korea russia usa

# ITER components from all over the world

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# ITER assembly

iter china eu india japan korea russia usa

# A revision of the approach to the Roadmap is needed

Interest in fusion has grown enormously thanks to

- Fusion successes at JET, NIF, W7-X, Medium-Size Tokamaks, ITER assembly
- Realization that baseload electricity power plants are essential for energy transition & security
- Booming of private fusion efforts

Present Roadmap contains all linked elements of a reactor-oriented program but is based on a sequential JET-ITER-DEMO approach

- Delays have impacted ITER, but also JT-60SA, IFMIF-DONES and DTT
- Unique and valuable lessons learned from every stage of ITER can and must be integrated into the Roadmap

# Main elements of the Roadmap revision

Definition of the DEMO step

Gaps to be addressed

Measures to accelerate the DEMO and FPP programs

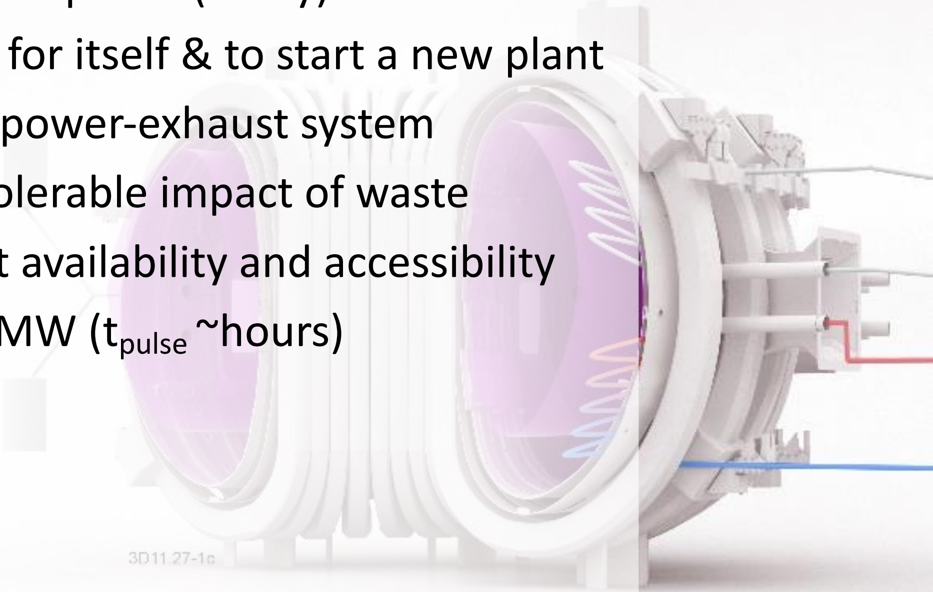

*These points are in addition to the specific activities for the ITER project, which remain central*

# Definition of the DEMO step – high level goals

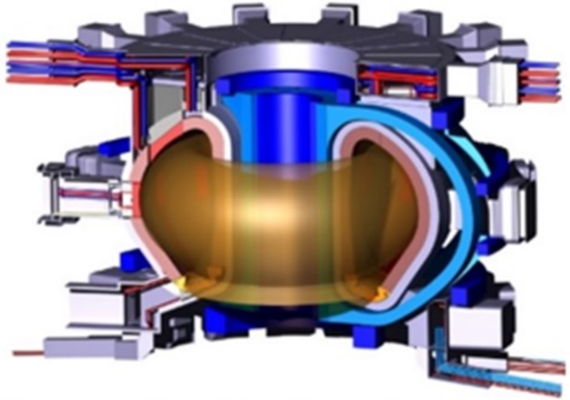
Demonstrate performance and integration of key technologies with tolerable failure rates to achieve adequate levels of availability

- Blanket radiation exposure ~20dpa in first phase (~6-7y)
- Self-sufficient fuel cycle: supply tritium for itself & to start a new plant
- Robust plasma operation scenario and power-exhaust system
- Demonstration of intrinsic safety and tolerable impact of waste
- Maintenance systems that ensure plant availability and accessibility
- Net electricity output to grid ~300-500MW ($t_{pulse}$ ~hours)

Tokamak configuration



# DEMO Design Activities

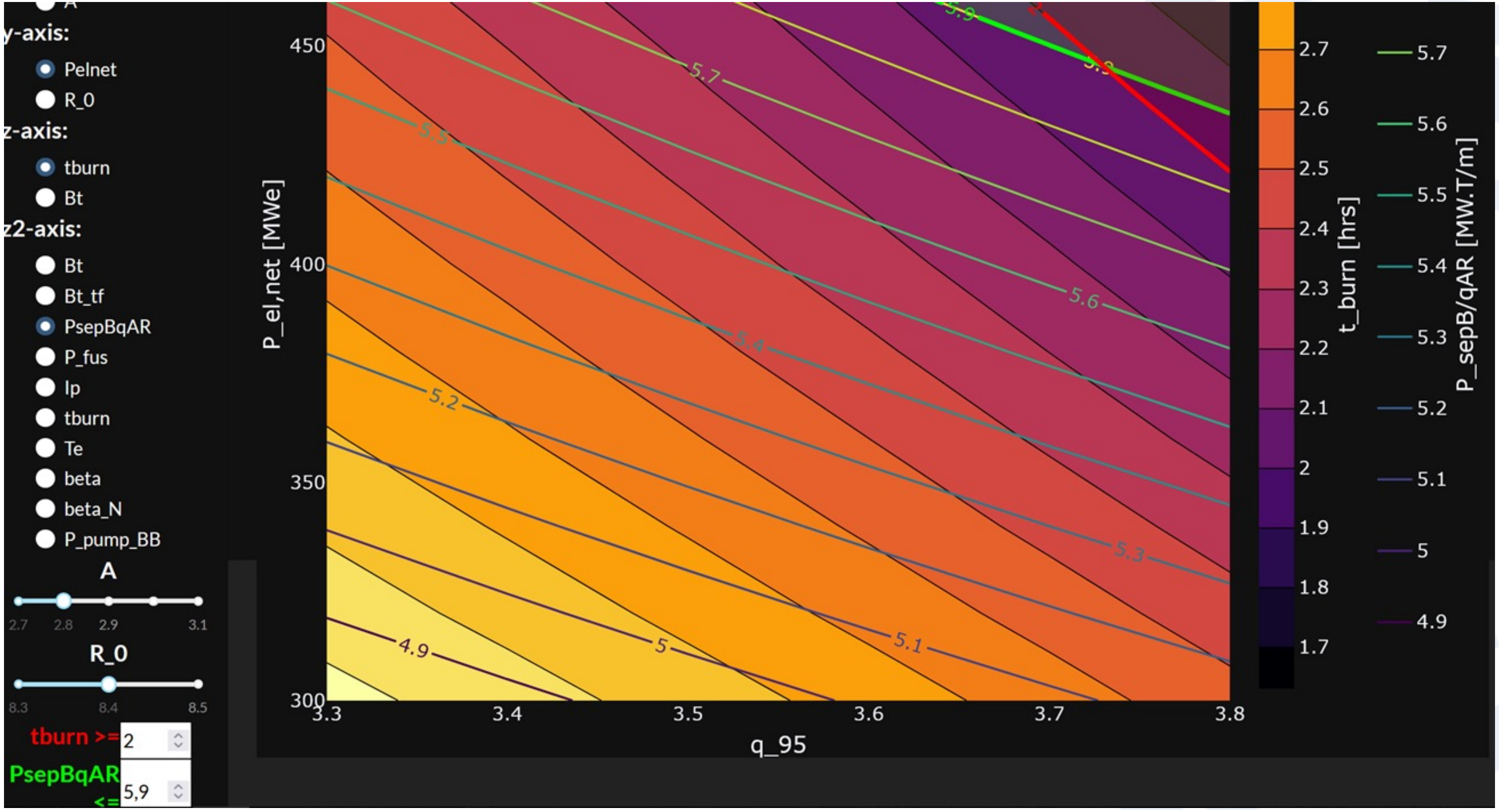


Representation of the G1 baseline Tokamak.

| Parameters | DEMO G1 | DEMO low A design space |
|---|---|---|
| $R_0$, a (m, m) | 9, 2.9 | 8.5, 3.15 |
| A | 3.1 | 2.7 |
| $B_0$(T) | 5.9 | 4.05 - 4.25 |
| $I_p$ (MA), q | 18, 3.6 | 19.1 - 19.8, 3.5 - 3.7 |
| $k_{95}$, $\delta_{95}$ | 1.6, 0.33 | 1.75, 0.33 |
| $<T_e>$ (keV) | 12.6 | 10.65 - 11.15 |
| $<n_{e,vol}>$ ($10^{20}m^{-3}$) | 0.73 | 0.66 - 0.69 |
| $Z_{eff}$ | 2.2 | 2.0 - 2.2 |
| H | 1.1 | 1.1 |
| $t_{burn}$ (hrs) | 2 | 2 - 2.25 |
| $f_{bs}$ (%) | 39 | 38 - 39 |
| $P_{CD}$ (MW), $P_{LH}$ (MW) | <10, 120 | <10, 89-93 |
| $P_{div}$ (MW) | 161 | 108 - 112 |
| $P_{fus}$ / $P_{e,net}$ (MW) | 2014, 500 | 1555 - 1750, 350 - 415 |
| $Av_{NWL}$ (MW/m²) | 1.0 | 0.75 - 0.87 |
| $P_{sep}B/qAR_0$ (MW.T/m) | 9.2 | 5.4 - 5.8 |
| Reattached heat flux [MW/m²] | 61.3 | 36 - 39 |

Source: G. Federici, H. Zohm

# Example of system code exploration of low aspect ratio solution




Source: M. Coleman, H. Zohm

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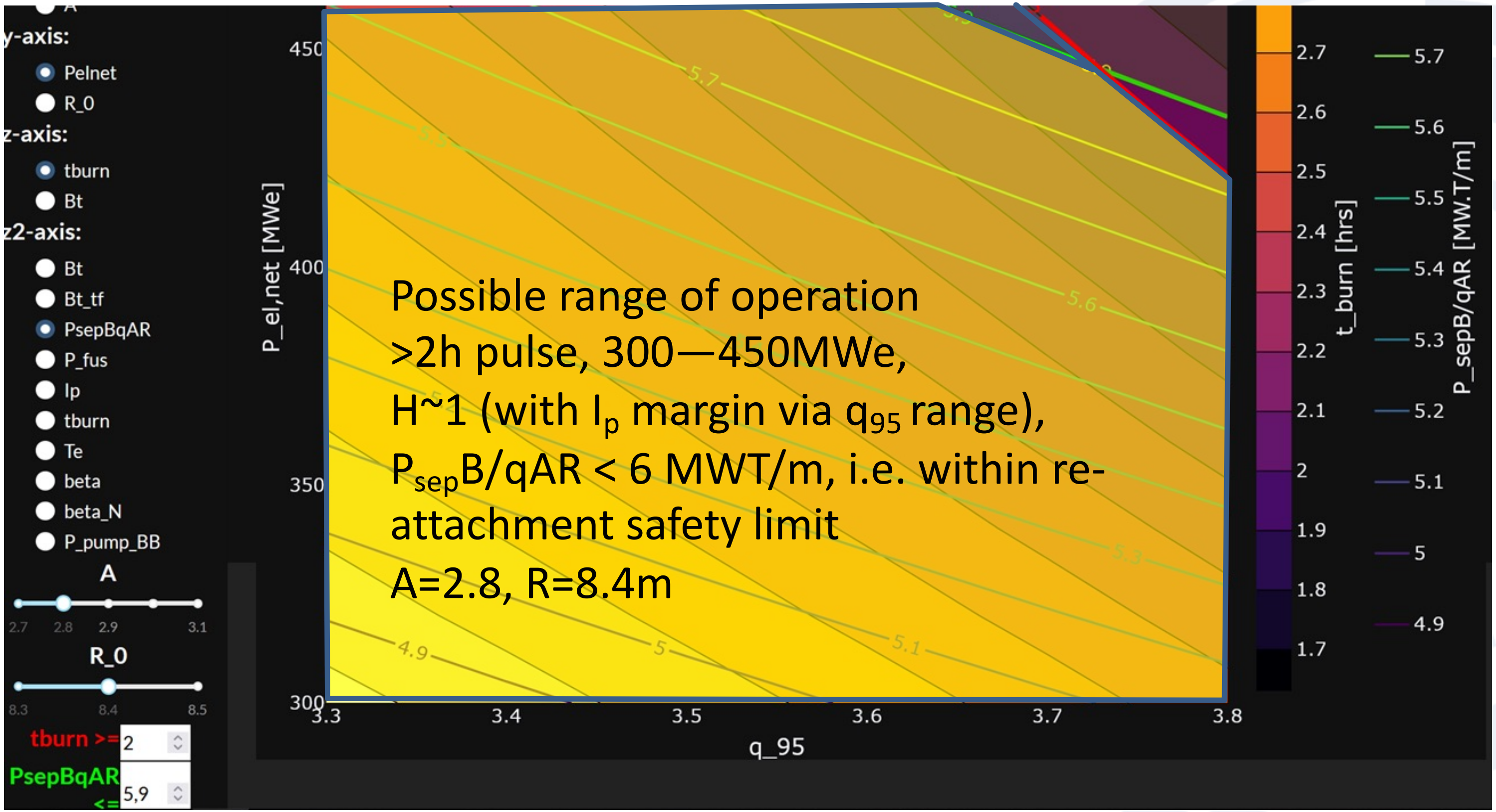
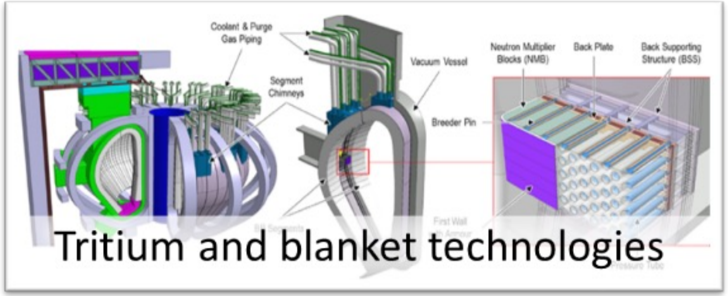
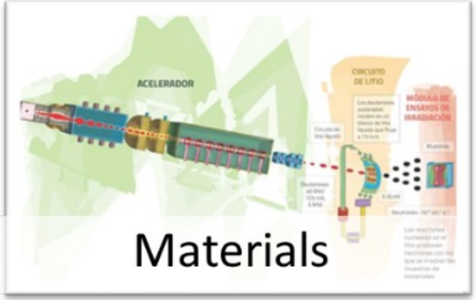
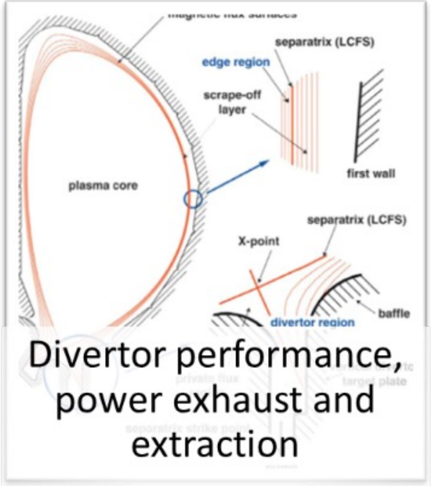


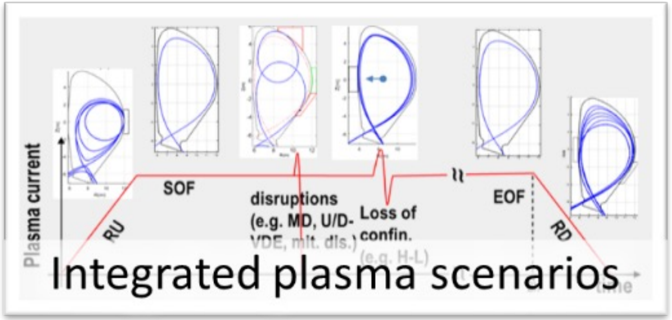

Source: M. Coleman, H. Zohm

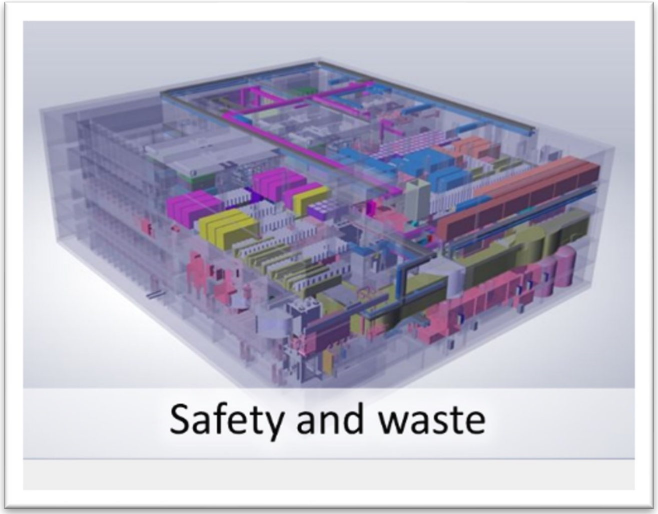
# Gaps to be addressed



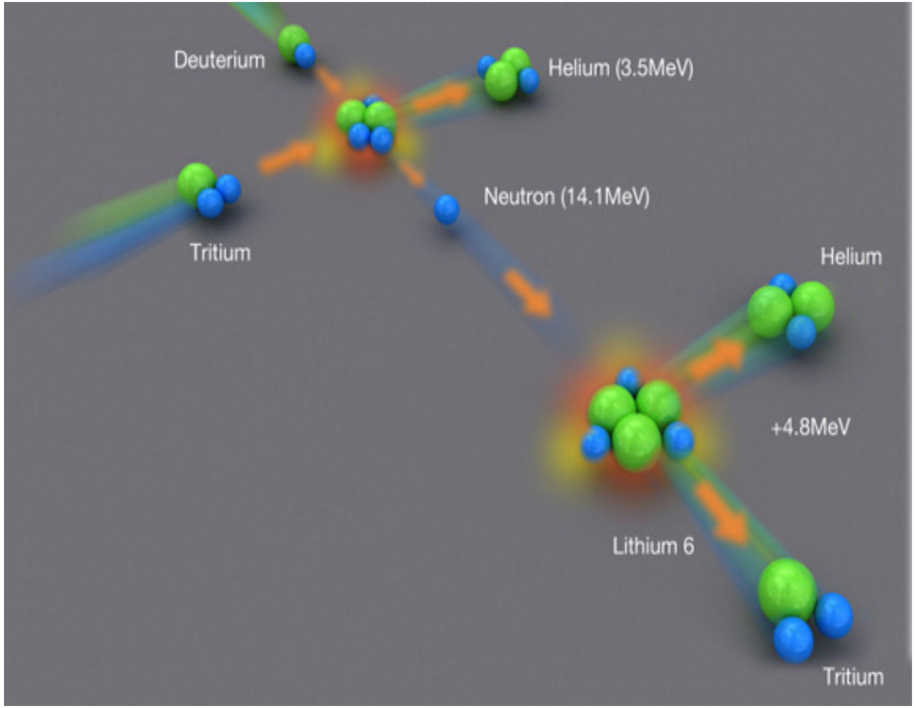



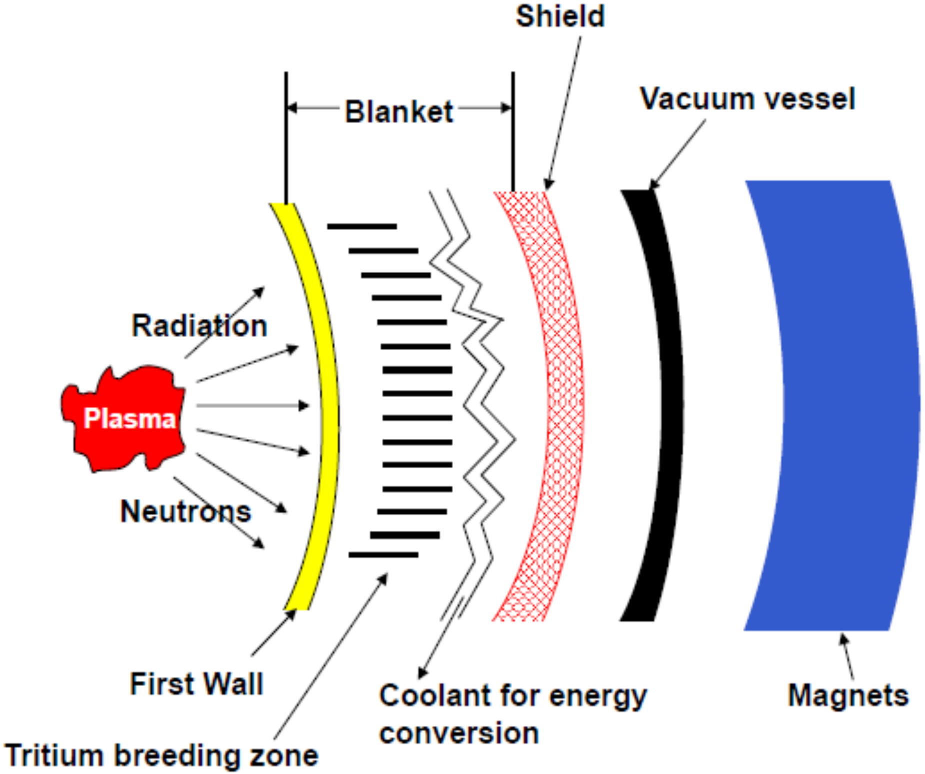



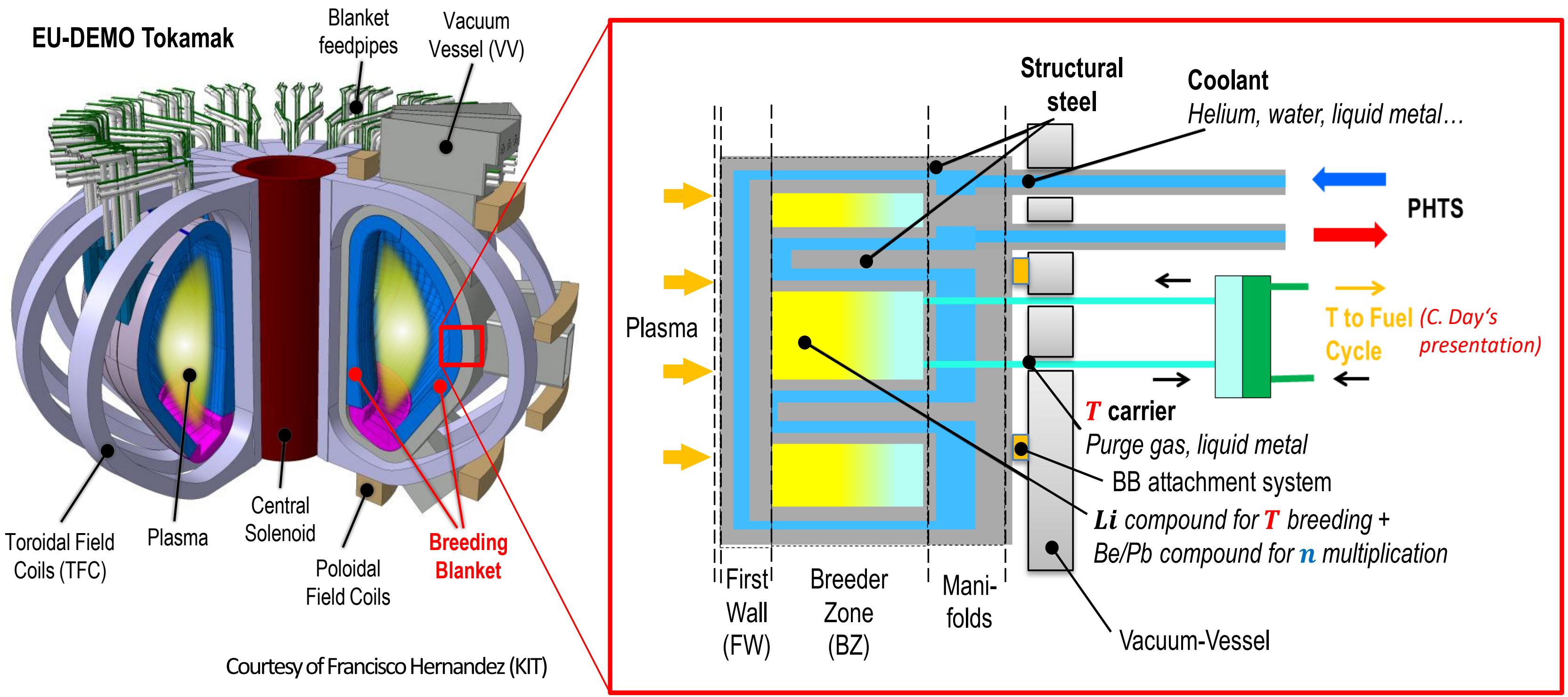




# Tritium and blanket technologies



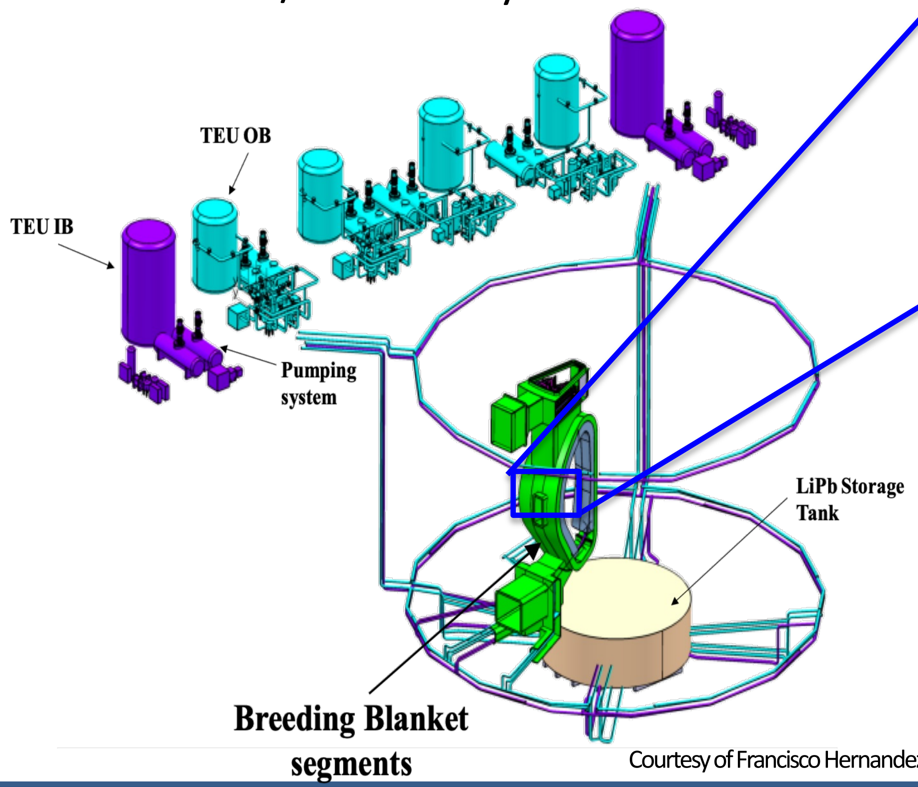
# Tritium and blanket technologies

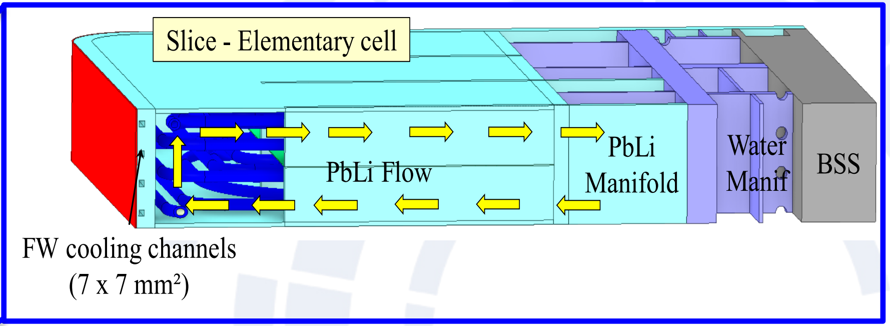


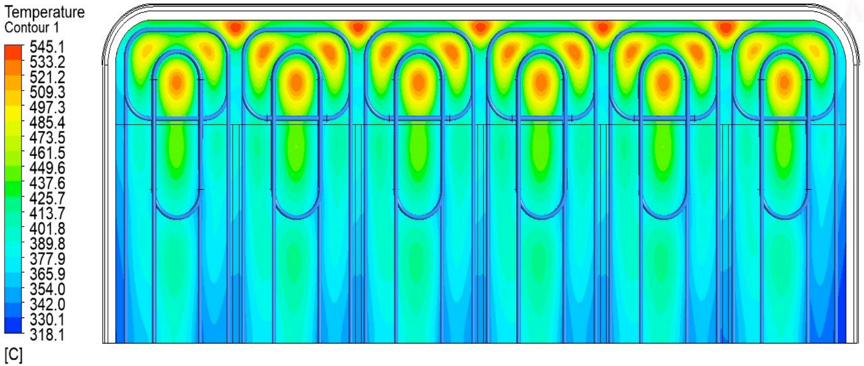

- In DEMO, the blanket is one of the most novel, low TRL and high-risk parts
- ITER TBM programme comes late and with a very low expected damage dose <0.1dpa

# Progress on BB system ex. 1: Water-Cooled Lithium Lead

Advanced stage in design of blanket and tritium extraction / removal system



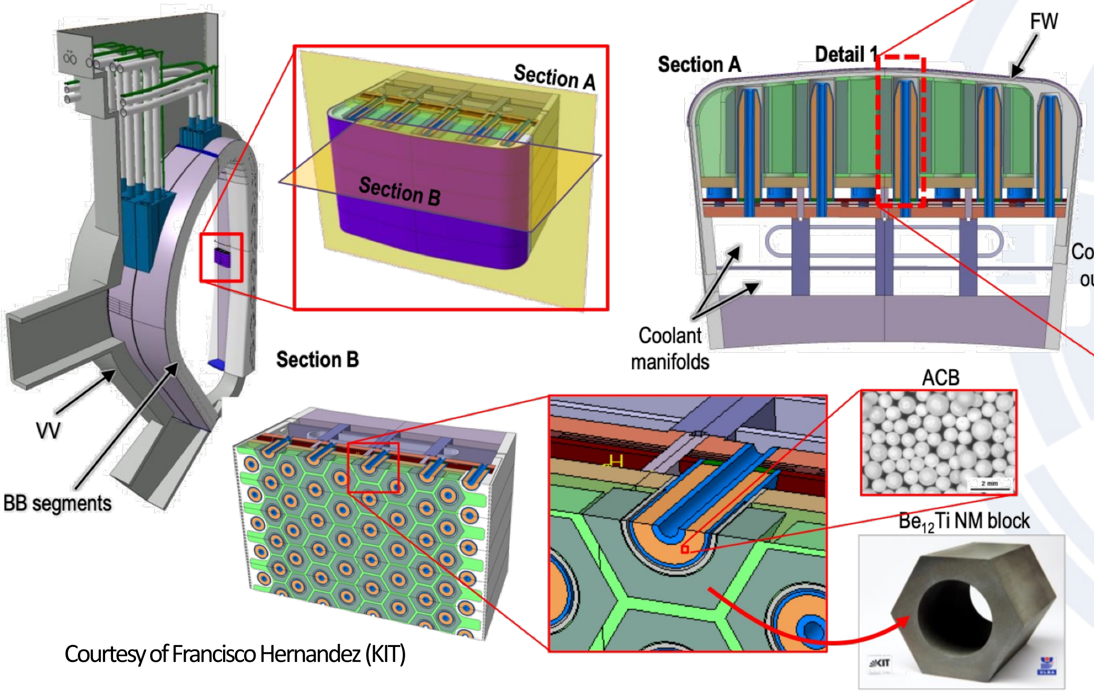




Courtesy of Francisco Hernandez (KIT)

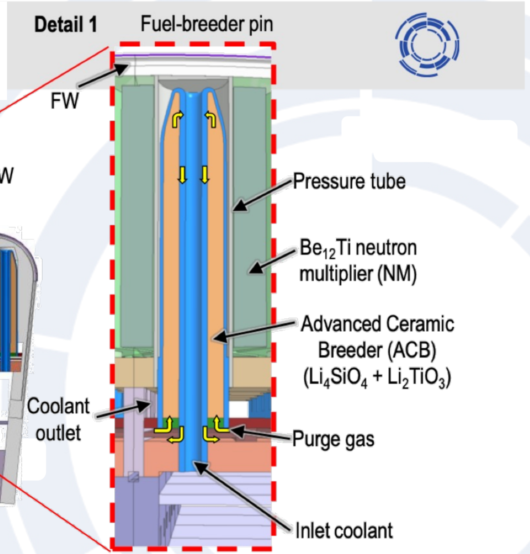
# Progress on BB system ex. 2: Helium-Cooled Pebble Bed

Maturation of the BB and TER designs for operation at high pressure purge gas

- HCPB: Helium Cooled Pebble Bed concept




Courtesy of Francisco Hernandez (KIT)




- He cooling (300-520°C, 8 MPa)
- $Be_{12}Ti$ blocks as n-multiplier
- $Li_4SiO_4 + Li_2TiO_3$ as (advanced) ceramic breeder (ACB)
- He purge gas and T carrier
- Structural steel: EUROFER97
- W-armor 2mm

F.A. Hernández et al. | BB Functions, Concepts and Associated Issues | Fusion/Fission Workshop, VC | 06.12.2023 | Page 6

# Challenges in Breeding Blanket

**Structure**

- Changes in properties and behaviour of materials
  - *Effect of heat flux and cycling on fatigue or crack growth-related failure*
  - *Premature failure at welds and discontinuities*
  - *Effect of swelling, creep and thermal gradients on stresses conc.*
- Tritium permeation through the structure
  - *Effectiveness of tritium permeation barriers*
  - *Effect of radiation on tritium permeation*
- **Structural activation product inventory and volatility**

**Solid Breeder / multiplier / structure interactions**

- Solid breeder mechanical and materials interactions
  - *Strain accommodation by creep and plastic flow*
  - *Stress concentrations at cracks and discontinuities*
- Neutron multiplier mechanical interactions
  - *Beryllium/beryllide swelling (swelling driving force in beryllium)*
  - *Strain accommodation by creep in Beryllium/beryllide*
- Thermal interactions
  - *Breeder/multiplier-structure heat transfer (gap conductance)*

**Coolant / liquid breeder-multiplier**

- MHD pressure drop and pressure stresses
- MHD and geometric effects on flow distribution
- **Helium bubble formation leading to hot spots**
- **Activation products in PbLi**

**Coolant / structure interactions**

- Mechanical and materials interactions
  - *Corrosion*
  - *Failure of coolant wall due to stress corrosion cracking*
  - *Failure of coolant wall due to liquid-metal embrittlement*
- Thermal interactions
- **Coolant/coatings/structure interactions**

**Breeder and purge**

- **Tritium recovery and inventory in solid breeder**
- **Liquid breeder tritium extraction**
- **Thermal conductivity changes under irradiation**
- **Effect of T mass transfer**
- **Breeder behaviour at high burn-up/high dpa**

**General blanket**

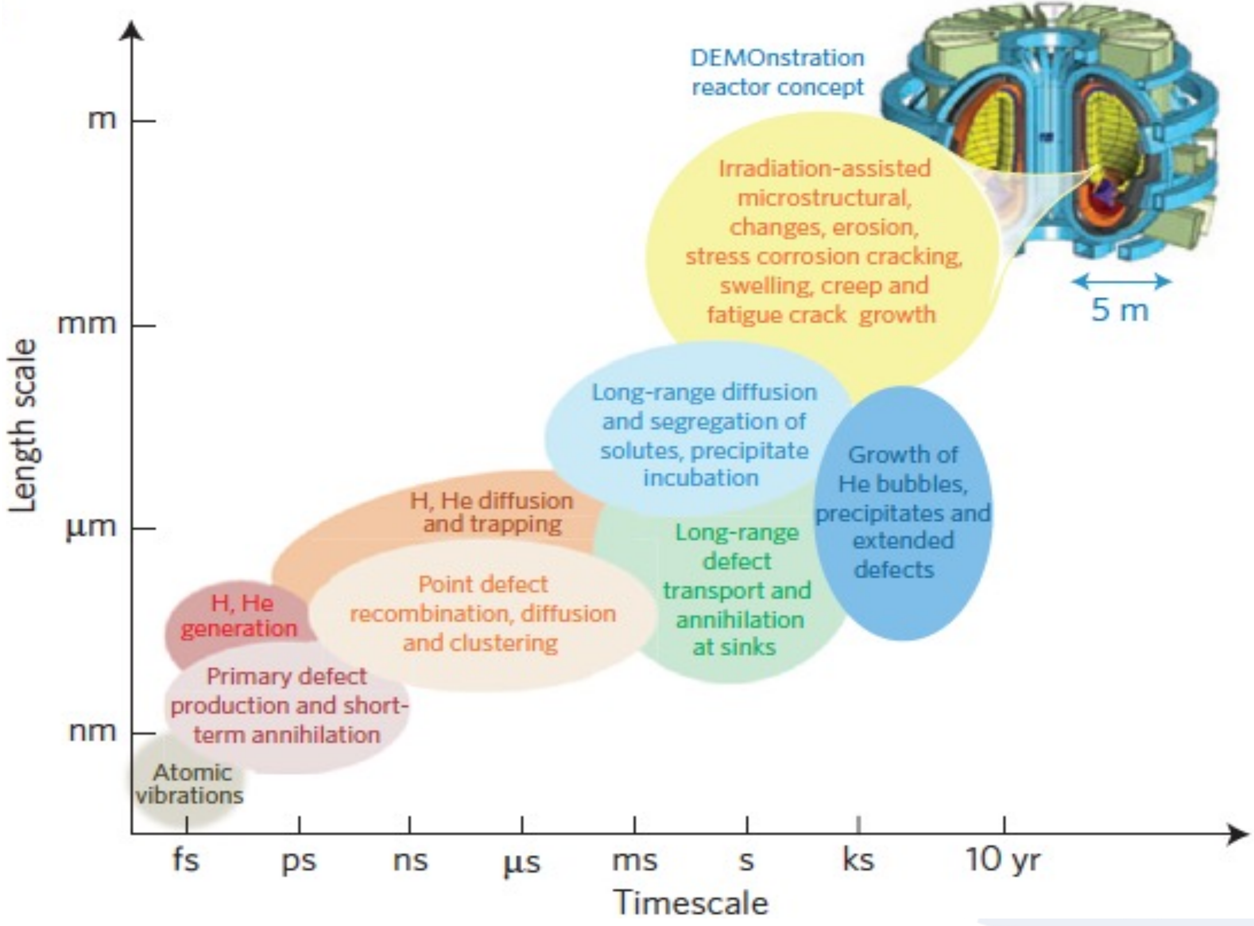
- **Tritium trapping**
- **Uncertainties in achievable breeding ratio**
- **Uncertainties in required breeding ratio**
- **Permeation to blanket coolant**
- **Failure modes and frequencies**
- **Nuclear heating rate predictions**
- **Prediction and control of radioactive effluent**

- **w/o neutrons**
- **w/ neutrons**
- **Fusion environment**



Courtesy of Francisco Hernandez (KIT)

# Materials



DEMOnstration reactor concept
5 m
Irradiation-assisted microstructural, changes, erosion, stress corrosion cracking, swelling, creep and fatigue crack growth
Long-range diffusion and segregation of solutes, precipitate incubation
Growth of He bubbles, precipitates and extended defects
Long-range defect transport and annihilation at sinks
H, He diffusion and trapping
Point defect recombination, diffusion and clustering
H, He generation
Primary defect production and short-term annihilation
Atomic vibrations
Length scale
m
mm
µm
nm
fs
ps
ns
µs
ms
s
ks
10 yr
Timescale

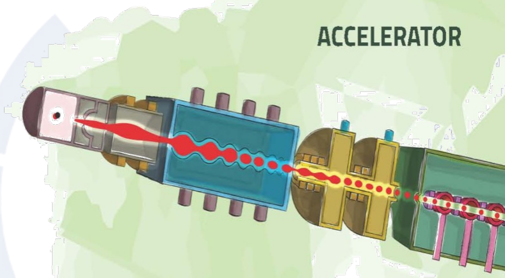
# Materials

A development program is needed to qualify materials to enable roll-out of FPPs

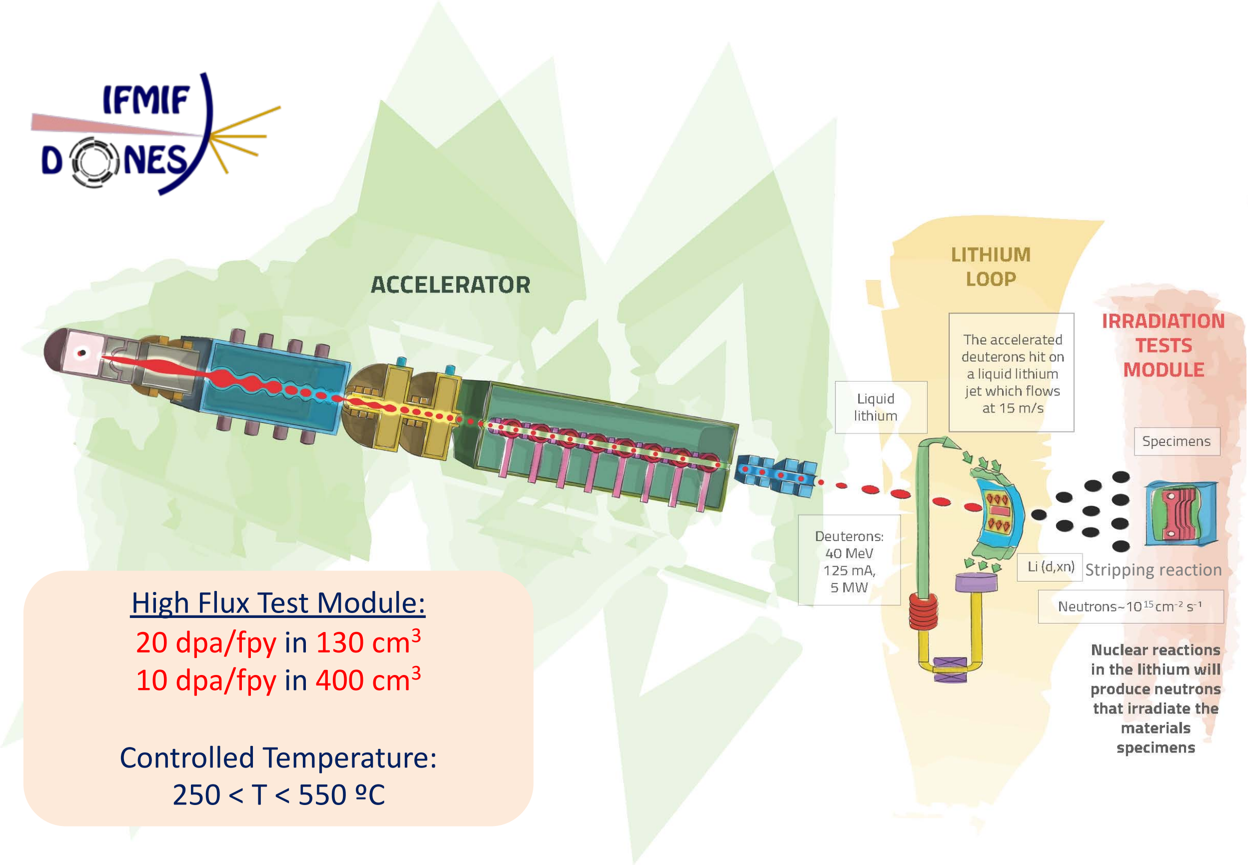
- mechanical and thermal properties
- response to plasma exposure and to 14-MeV n-irradiation >20dpa
- chemical compatibility and safety issues

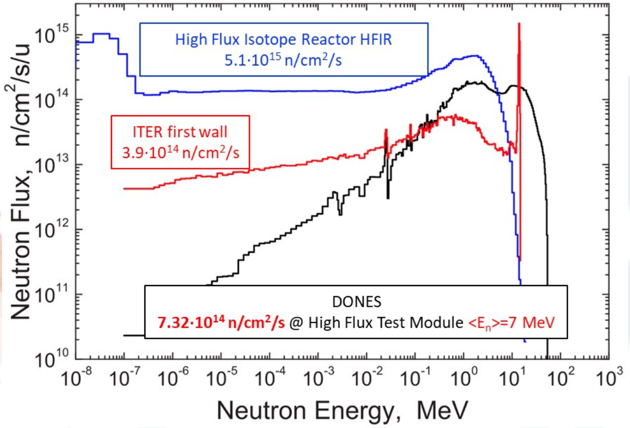
The maturity and robustness of industrial fabrication must be increased

IFMIF-DONES will be the only facility with neutrons of adequate spectrum and fluence to qualify materials using small samples



# IFMIF-DONES: accelerator-based neutron source




**High Flux Test Module:**

20 dpa/fpy in 130 $cm^3$

10 dpa/fpy in 400 $cm^3$

Controlled Temperature:

250 < T < 550 ºC

# IFMIF-DONES: construction has started



Site at Escúzar, close to Granada, Spain

Operation expected in ~2034

# Materials

A development program is needed to qualify materials to enable roll-out of FPPs

- mechanical and thermal properties
- response to plasma exposure and to 14-MeV n-irradiation >20dpa
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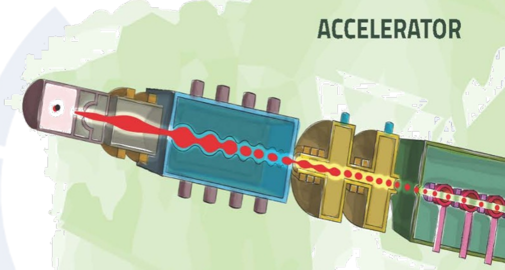
IFMIF-DONES will be the only facility with neutrons of adequate spectrum and fluence to qualify materials using small samples

As the present approach implies that the combined effects of neutrons and other ways of degradation during operation would be detected in the integral testing on DEMO only, the feasibility of a Volumetric Neutron Source (VNS) to qualify components is under consideration (instead of DEMO Phase 1)



# Volumetric Neutron Source - Physics Basis

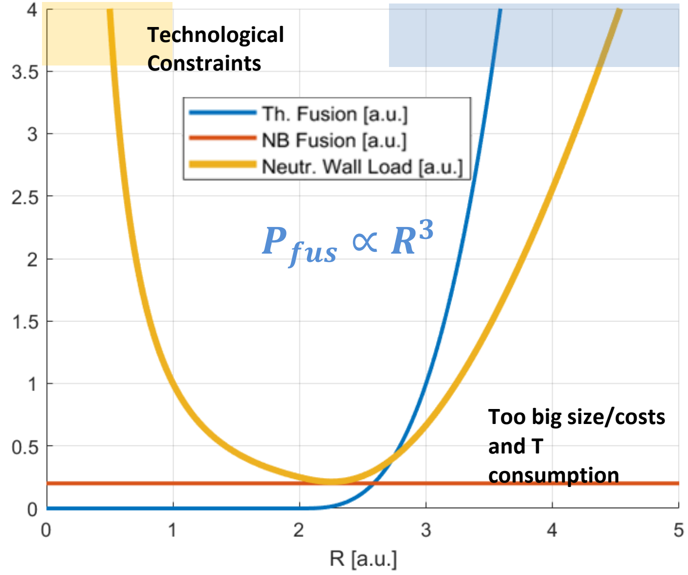
The device should be a 14 MeV neutron source with **a peak Neutron Wall Loading of at least ~ 0.5 MW/m²**

- The only way to keep the machine size low is to rely on **beam-target fusion reaction** (like JET record shots)
- Beams are also employed to drive the plasma current, as there is no space for a large central solenoid
- **$\beta_N$ < 3.5 %Tm/MA; Max. Field on TF < 14.7 T (i.e. LTS conductor); $q_{95}$ > 3; P_el_NBI < 150 MW**
  **→ R ≤ 3 m and $P_{fus}$ < 50 MW (also for T consumption)**

**The neutron rate is (at zeroth order) independent on the plasma density!**
However, it goes like $T_e^{3/2}$. Additional EC/IC electron heating is foreseen.

$$P_{fus} \propto n_e \frac{P_{beam}}{E_{beam}} \cdot \tau_s \qquad \tau_s \propto \frac{T_e^{3/2}}{Z_b^2 n_e}$$

$$\beta_N \propto \frac{P_{beam}}{R^3} A^3 \frac{q}{B^2 n_e} \frac{T_e^{3/2}}{Z_b^2} \qquad NWL \propto \frac{A}{R^2} \frac{P_{beam}}{E_{beam}} \frac{T_e^{3/2}}{Z_b^2}$$

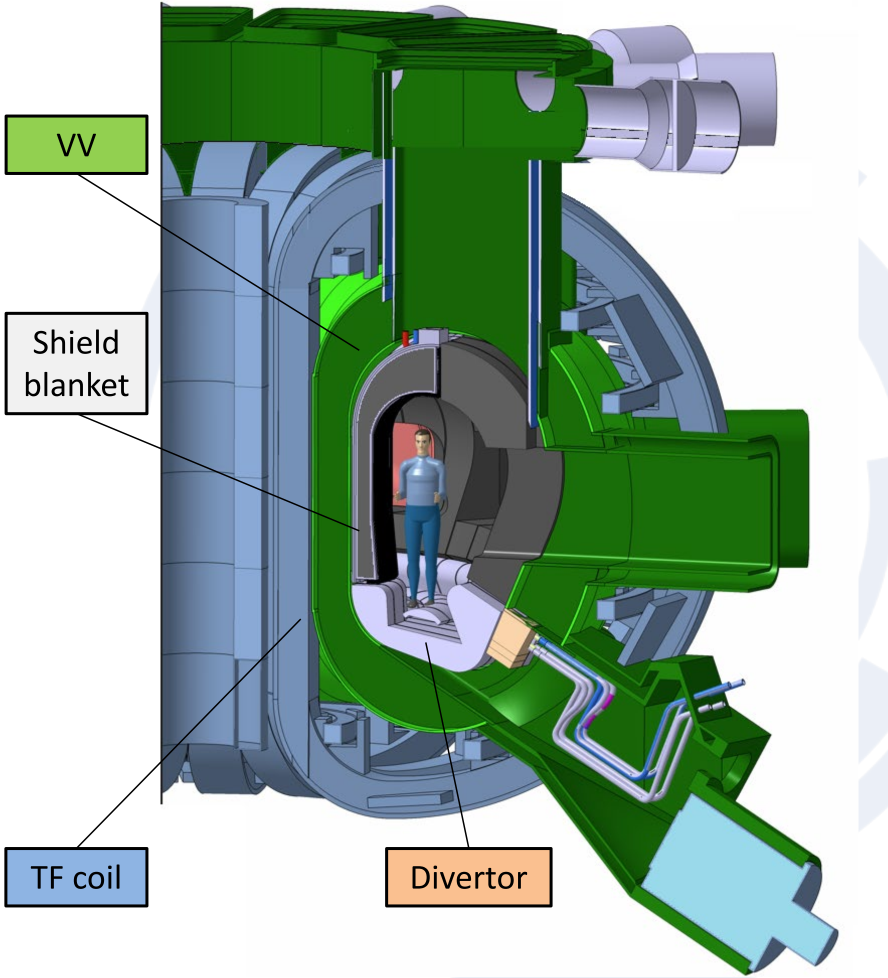



$NWL \propto 1/R^2$ $NWL \propto R$

**Competition between performance (NWL) and stability ($\beta_N$)**
**Knobs:** Aspect Ratio A and Magnetic Field Strength B

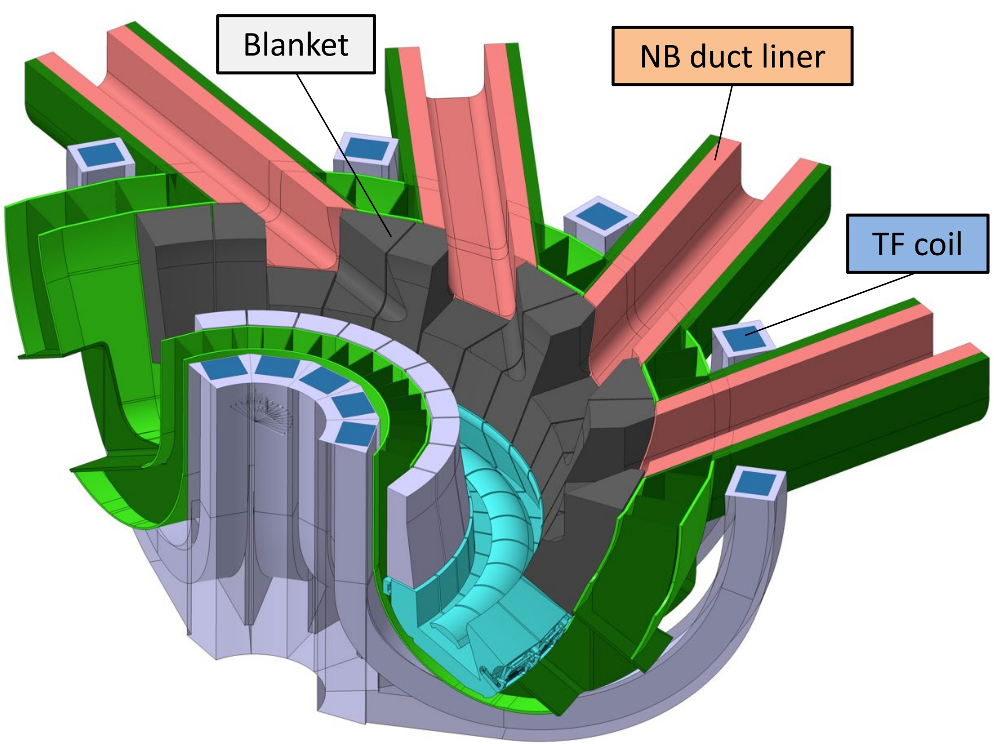
# The smallest VNS we could find:

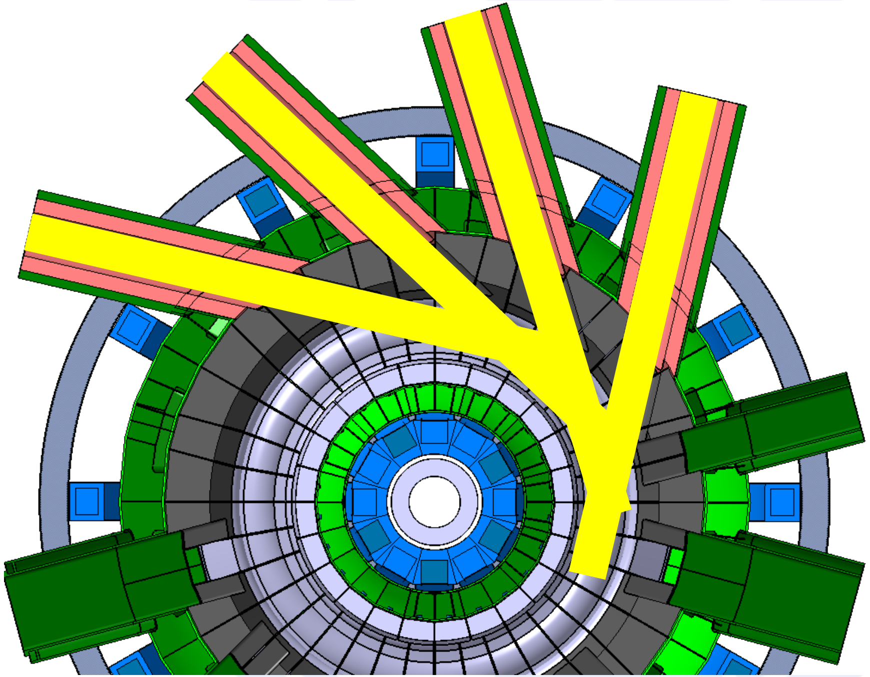
| R = 2.53m, $B_0$ = 5.4 T | |
|---|---|
| **A=4.6** | High aspect ratio to create space on the inboard side while minimising the surface |
| **CS** | $Nb_3Sn$, sized to ramp up the plasma, $I_p$ = 1.76 MA |
| **TF coil** | $Nb_3Sn$, $B_{max}$ =12.8 T – trading-off B with TFC size |
| **n-shield (inboard)** | Comparable to ITER |
| **$P_{fus}$** | 29 MW |



# NB configuration, 3 · 14 MW, 120 keV

12 TF coils allow the integration of an ITER-like NB duct in-between TF coils.



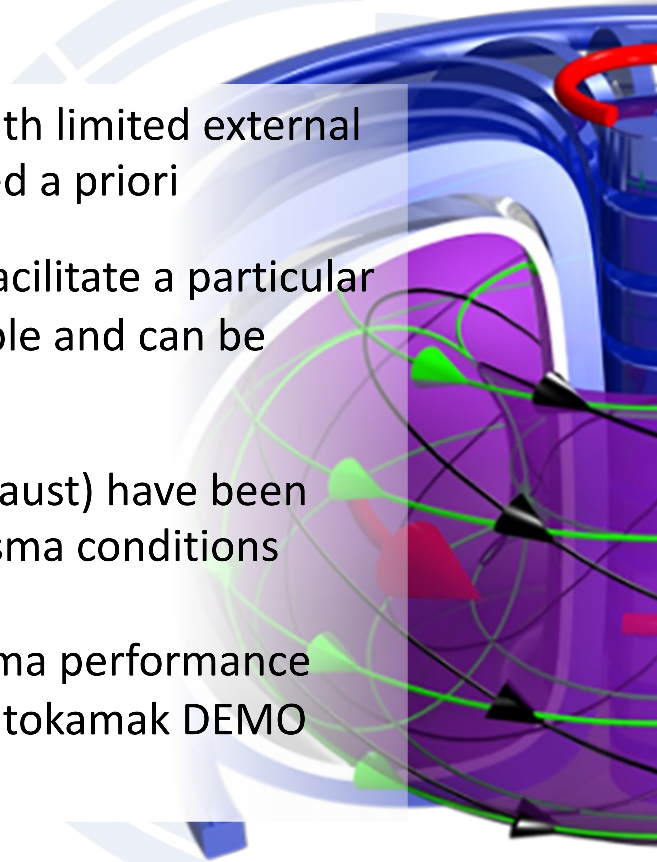
# Integrated plasma scenarios

Magnetized plasmas are complex self-organized systems, with limited external control, whose parameters and profiles cannot be prescribed a priori

It is only possible to prepare experimental conditions that facilitate a particular scenario, i.e., a set of properties that are mutually compatible and can be reproducibly maintained for long enough using actuators

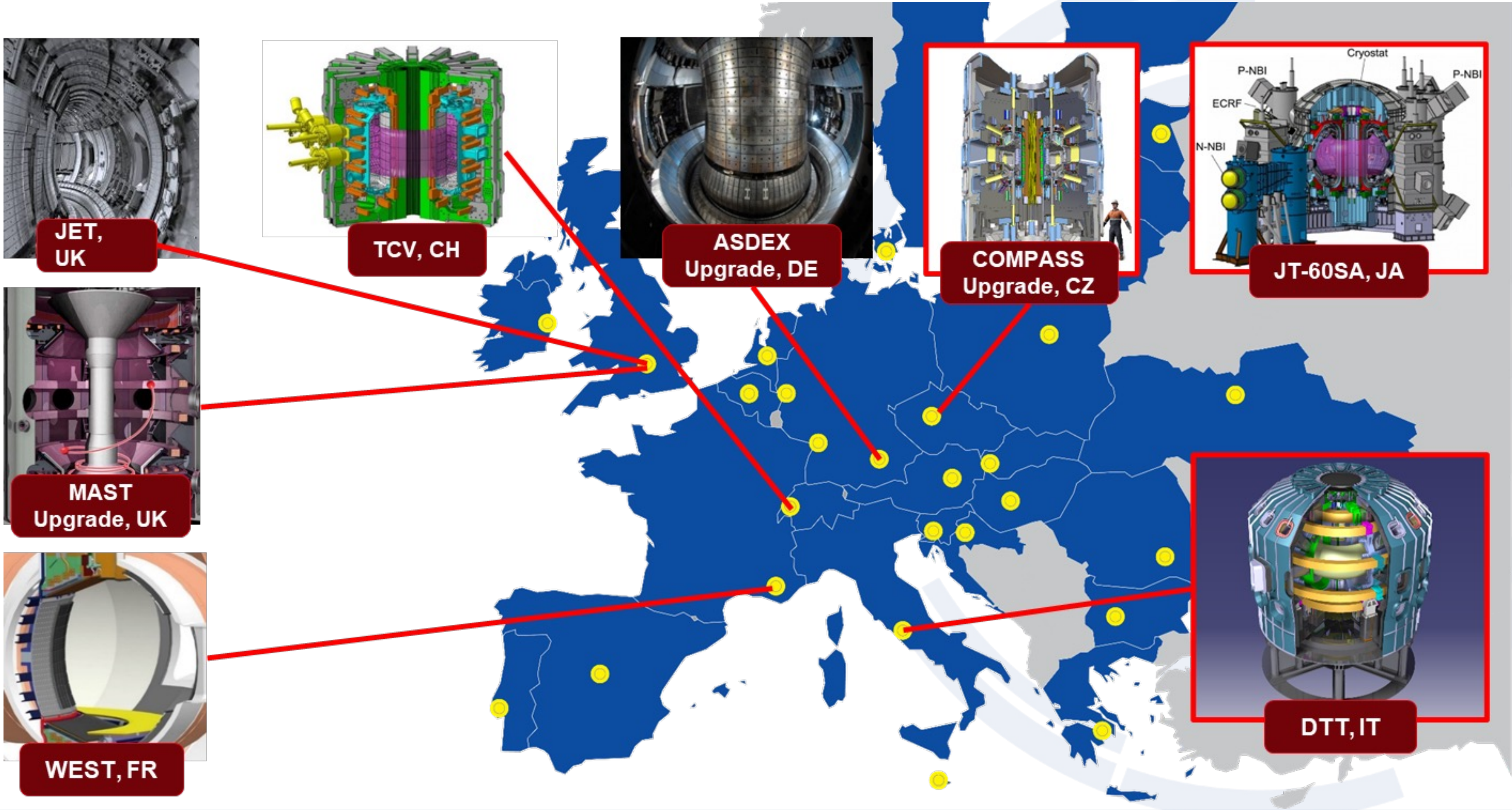
Attractive solutions for individual elements (core, edge, exhaust) have been found, but integration remains a challenge since DEMO plasma conditions cannot be met simultaneously in present devices

- Exhaust solutions can strongly affect the overall plasma performance
- Disruptions are a severe threat to attractiveness of a tokamak DEMO and affect its availability



Source: IPP

# Joint operation of tokamaks in support of ITER and DEMO



# Joint progress on plasma control at EU devices

Tokamak plasma control through deep reinforcement learning

[Degrave Nature 602, 414 (2022)]

Supervisory control & dynamic pulse scheduling

[Vu IEEE TNS 2021]

State observer implementations using RAPTOR / RAPDENS on ASDEX-Upgrade and TCV

[Bosman F.E.Des. 2021, Blanken F.E.Des. 2019, Felici IAEA 2016]

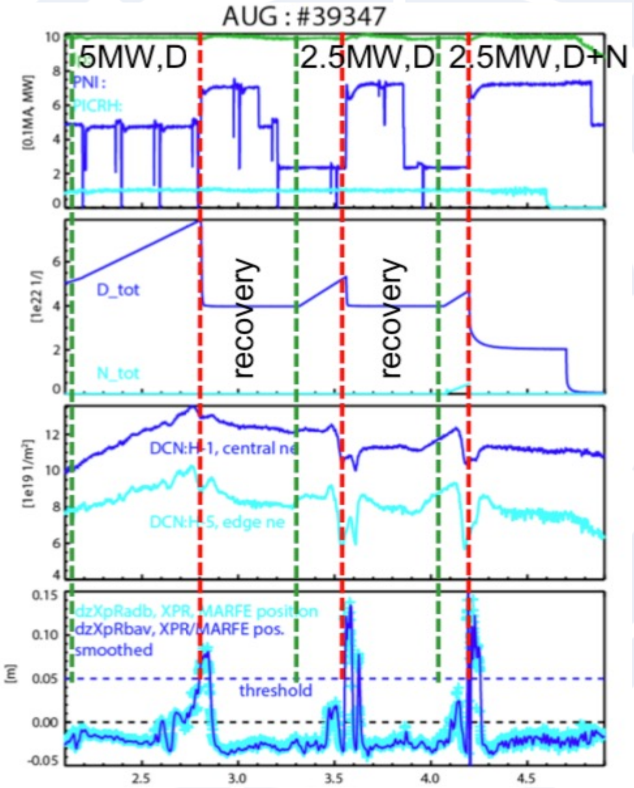
Real-time disruption proximity monitoring and control to avoid high-density H-mode limit

[Pau EPS 2022]

'Virtual actuators' and optimization methods

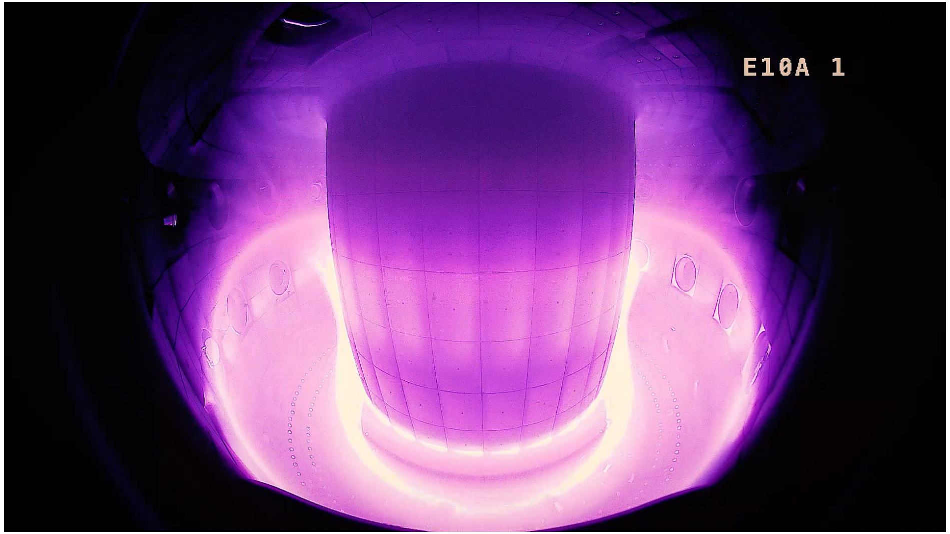
[Kudlacek Fus. Eng. Des 146 (2019), Maljaars Fus. Eng. Des 122, 2017]

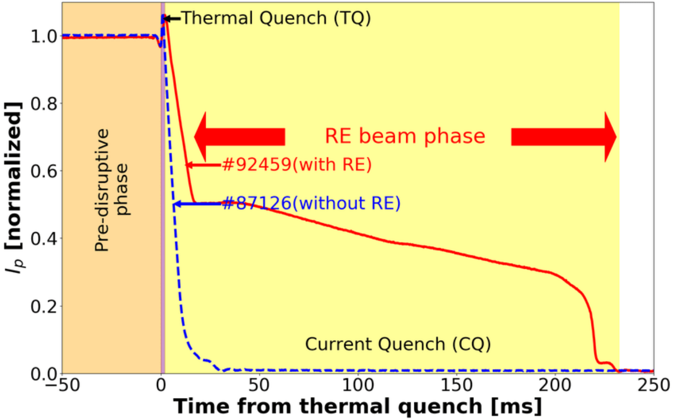
**Ex: recovery of discharge in ASDEX-Upgrade based on MARFE position monitoring, acting on gas & NBI**



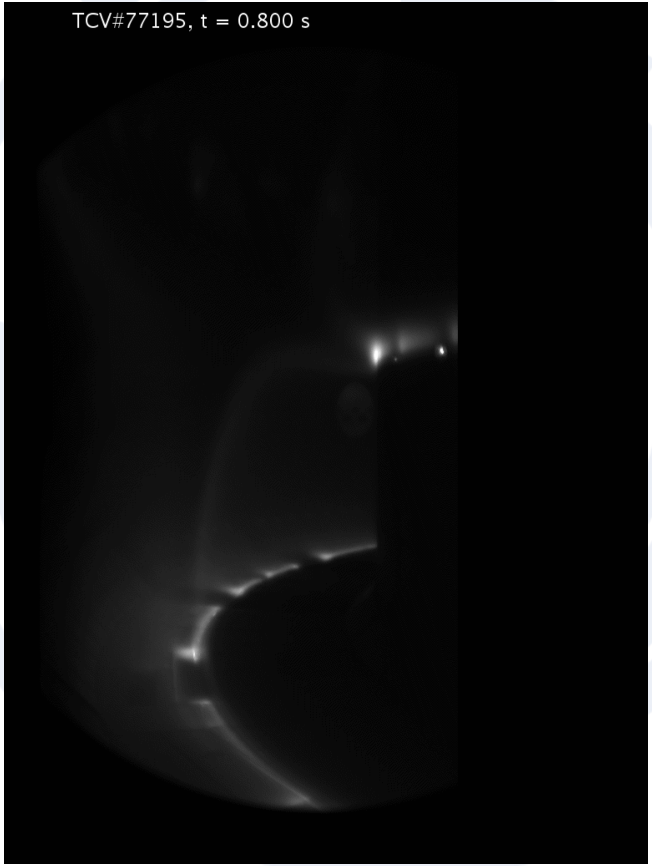

[B. Sieglin, M. Maraschek, M. Bernert - ASDEX Upgrade]

# Disruptions and runaway electrons




TCV



# Benign termination of runaway electron beam

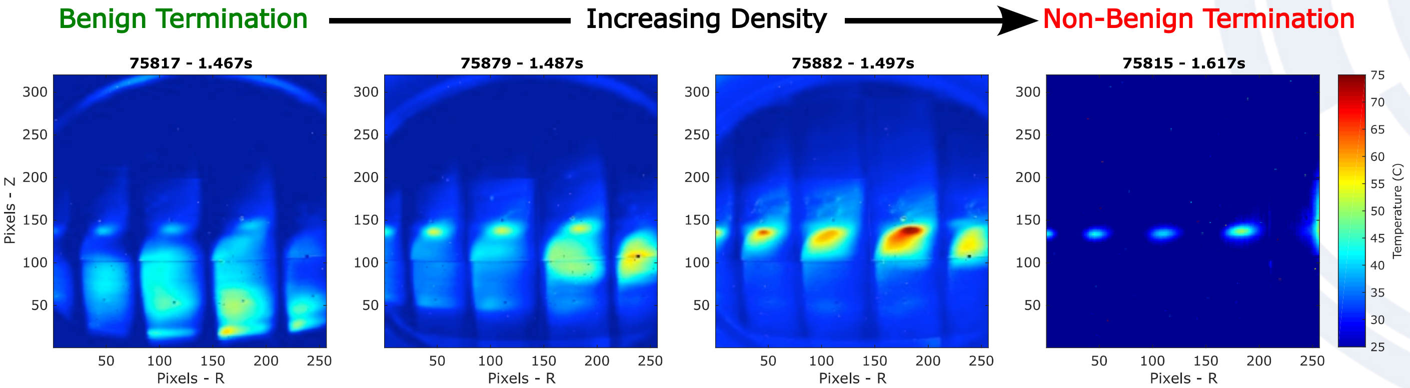
TCV disruption and runaway electron studies enabled by EUROfusion

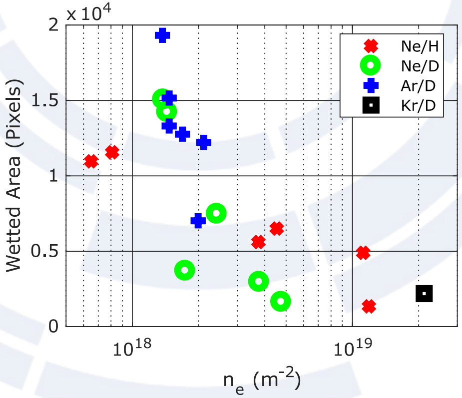
Gas injection to maximize power spread on wall

Increased wetted area and conversion of magnetic energy to radiation prevents localized heat flux from runaway electrons

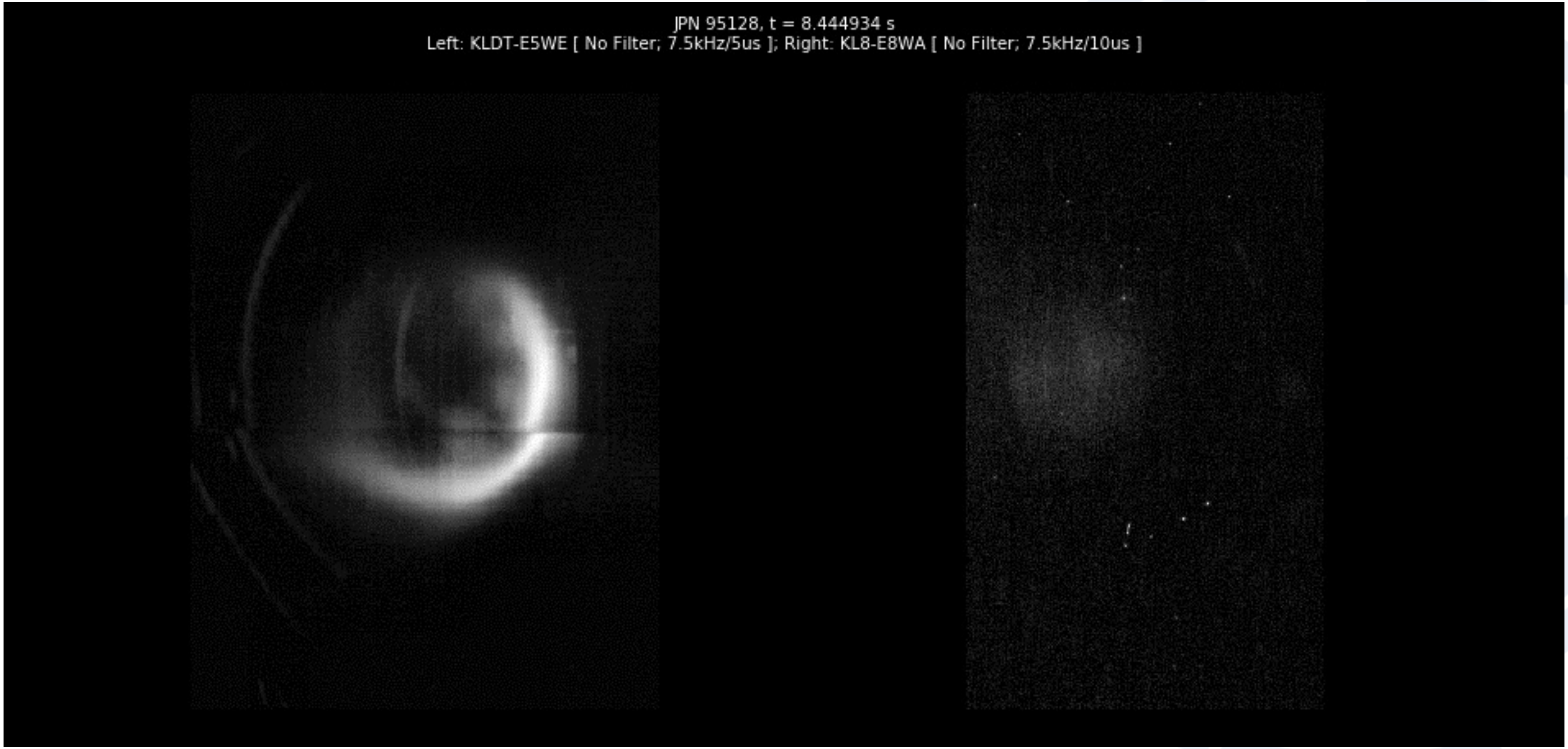
Models developed using multimachine database to extrapolate to ITER

*Courtesy of U.Sheik*

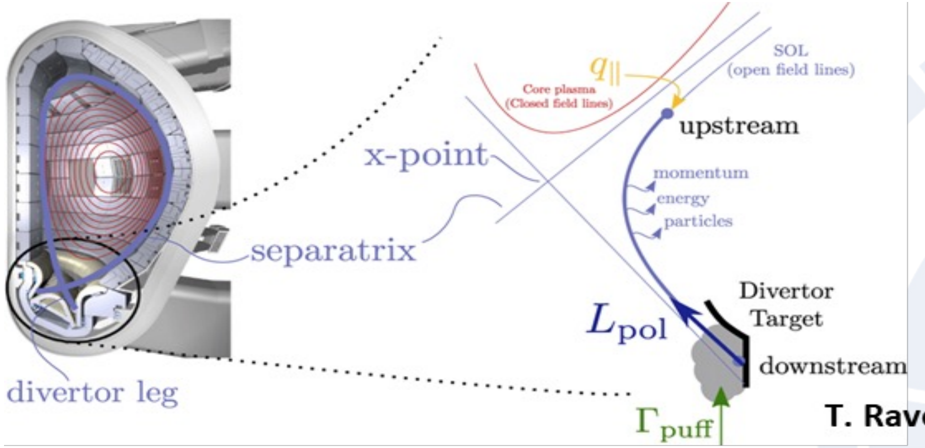


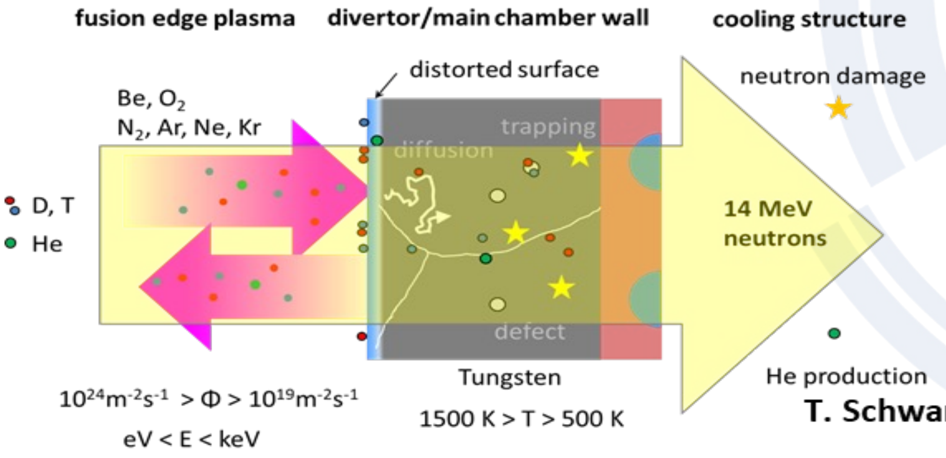
# Shattered Pellet Injector at JET/ASDEX-Upgrade to confirm ITER design



# Power and plasma exhaust

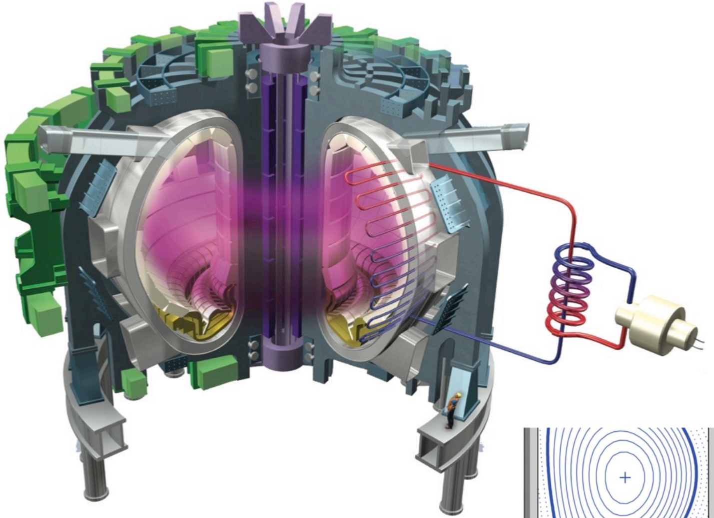



T. Ravensbergen

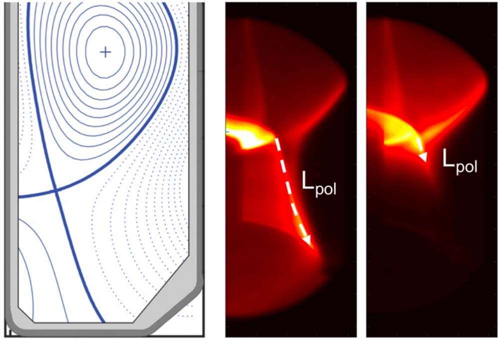



T. Schwarz-Selinger

# Power and plasma exhaust



$10 MW/m^2$

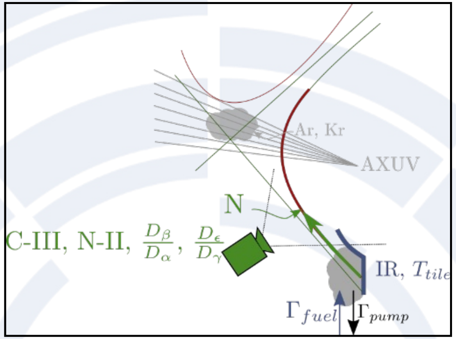


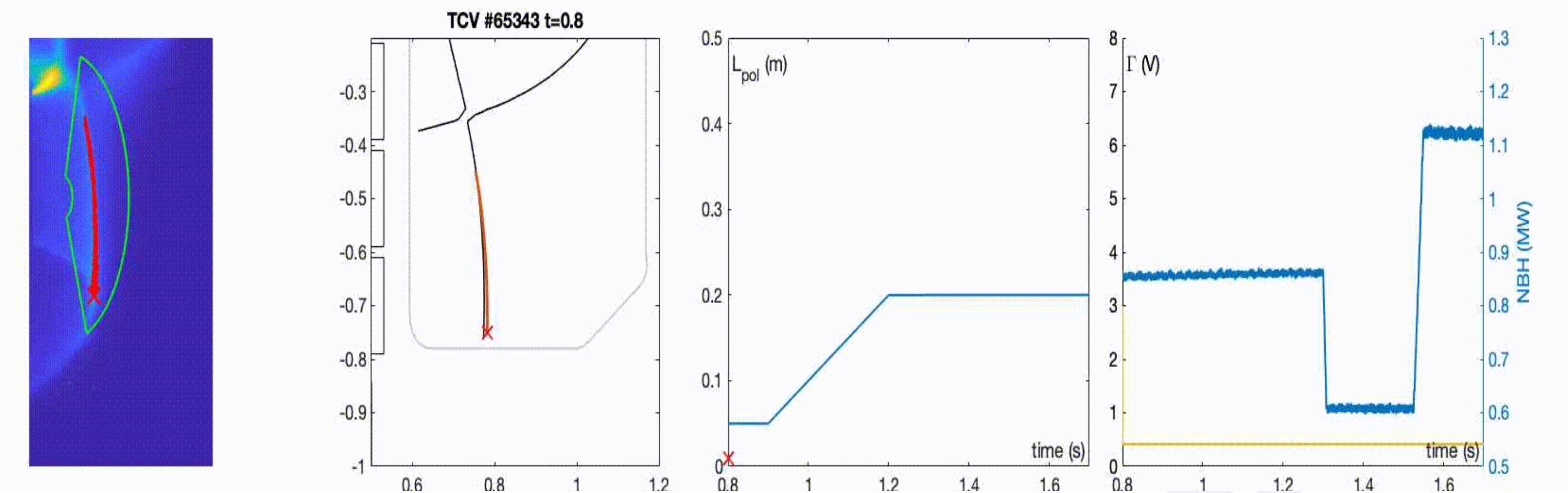

$\sim 1 MW/m^2$

# Divertor detachment control

System identification applied to characterize dynamic behaviour on ASDEX-Upgrade, TCV, JET, MAST-U

Ex. real-time control of the C-III emission front in TCV based on MANTIS 10-channel, 400Hz camera




DIFFER

W.A.J. Vijvers *et al* 2017 *JINST* **12** C12058
A. Perek *et al.* Rev. Sci. Instrum. **90** (12) 2019

# Quasi-Continuous Exhaust regime

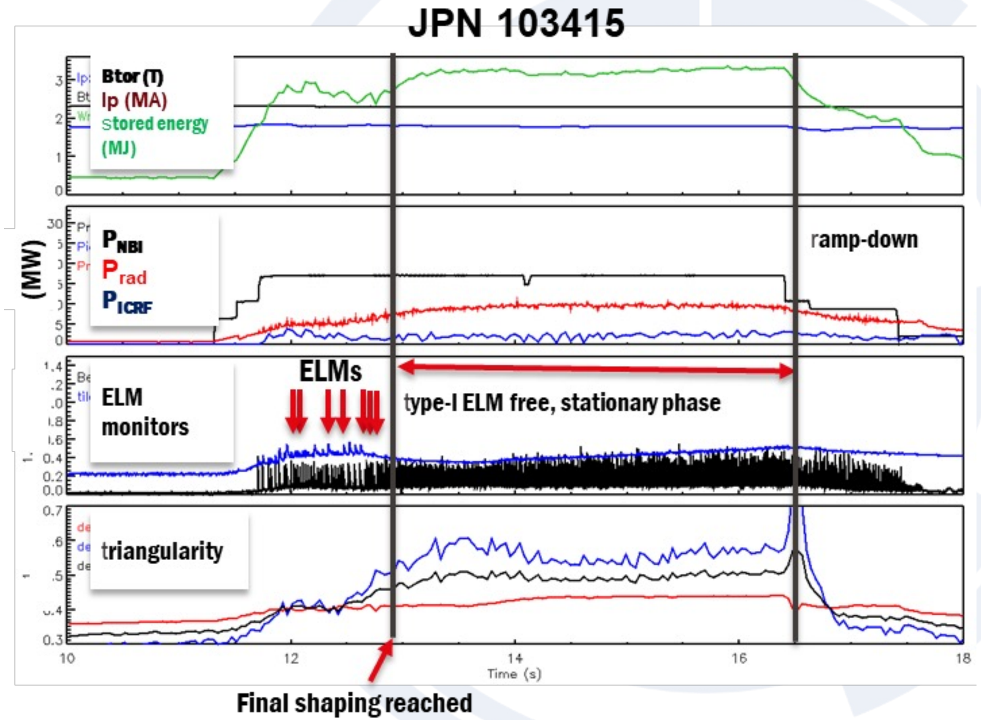
QCE regime obtained on JET building on expts in ASDEX-Upgrade and TCV

Main features

- no type-I ELMs
- high line-averaged and SOL density
- only modest decrease of confinement compared to type-I ELMy data base

Key access parameters

- shaped plasma cross-section (κ, δ, closeness to double null)
- high pressure in the vicinity of the separatrix through strong gas puffing



# X-Point Radiator control

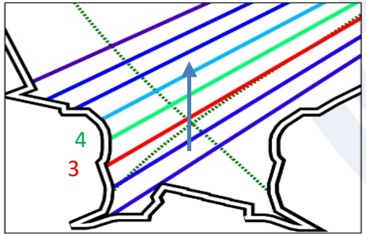
## X-Point Radiator has promising features

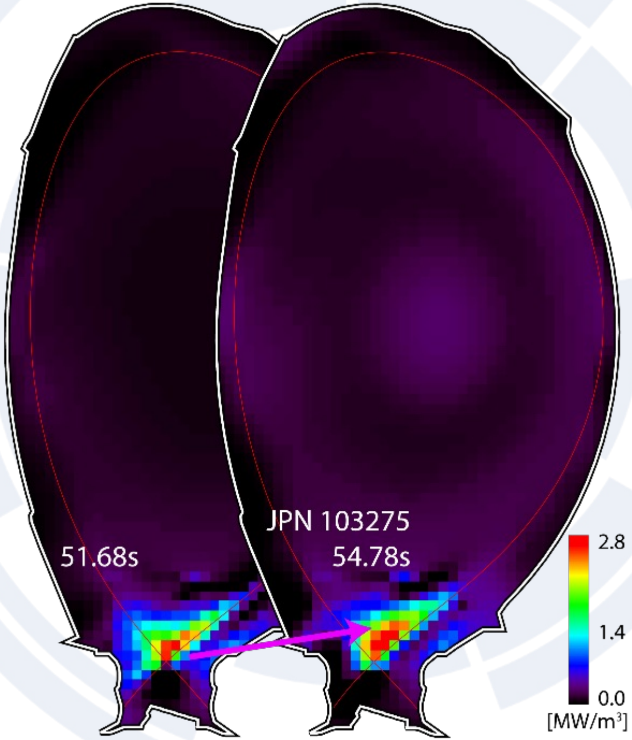
- Full detachment
- Maximum power dissipation
- Controllable

## Observed at ASDEX-Upgrade, TCV, WEST & JET – inter-machine comparisons essential for predictions

## On JET

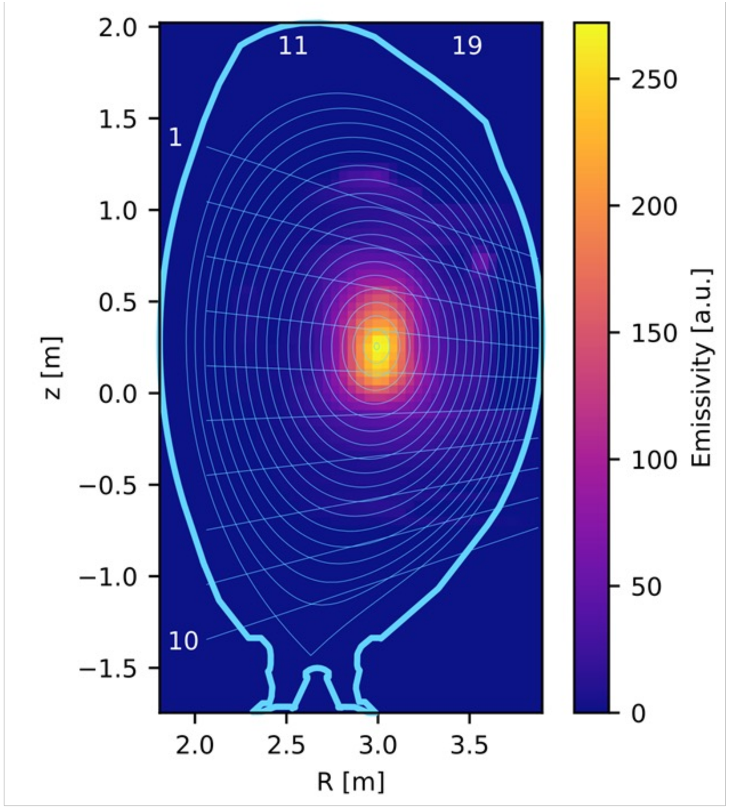
- Created with $N_2$, Ne and Ar seeding
- Movement tracked with bolometry
- XPR location controlled within 4mm
- ELMs diminish
- First control of full detachment




[RT22-05: M.Bernert, D.Brida, H.Reimerdes, N.Fedorczak + RT22-04: B. Sieglin, P.Fox, T.Bosman, M.Lennholm]

# Fast-ion physics studies




***JET:*** Spatial profile of the *E*γ = 16.4 MeV emission from the D+3He → γ+5Li reaction in the poloidal plane obtained by a tomographic inversion.
**Confined Alphas!** **E. Panontin**

Direct observation of confined fusion-generated $\alpha$ particles in JET

# Fast-ion physics studies

Heating scenarios with MeV ions at JET

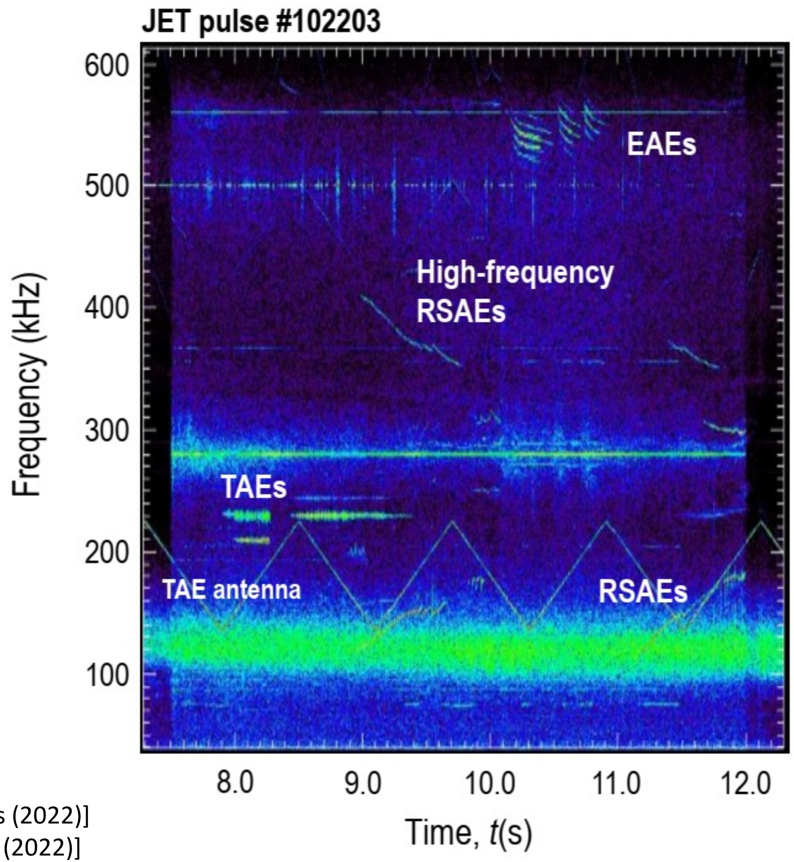
Dominant electron heating as in ITER

Access to high $T_i$

Destabilization of Alfvén Eigenmodes, which do not appear to be detrimental

Stabilizing impact on microturbulence

Non-linear interplay between fast ions, ITG and Alfvén Eigenmodes




[Y. Kazakov et al., Phys. Plasmas (2022)]
[S. Mazzi et al., *Nature Physics* (2022)]

EUROfusion

UK Atomic Energy Authority

# A New Fusion Energy Record

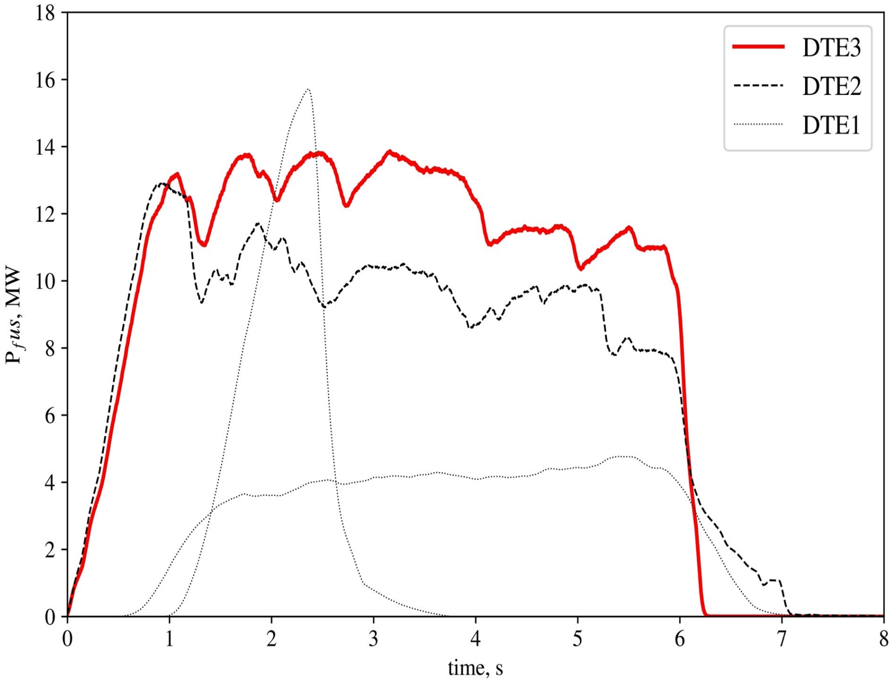
| | |
|---|---|
| **Pulse** | #104522 |
| **Date** | 3 October 2023, 19:14 GMT |
| **D-T fuel** | 0.2 milligrams |
| **Fusion energy** | 69 megajoules |

# High fusion energy repeatably achieved at JET in DTE2 and DTE3

High fusion power produced and sustained for 5 seconds

- First ever high confinement plasmas using D-T with Beryllium/Tungsten ITER-like interior wall

- Confirming predictions of plasma behaviour advances development of ITER high performance scenarios



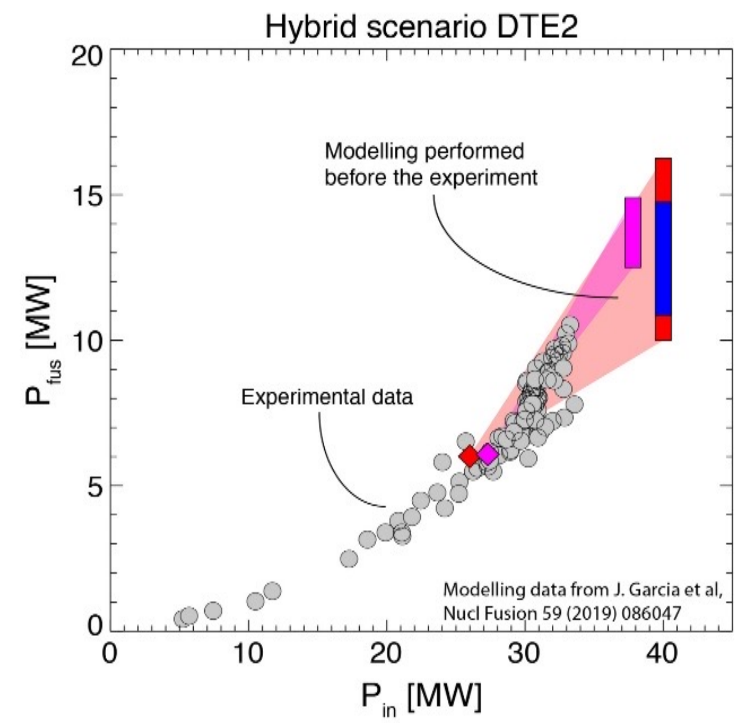
# D-T results confirm modelling predictions

D-T fusion power matches predictions

New JET data are crucial to predict fusion in ITER and future machines

Wealth of new JET data in many areas to validation the models and extrapolate to ITER and beyond

*Much more to come in future conferences and journal papers…*



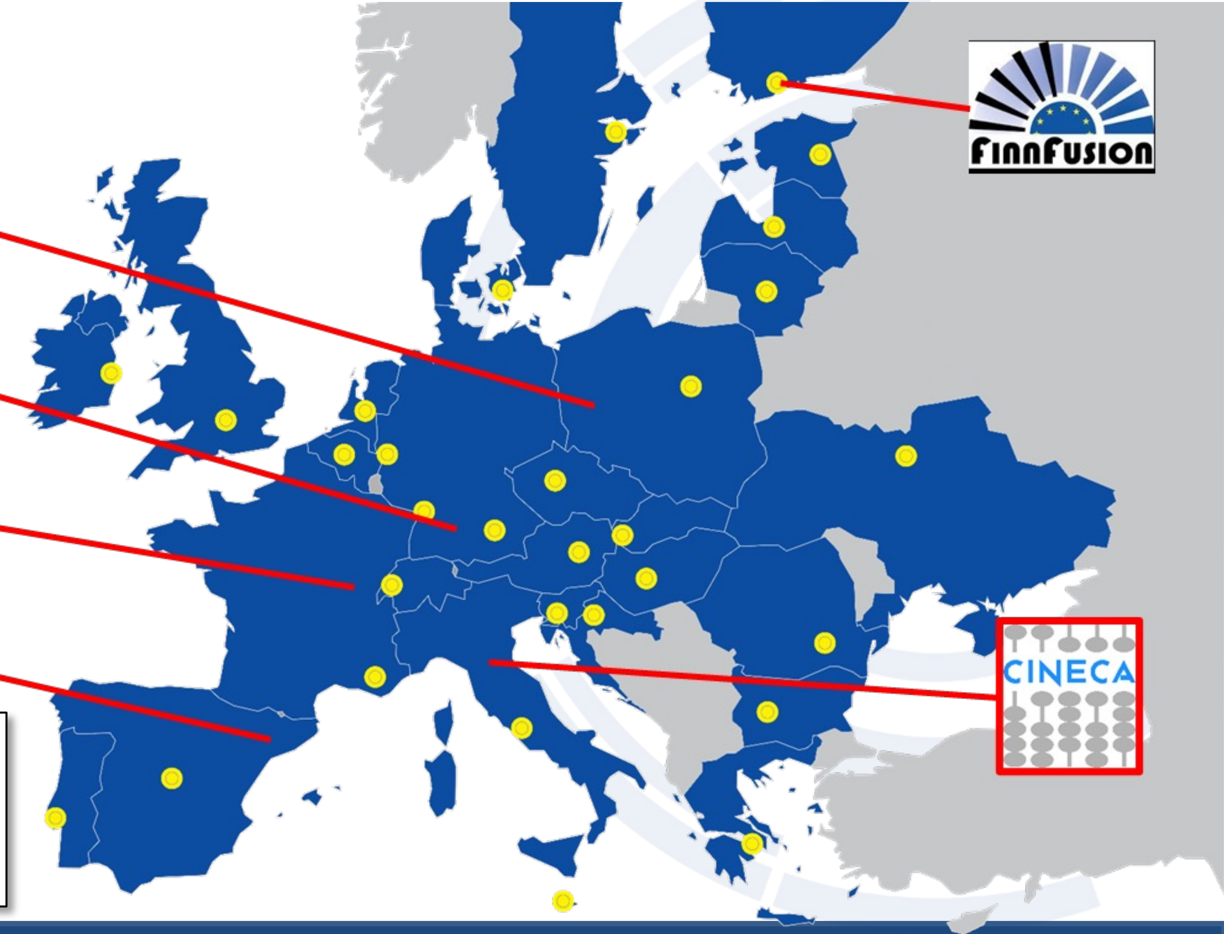
# EUROfusion has integrated theory & simulation activities

PSNC
Poznan Supercomputing and Networking Center

IPP Max Planck Institute for Plasma Physics

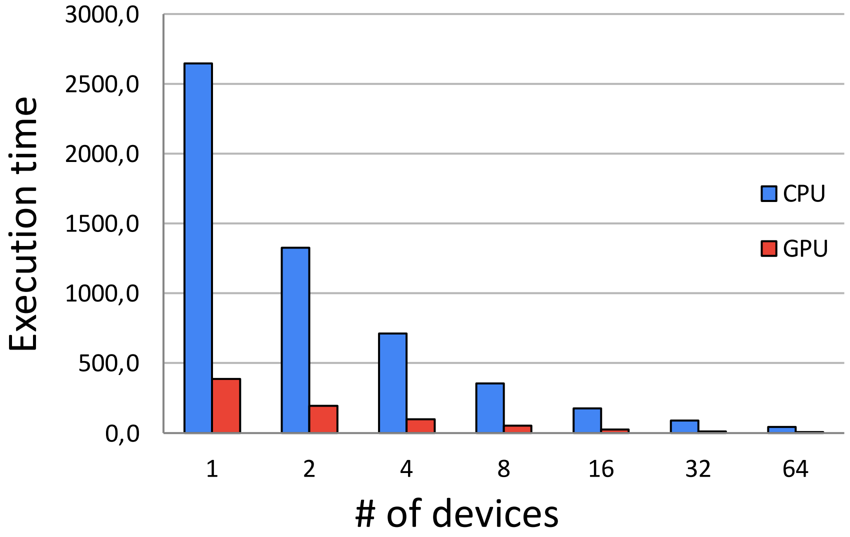
EPFL SWISS PLASMA CENTER

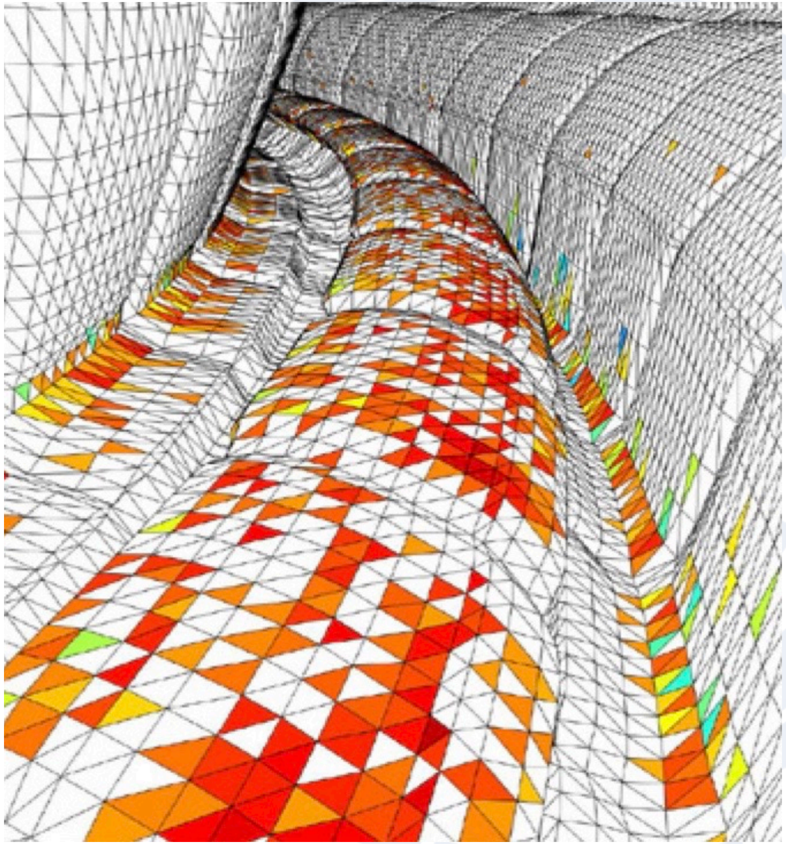
BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación




- 5 Advanced Computing Hubs
- Marconi-Fusion High-Performance Computer

# Example: porting of ASCOT5 to advanced HPC architecture



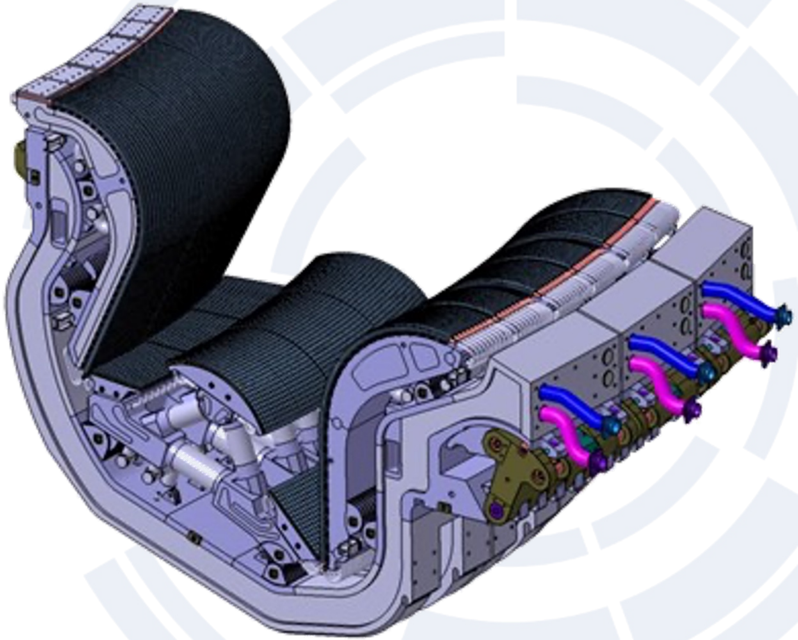



# Divertor performance, power exhaust & extraction

Solutions need to be found in which most power is radiated before it reaches the walls to reduce the thermal load to plasma facing components

Advanced divertor configurations and materials must be assessed to ensure optimal PFC cooling, thermal mechanical integrity and sufficient shielding to the vessel

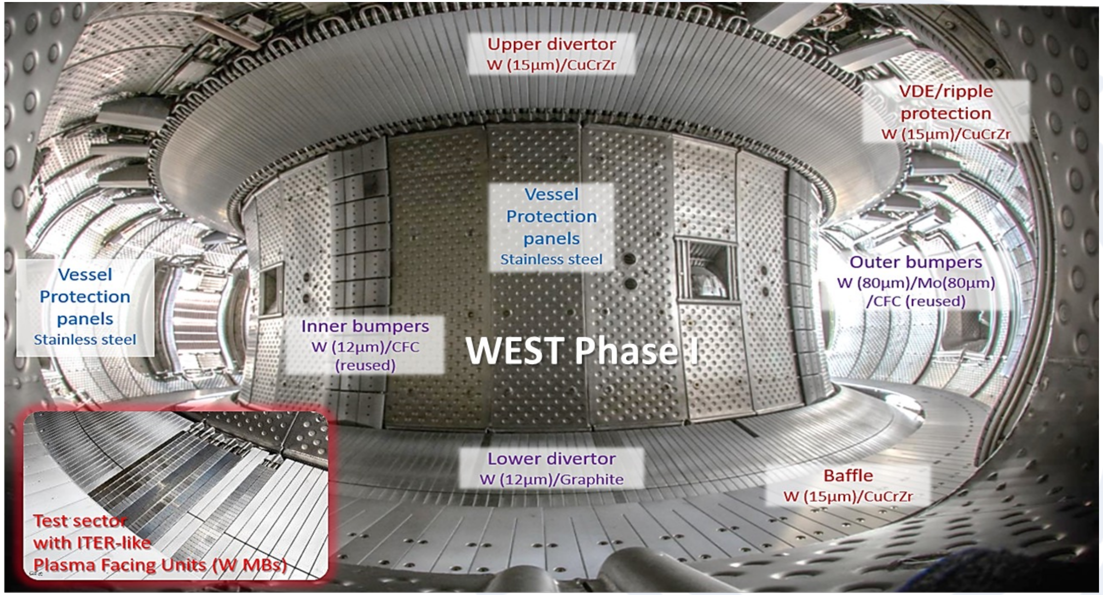
Some alternatives have a large impact on the machine design and remote maintenance



Source: ITER

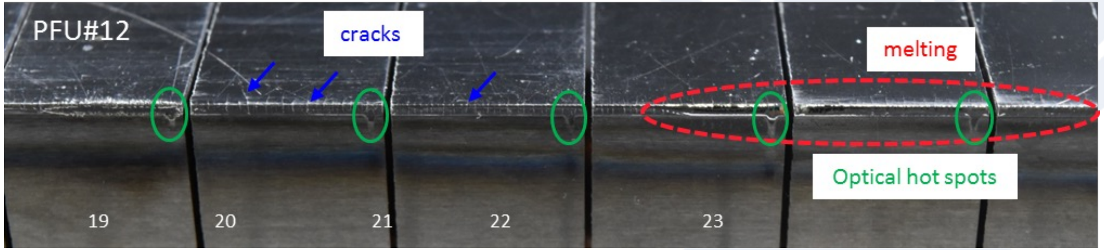
# Test of ITER-like divertor prototypes

WEST first phase of operation with ITER prototypes (W monoblocks on CuCrZr heat sink) in lower divertor




Long pulses up to 1min with upper actively cooled divertor

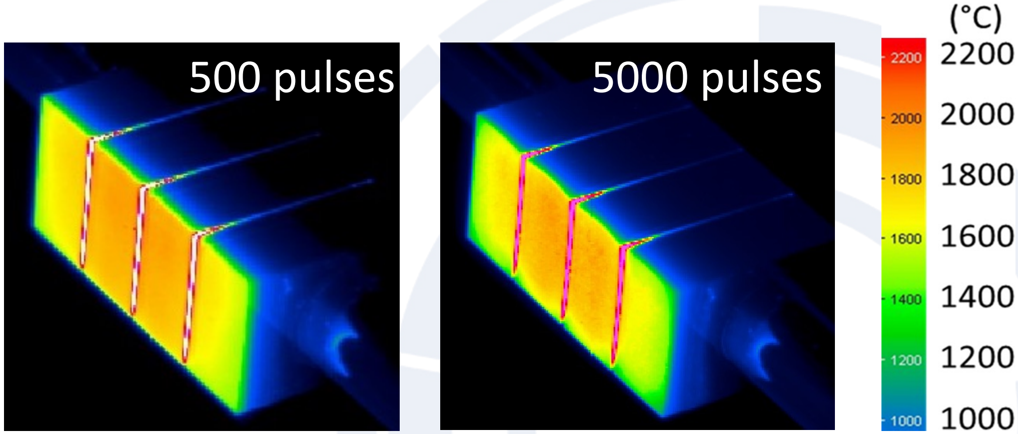
Damages observed on ITER-like plasma facing unit after exposure



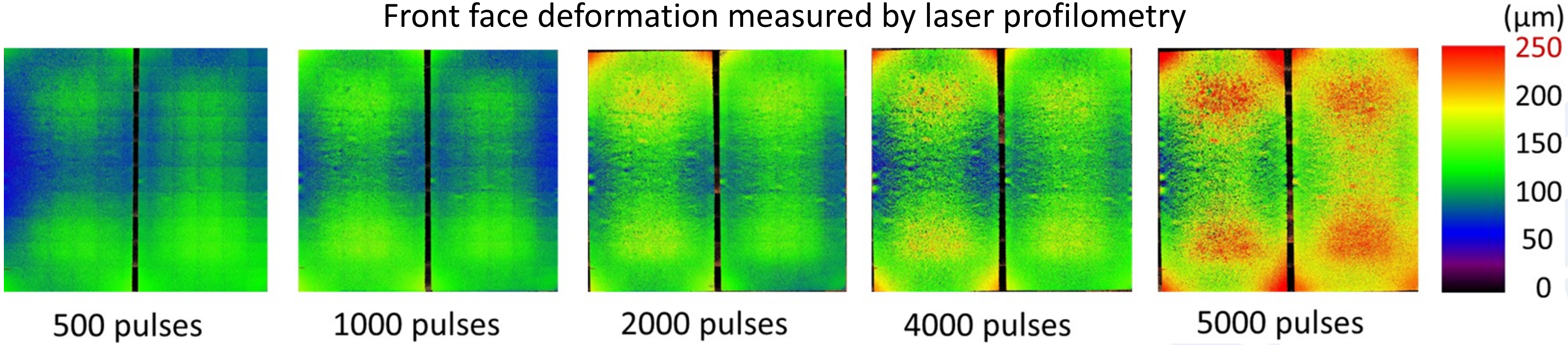
# Divertor performance – ex. of recent progress

High-heat-flux tests to simulate divertor strike-point sweeping on GLADIS (IPP Garching)

40MW/m², 5000 loading cycles (pulse: 0.4s, frequency: 0.63Hz, coolant: 20°C)




Front face deformation measured by laser profilometry

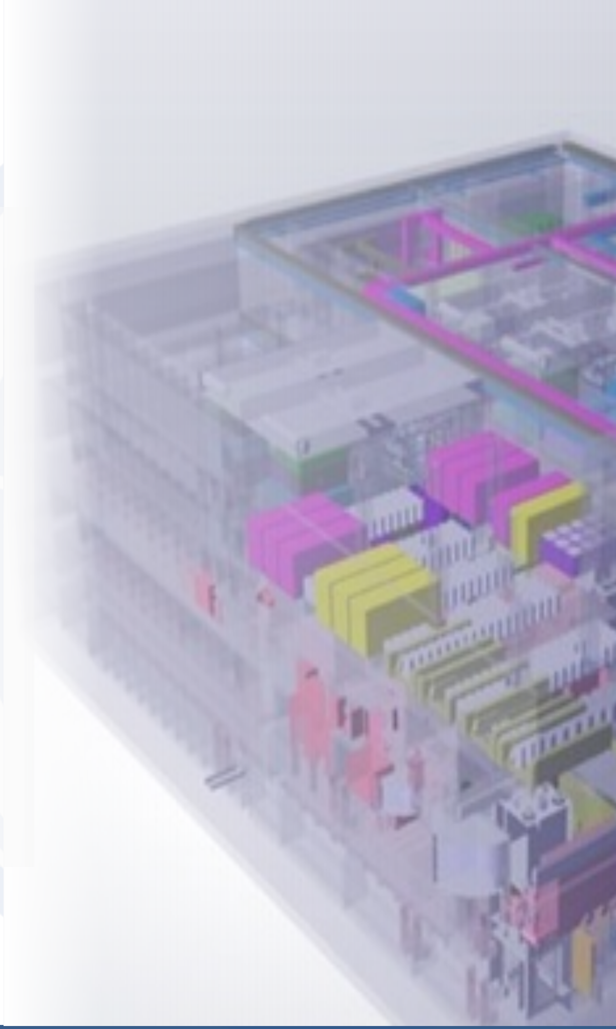



J.H. You et al. Nucl. Mater. Ener. 33 (2022)

# Safety and waste

A few R&D elements remain open

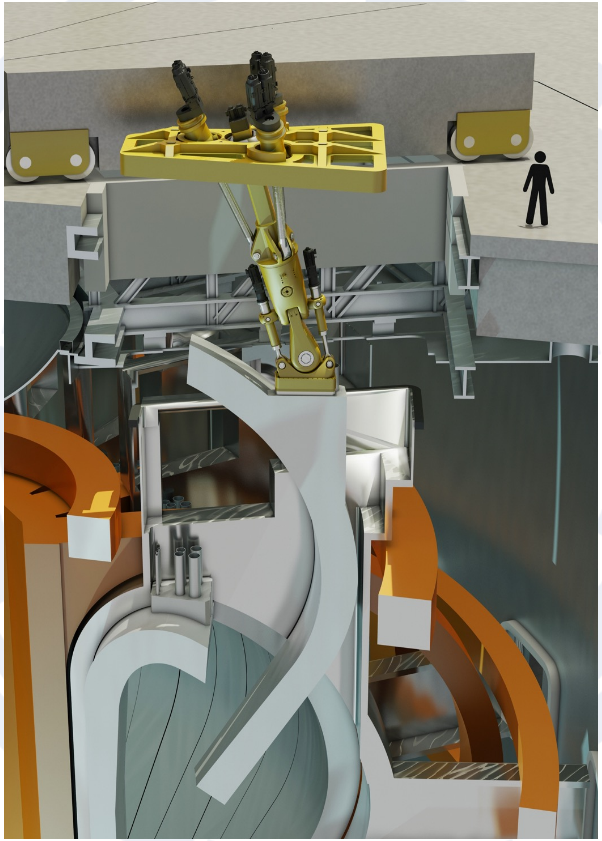
- More accurate quantification of key radiological source terms
- Assess after how long waste arising from operation can meet Low-Level Waste criteria
- Understand whether any Intermediate-Level Waste can be managed in near-surface disposal facilities using techniques for detritiation and decarburization, and/or barriers developed to assure removal or containment of long-lived activation products



# Remote maintenance

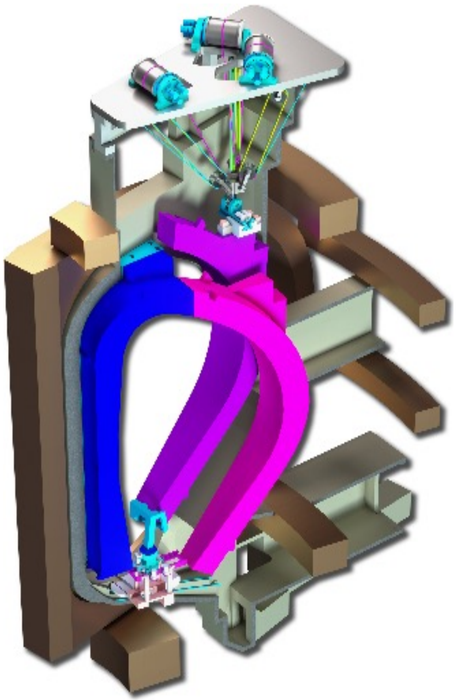
Remote maintenance system and related strategy must be developed to

- Assure removal of components also in case of damage
- Minimize the time duration of maintenance
- Guarantee compliance with safety requirements (e.g. T containment)



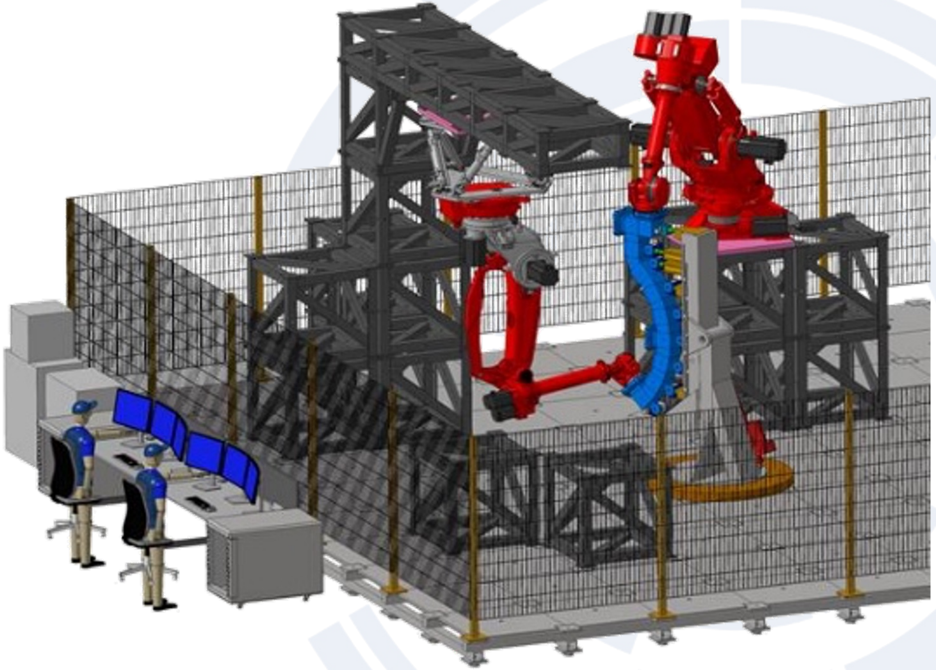
Source: RACE

# Remote maintenance: examples of recent progress



**Blanket Handling**

Development of the Two Port, High Payload, Precision Mover and co-operative handling control (UKAEA RACE, EK-CER, VTT, ENEA)



**Remote Maintenance Test Facility**

Concept design to test performance of RH equipment, control algorithms and sensor technology for precision handling of large flexible loads (UKAEA)

# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

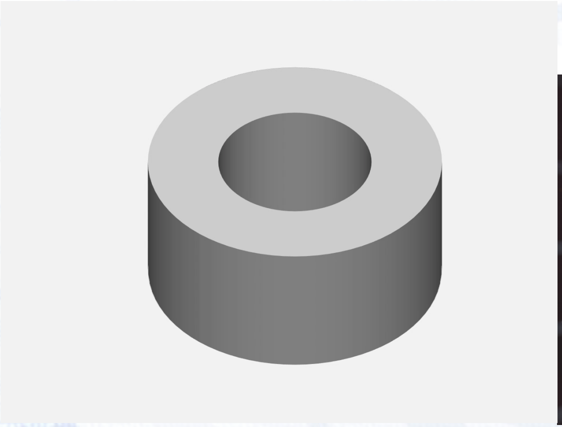
Strong synergy with new ITER Baseline (W-related work), exploitation of JT60-SA

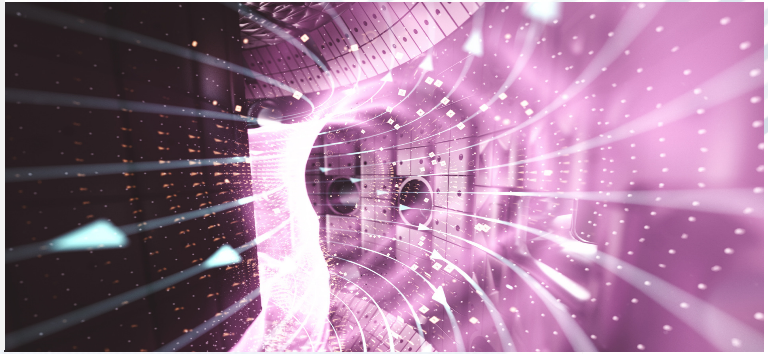
# Measures to accelerate the DEMO program

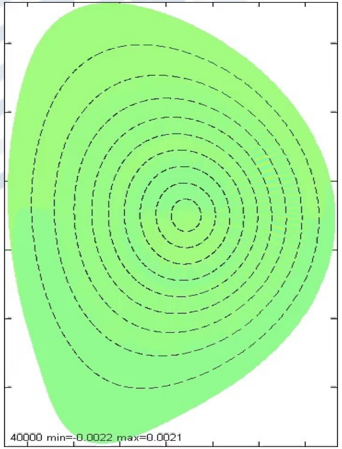
Strengthening R&D in the identified gap areas

Increased effort in simulations for plasma and for engineering

Digitalization effort, including innovative AI approaches







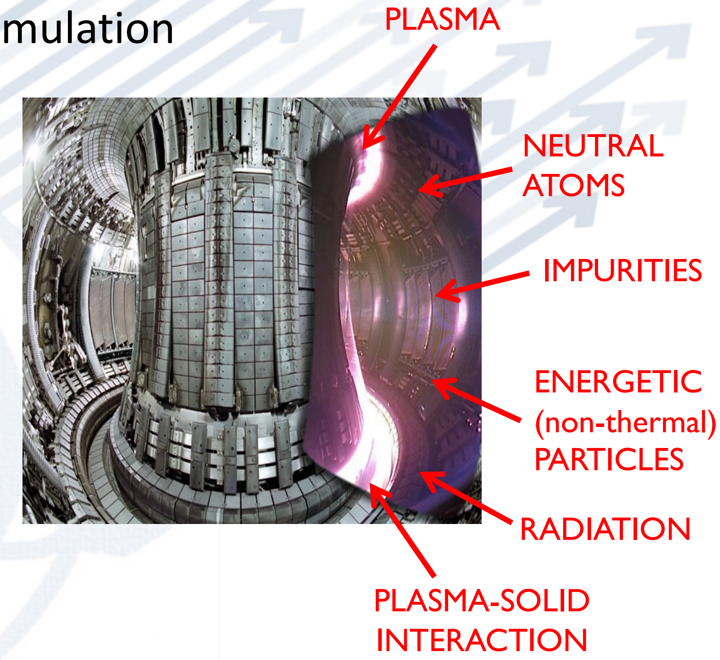
# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

## Increased effort in simulations for plasma and for engineering

Examples of challenges in theory & simulation

- Multiscale
- Multiphysics
- Intrinsic nonlinearity
- Turbulent dynamics
- Extreme anisotropy
- Complex geometry



# Measures to accelerate the DEMO program

- Strengthening R&D in the identified gap areas
- Increased effort in simulations for plasma and for engineering
- Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site
  - Crucial for timing – working group has defined the path

# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

Increased effort in simulations for plasma and for engineering

Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site

Development and maintenance of adequate workforce

- Increase connections with EU academic and industrial networks, and diversity at all levels, try to create a 'post-JET hub'

# Measures to accelerate the DEMO program

- Strengthening R&D in the identified gap areas
- Increased effort in simulations for plasma and for engineering
- Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site
- Development and maintenance of adequate workforce
- Mutually beneficial new international collaborations
  - Collaborations with China (CRAFT, EAST, BEST, …), US (SPARC, …) etc., for technology facilities and early burning plasma developments

# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

Increased effort in simulations for plasma and for engineering

Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site

Development and maintenance of adequate workforce

Mutually beneficial new international collaborations

Knowledge management

- Document lessons learned in the ITER design and developments

# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

Increased effort in simulations for plasma and for engineering

Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site

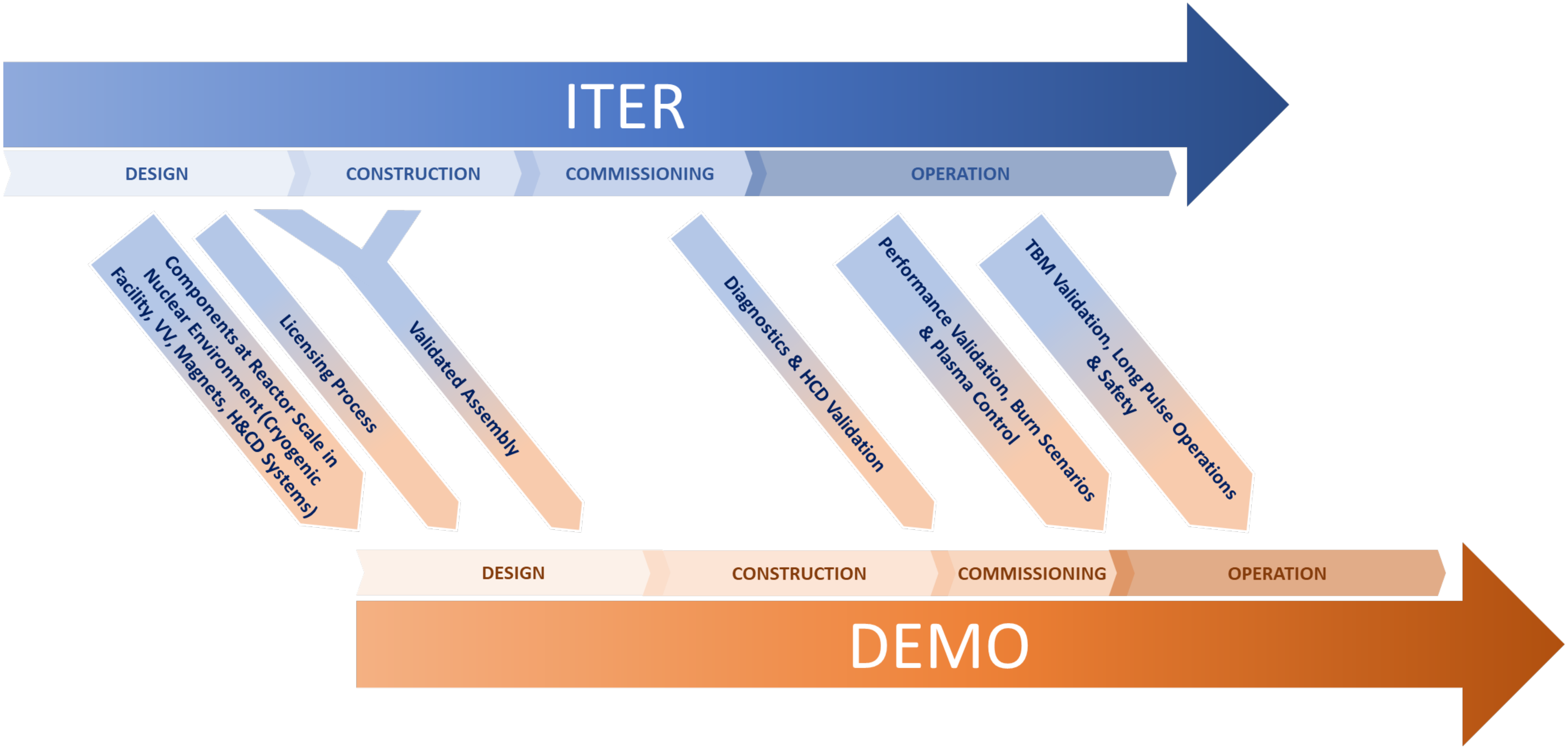
Development and maintenance of adequate workforce

Mutually beneficial new international collaborations

Knowledge management

Parallelization of activities to reduce the sequential coupling of ITER milestones and DEMO decision points

# Parallelization of ITER and DEMO and the role of ITER



# Measures to accelerate the DEMO program

Strengthening R&D in the identified gap areas

Increased effort in simulations for plasma and for engineering

Streamlining licensing towards a regulatory framework for fusion and rapidly identifying site

Development and maintenance of adequate workforce

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Knowledge management

Parallelization of activities to reduce the sequential coupling of ITER milestones and DEMO decision points

Public Private Partnerships and involvement of industry

# Public-Private Partnerships and involvement of industry

DEMO will be built within an industrial framework, utilizing fully industrial practices

Need to combine industrial and entrepreneurial approaches with the extensive know-how, and the ambitious yet realistic vision of public-funded European fusion program

Collaborative approach involving joint leadership, combination of public and private IP, agile procurement processes compatible with EU industry development, and strategic partnerships

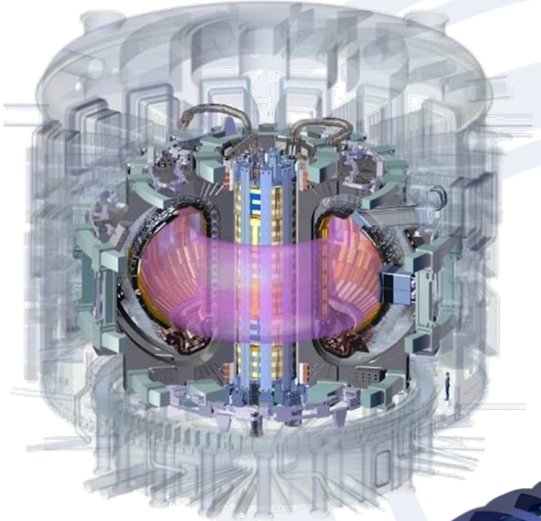
Innovation, industrial view and strategic partnerships are also crucial to address technological gaps prior to DEMO design, and develop capability and capacity in supply chains, especially in areas that are not stimulated by ITER procurement

# Measures to accelerate the FPP program beyond DEMO

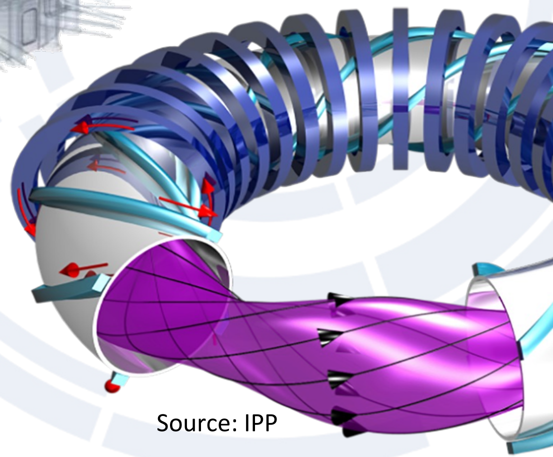
Dedicated test facilities to qualify technologies for FPPs that will be different from DEMO

Investigations to increase attractiveness of FPPs

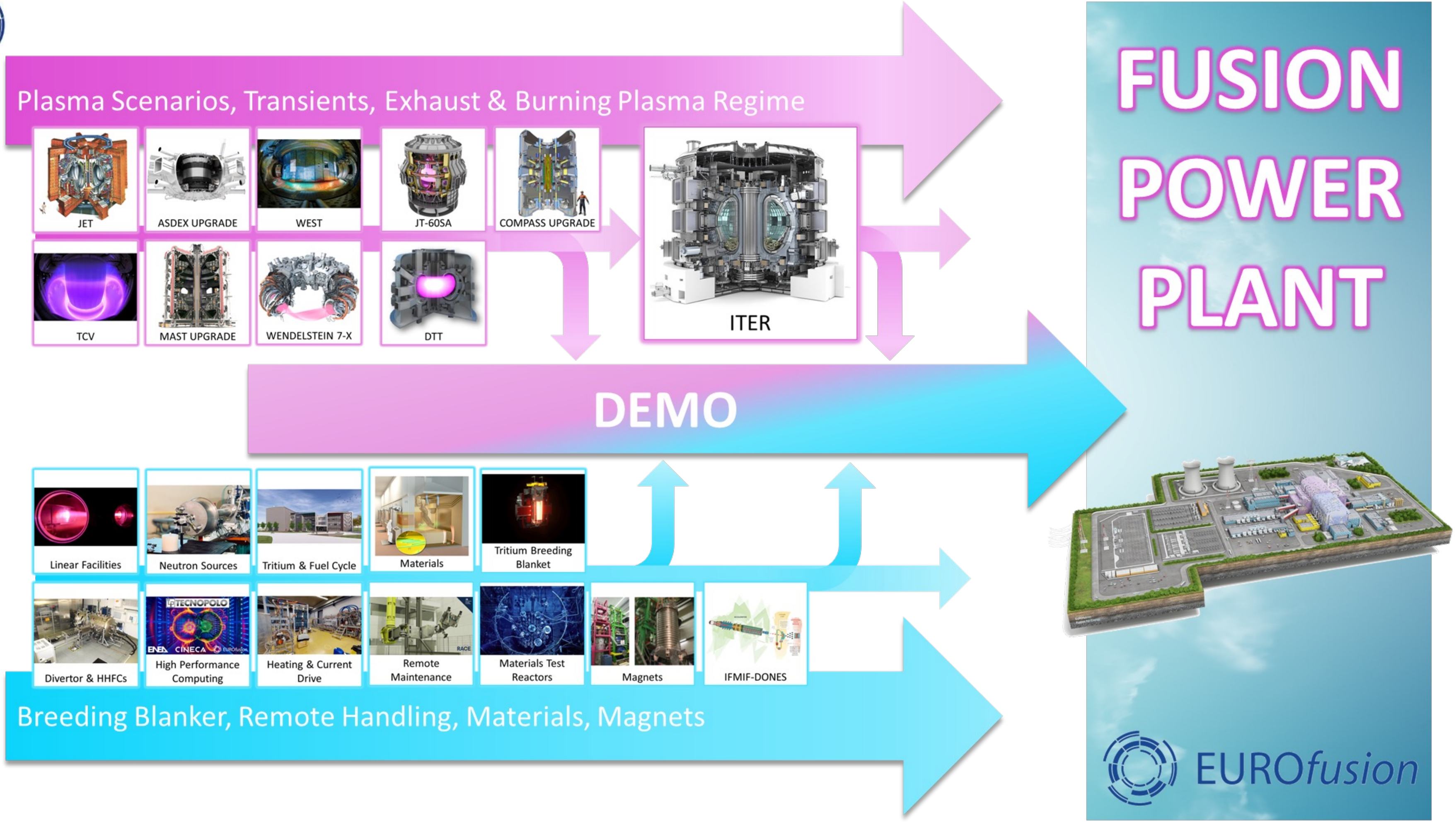
- Stellarator FPP design studies
- HTS magnets
- Advanced structural materials
- Alternatives to water as primary coolant



Source: ITER



Source: IPP



Plasma Scenarios, Transients, Exhaust & Burning Plasma Regime
JET
ASDEX UPGRADE
WEST
JT-60SA
COMPASS UPGRADE
TCV
MAST UPGRADE
WENDELSTEIN 7-X
DTT
ITER
DEMO
Linear Facilities
Neutron Sources
Tritium & Fuel Cycle
Materials
Tritium Breeding Blanket
Divertor & HHFCs
High Performance Computing
Heating & Current Drive
Remote Maintenance
Materials Test Reactors
Magnets
IFMIF-DONES
Breeding Blanker, Remote Handling, Materials, Magnets
FUSION POWER PLANT
EUROfusion

# The Swiss Plasma Center

National laboratory with international facilities in an academic environment

Aims: make ITER a success

develop the science and technology basis of DEMO

prepare the ITER/DEMO generations of scientists and engineers

exploit plasma and fusion spinoffs for industry and society

Size: ~200 staff, ~50 PhDs, ~35MCHF/y (>65% external)

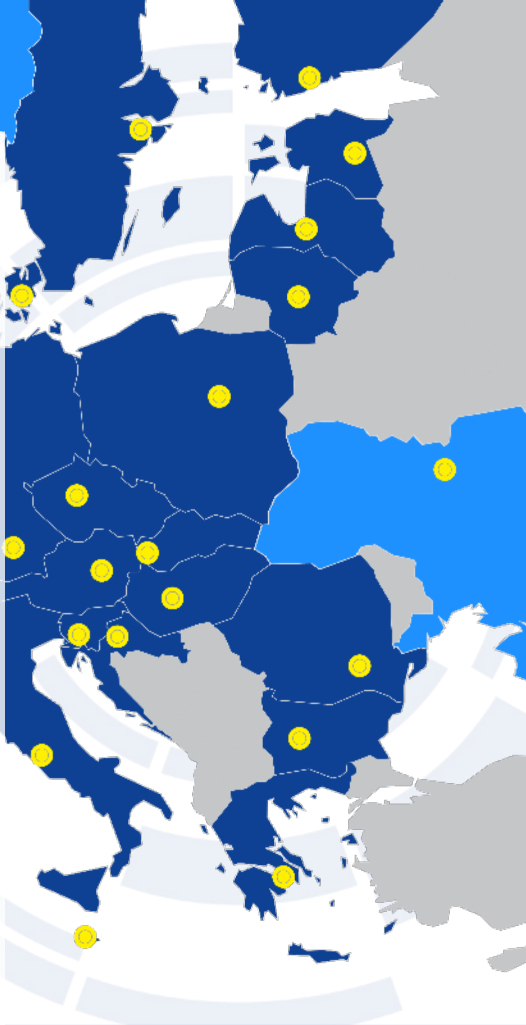

# Summary

EUROfusion plays an increasingly important role to

- Conduct R&D on remaining gaps for ITER, DEMO and FPPs
- Assist ITER developments and have a crucial role in ITER operation
- Document and make best use of lessons learned from ITER, which continues to be an essential element of the European Roadmap
- Feed increasing demand for education & training
- Ensure cohesion in the European fusion programme

Public-private-partnerships must be established to

- Address & accelerate the long-lead R&D issues (e.g. T breeding, materials)
- Take ownership of the DEMO and FPP design



# Thank You!

## FAIRNESS

Transparency
Collaboration
Loyalty

## OPENNESS

Open doors
Open hearts
Open minds
Open ears

## COMMITMENT

Ownership
Critical thinking
Determination
Respect

## DIVERSITY

Cooperation
Equal opportunities
Inclusion