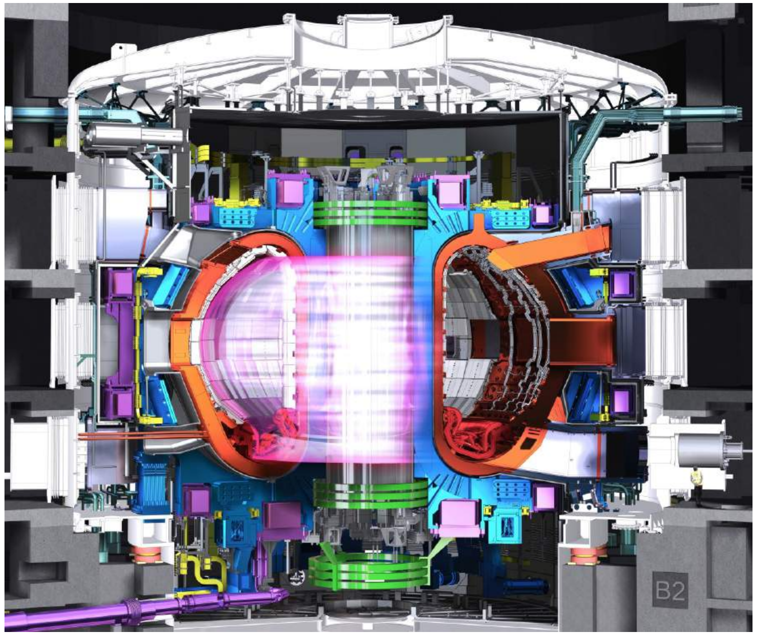
The Path to Delivering Fusion Power



Howard Wilson

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York Plasma Institute Director

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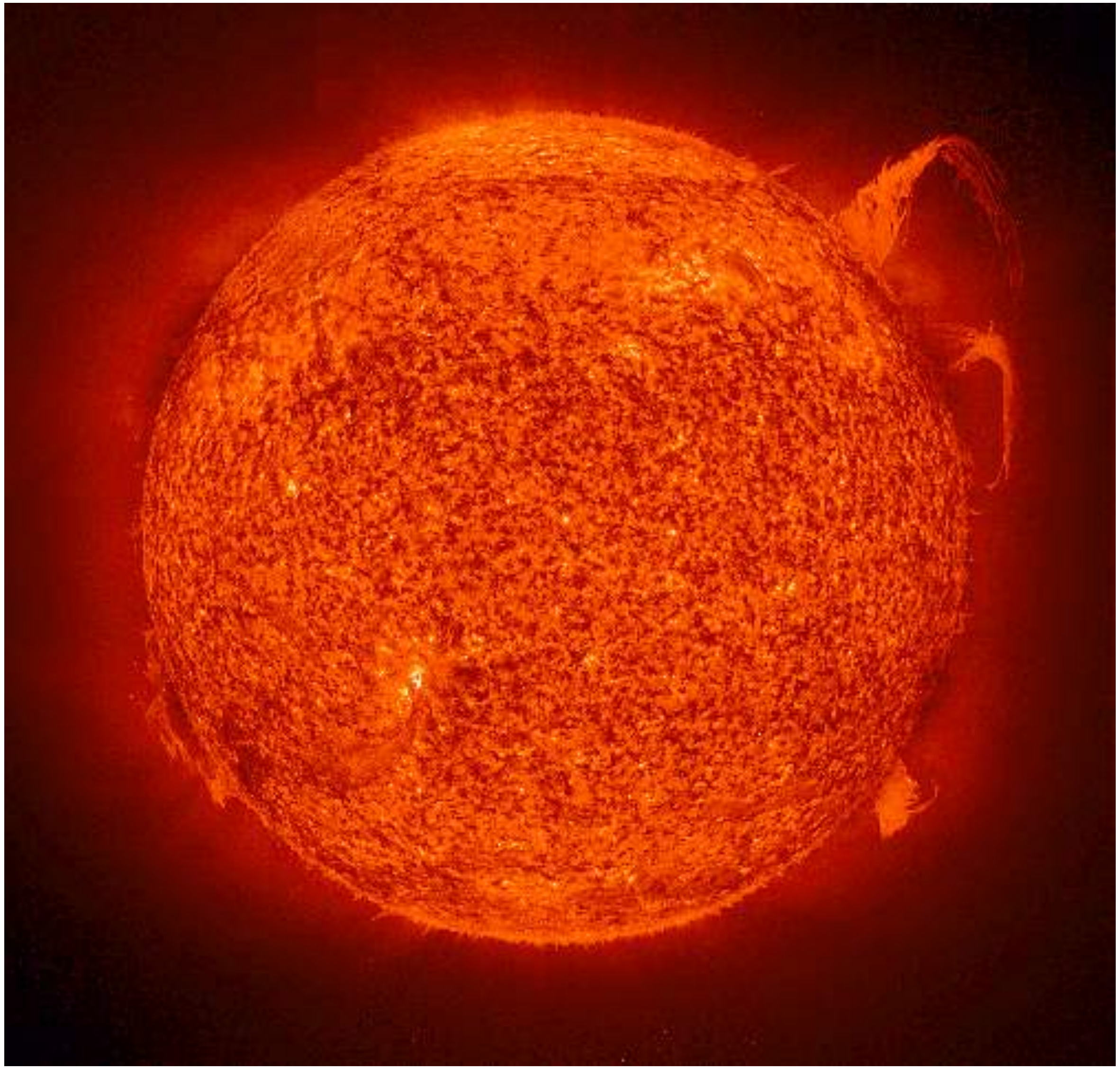
UNIVERSITY of York

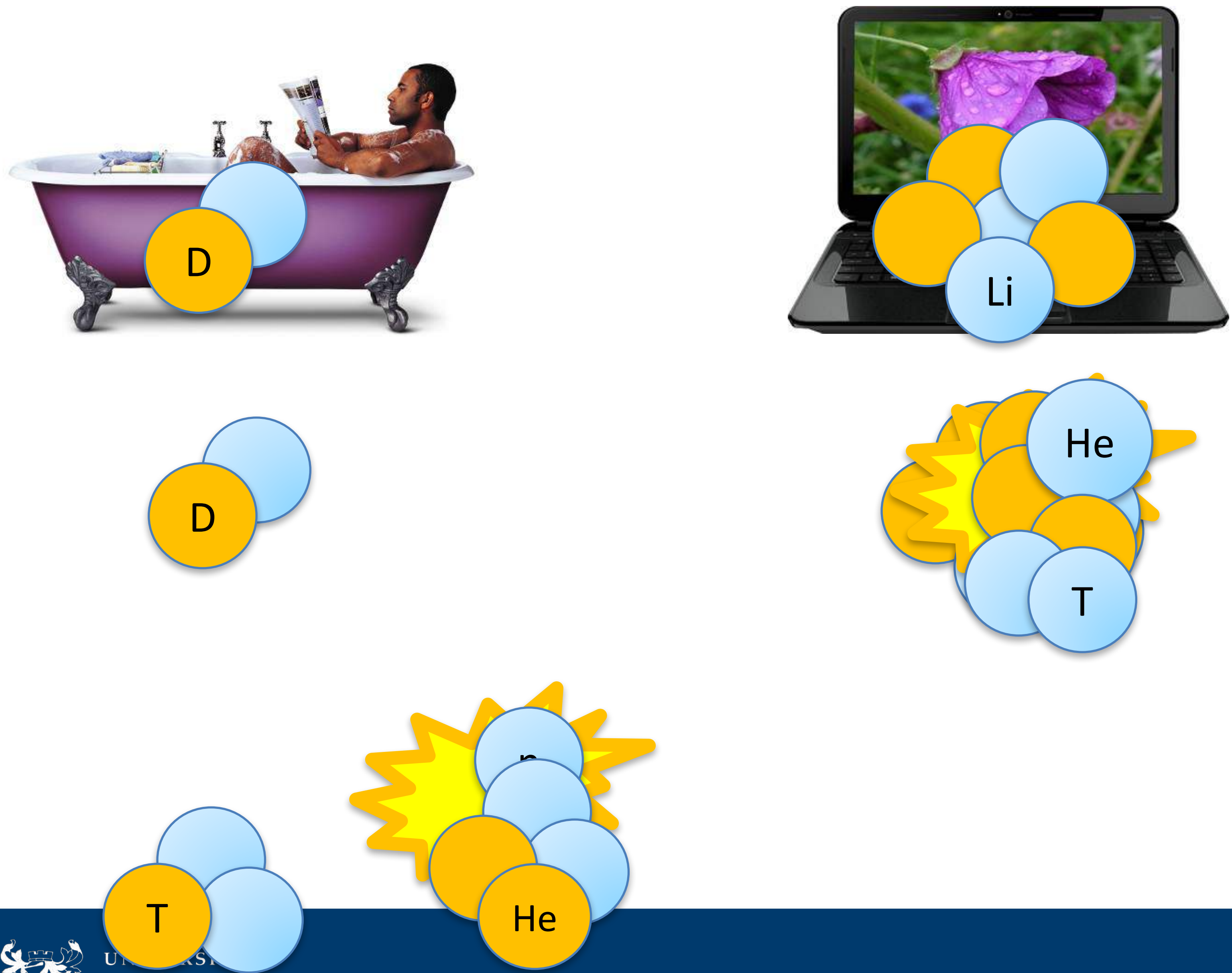
Research Councils UK Energy For a Low Carbon Future

UK Atomic Energy Authority

Our Fusion Reactor



Fusion energy – plentiful fuel and no greenhouse gas emissions



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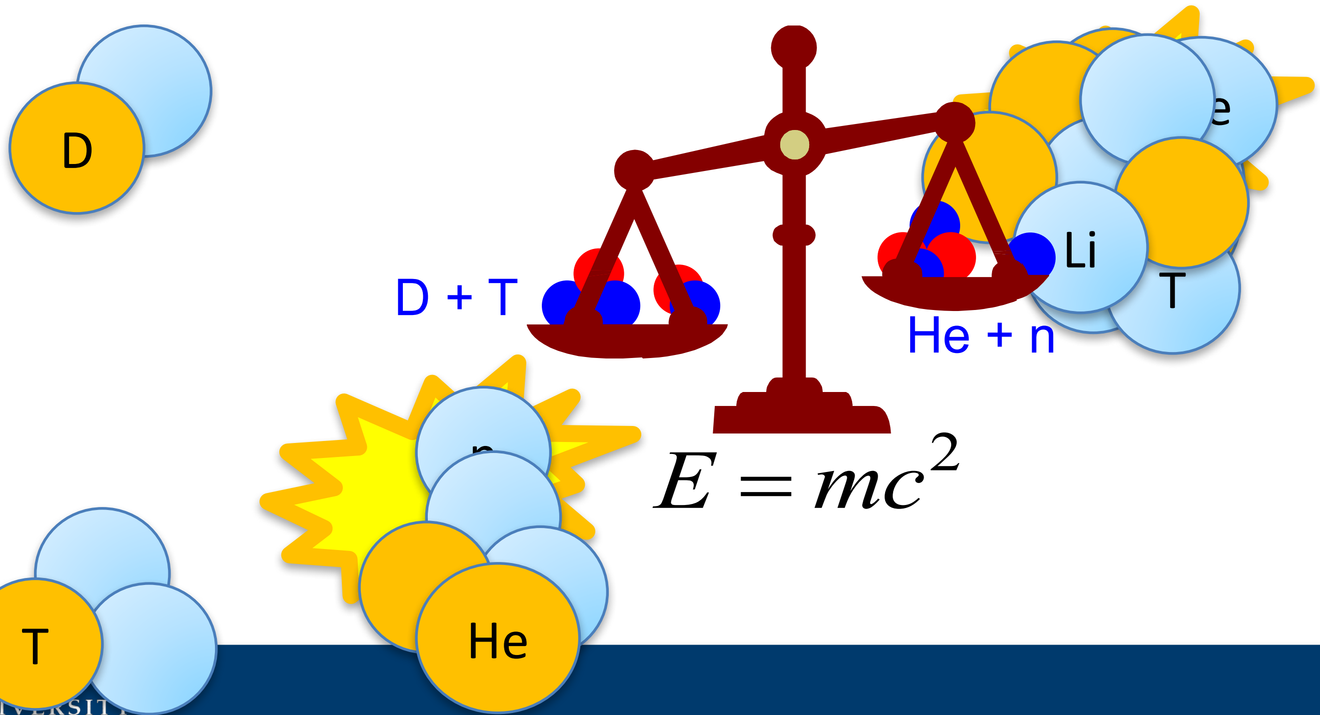
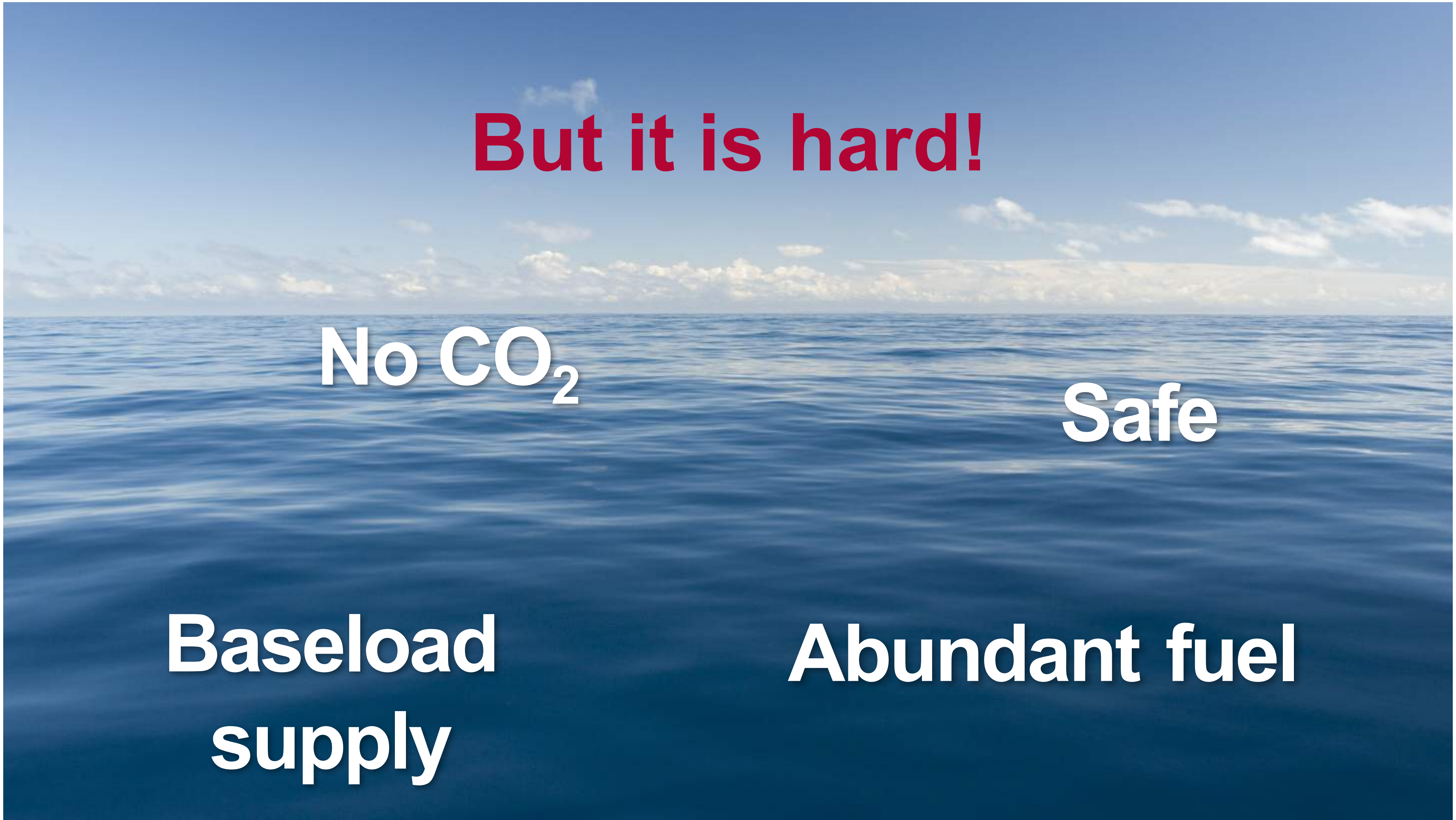
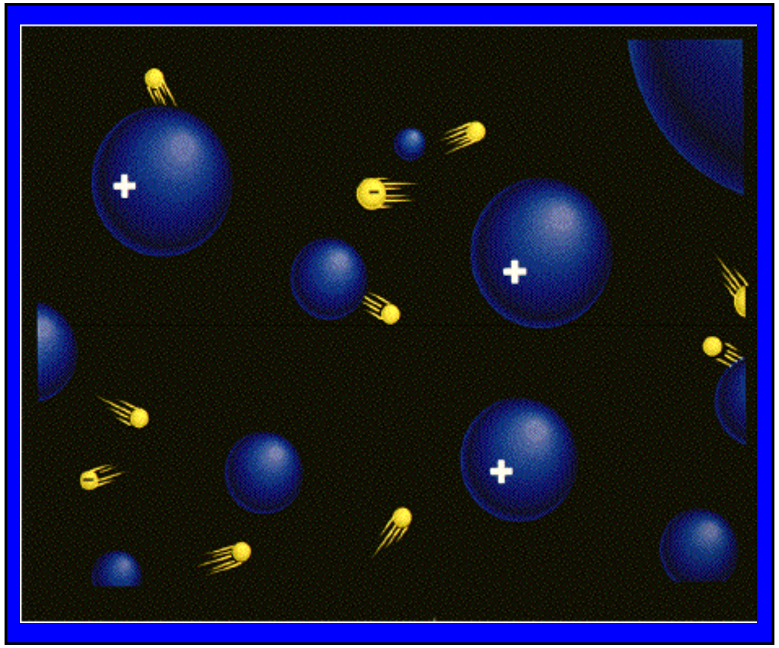


Fusion – the ultimate energy source

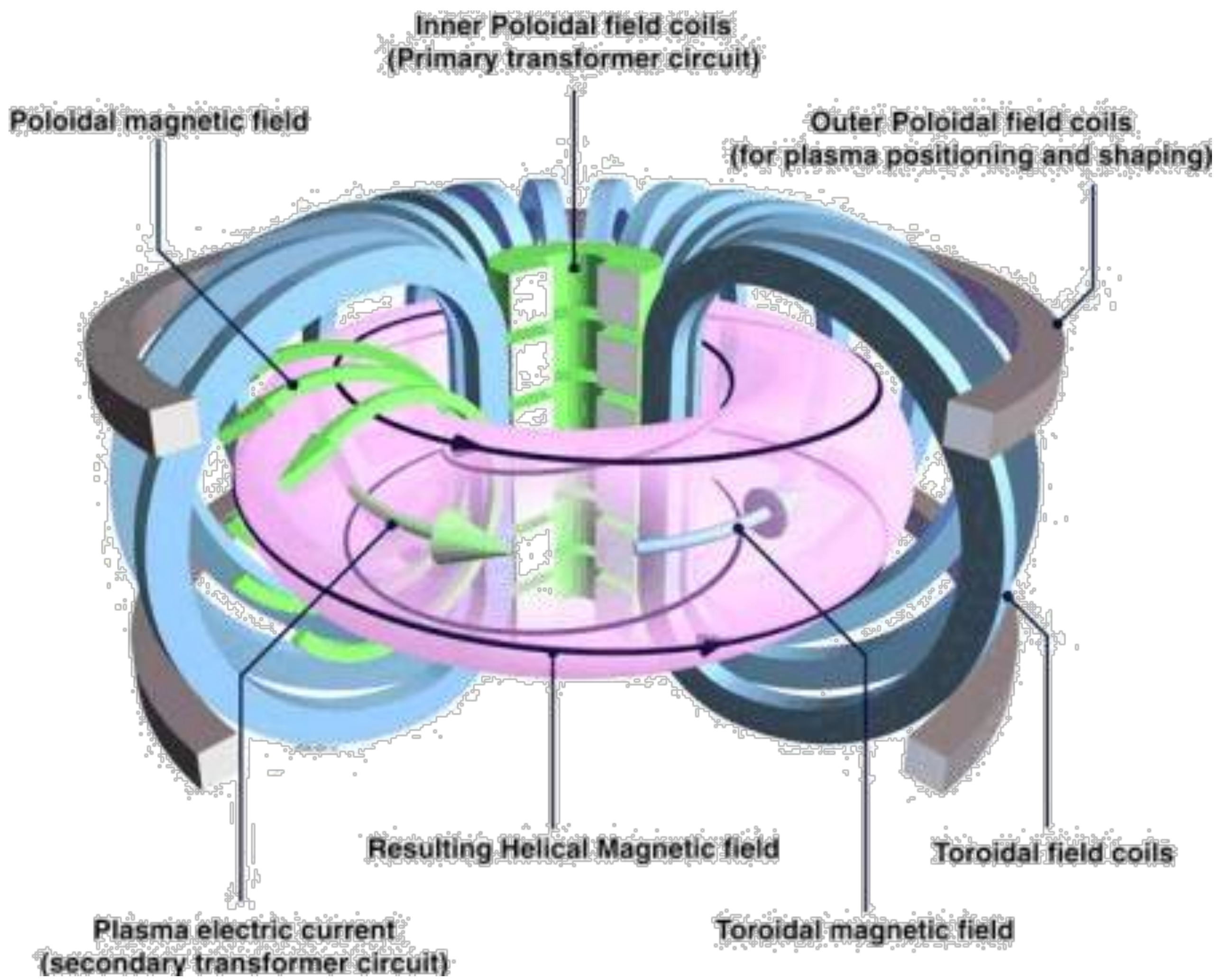


Fusion: Creating the conditions

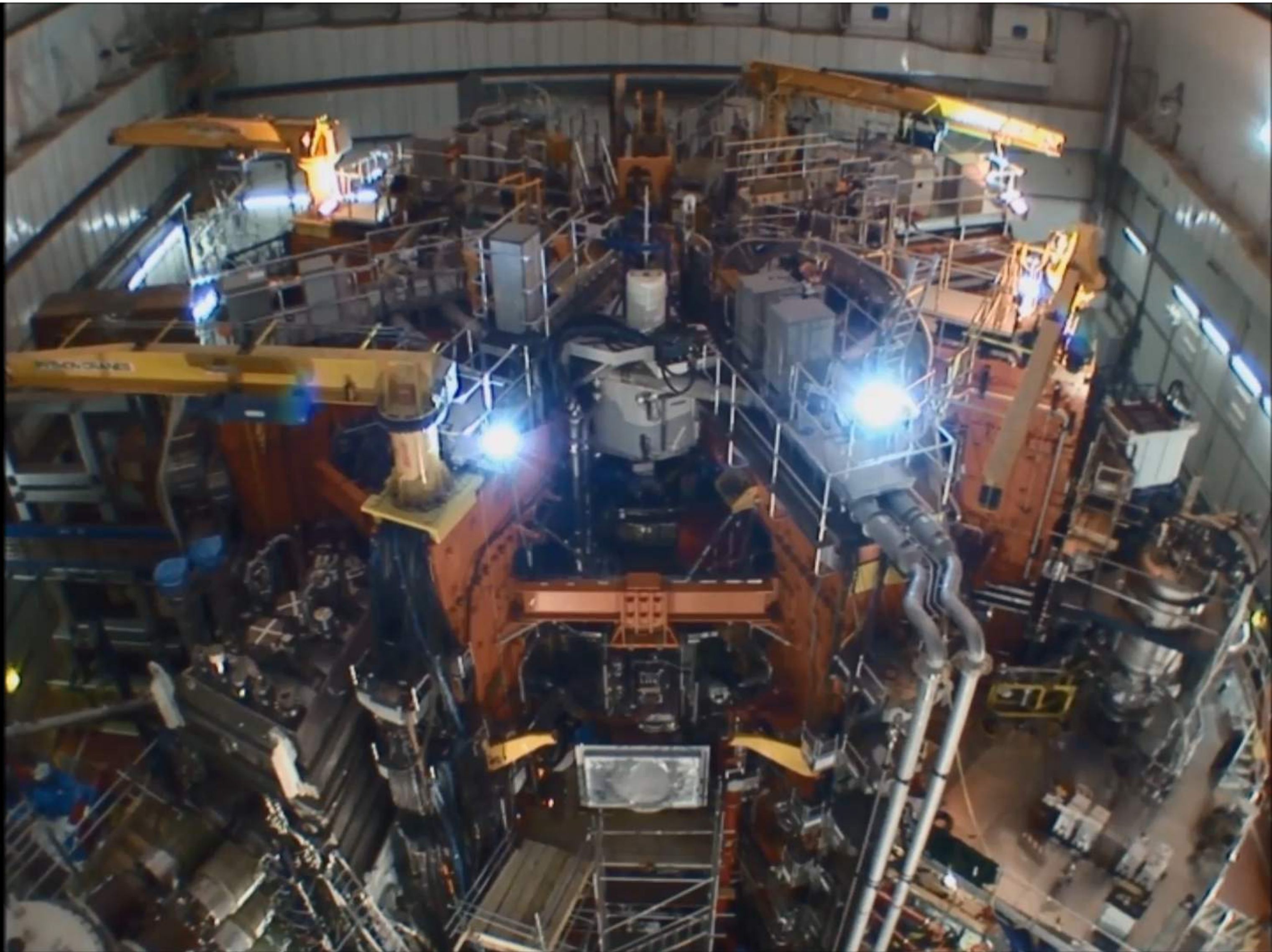


- The basic problem: Deuterium and tritium nuclei are both positively charged
  - ⇒ hard to force them together
  - ⇒ they need to be heated to ~10 times the temperature in the sun's core!
- A sufficiently hot gas converts to a new state: the plasma state
  - – Electrons are stripped from the nucleus
  - – A plasma contains charged particles, but is electrically neutral
- So how do we "confine" such a hot fuel long enough for fusion to occur?
- There are two principle techniques:
  - – magnetic confinement
  - – inertial confinement
- Here we shall consider magnetic confinement
  - – presently the more advanced approach

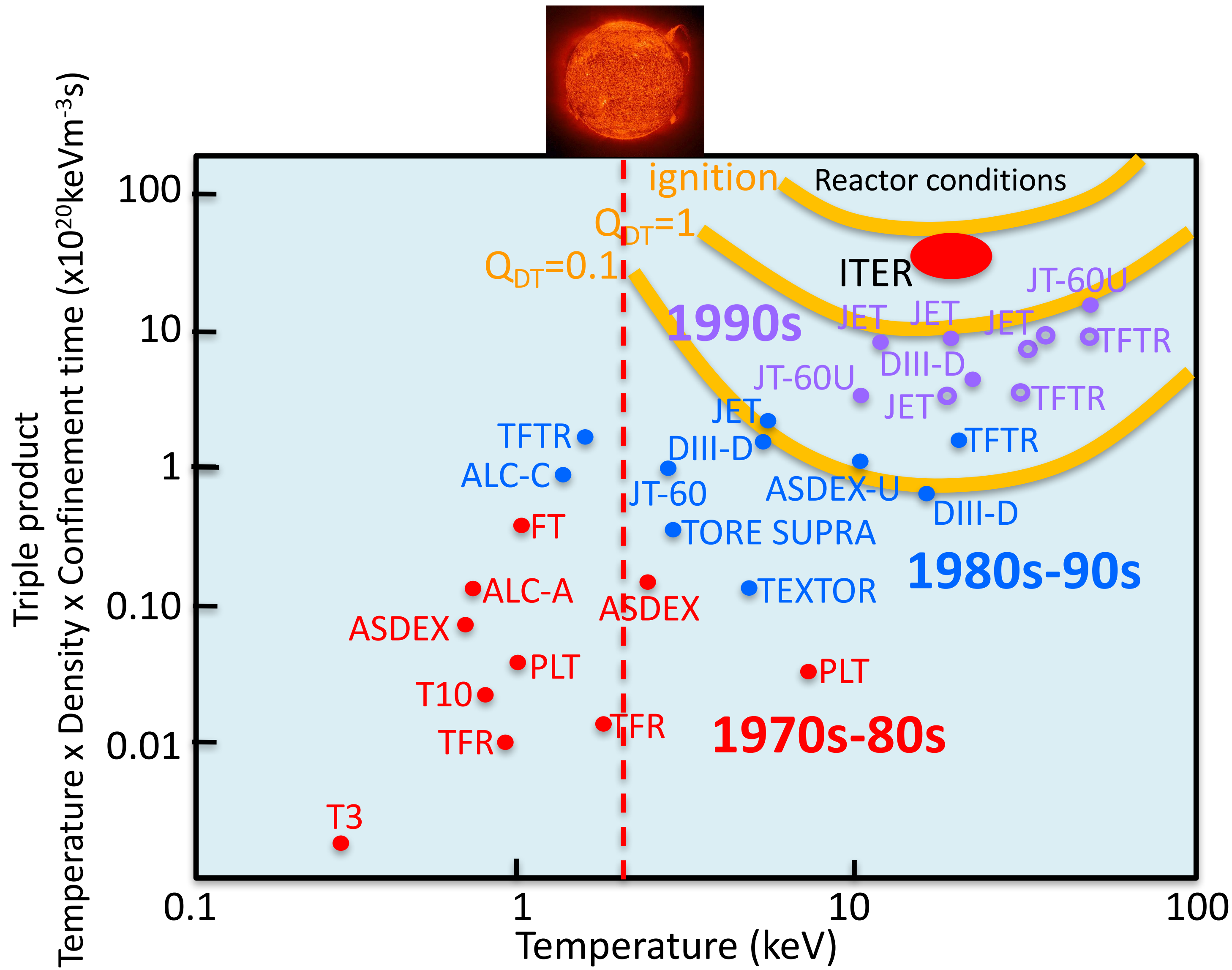
Fusion: The tokamak



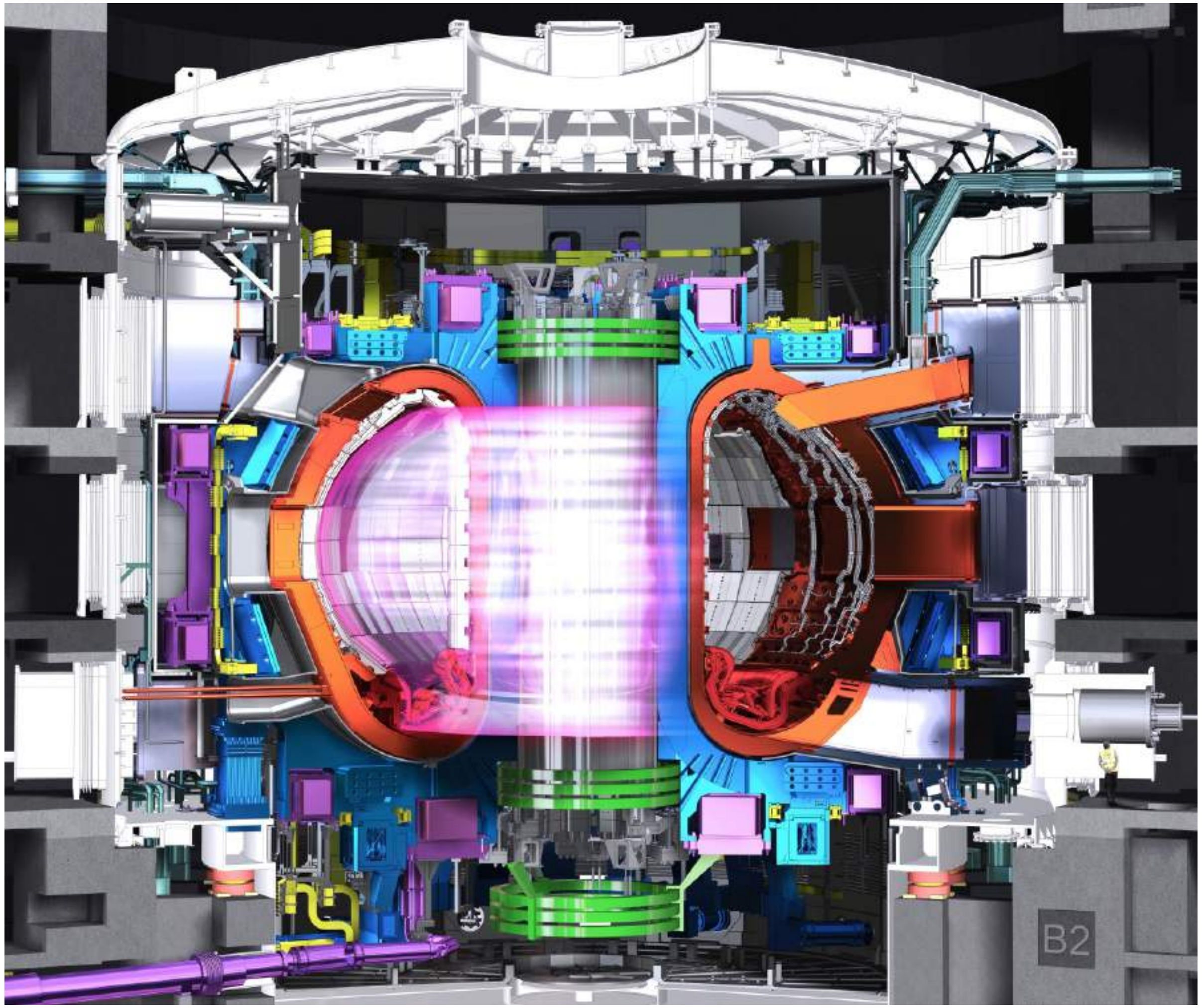
JET – the world's most advanced tokamak



Progress Towards Fusion Power

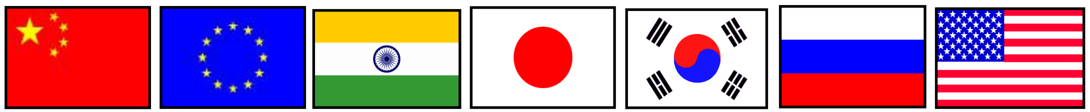


ITER – "the way" to Fusion Power



10x power gain

'Burning' plasma



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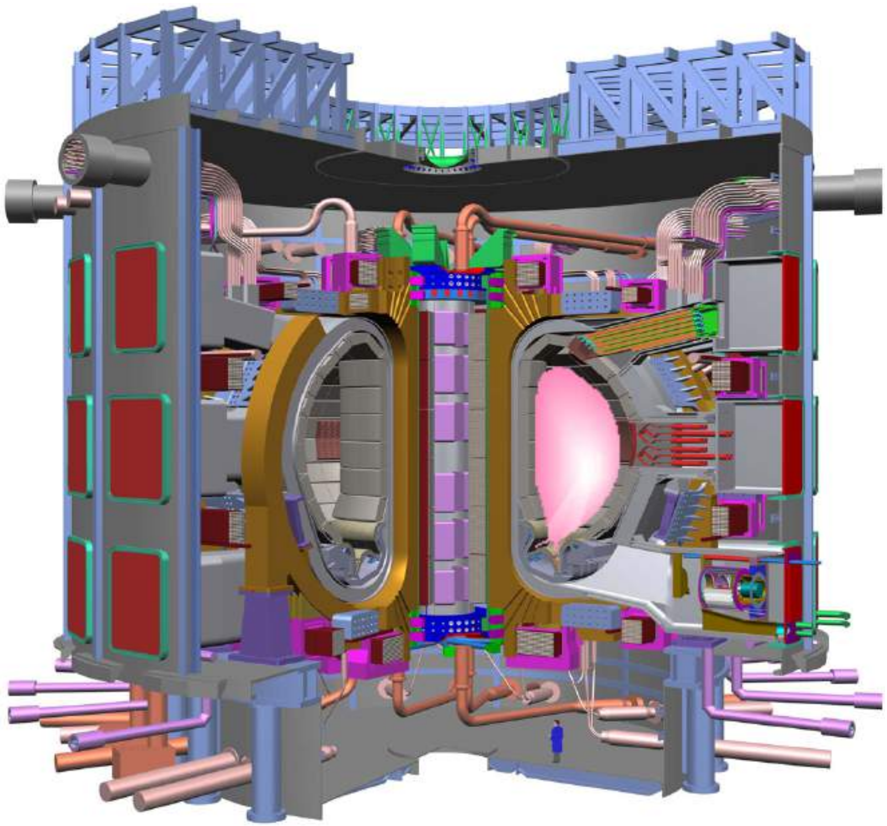
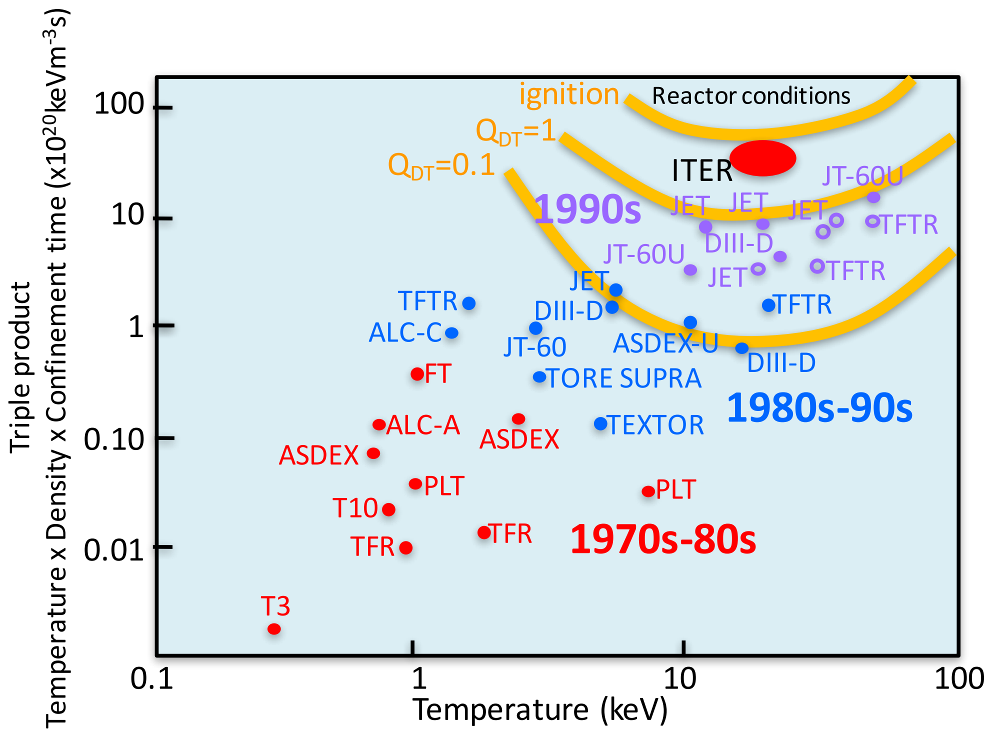
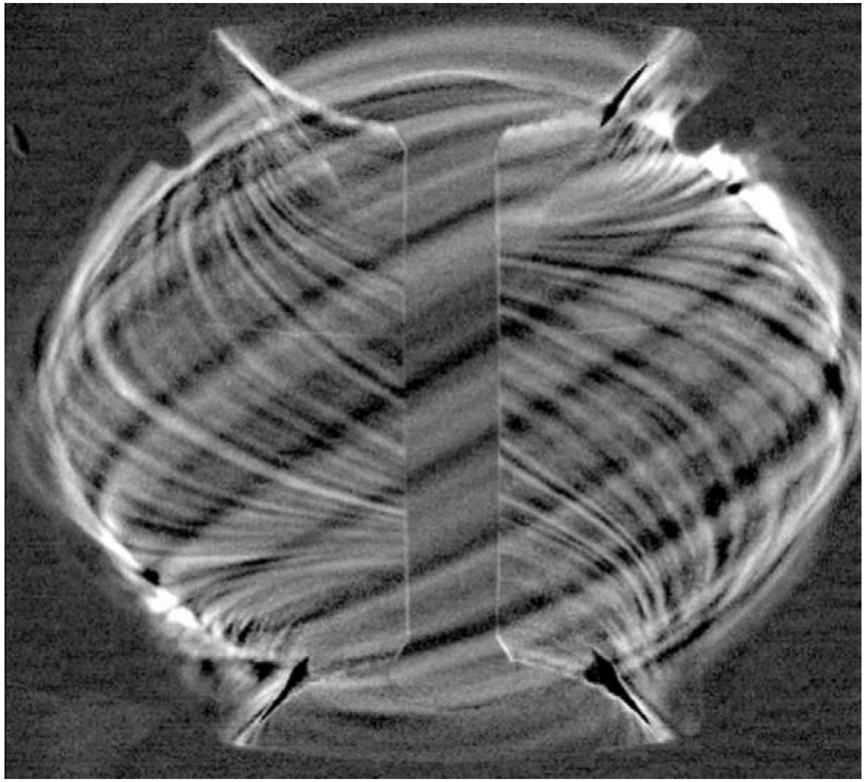
Why is ITER the size it is?



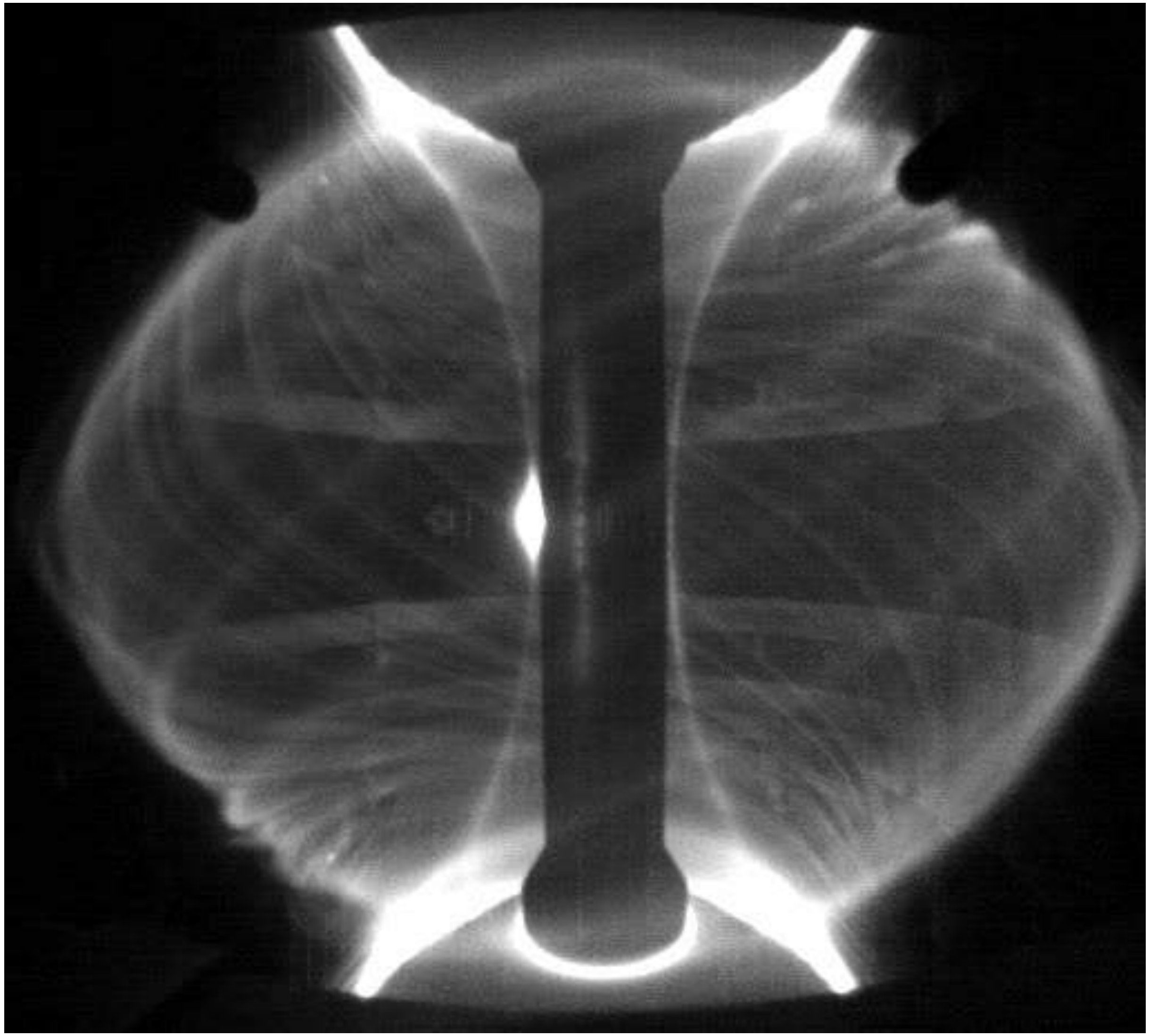


Plasma Turbulence determines the size of a fusion reactor to a large extent

MAST – the UK domestic tokamak facility

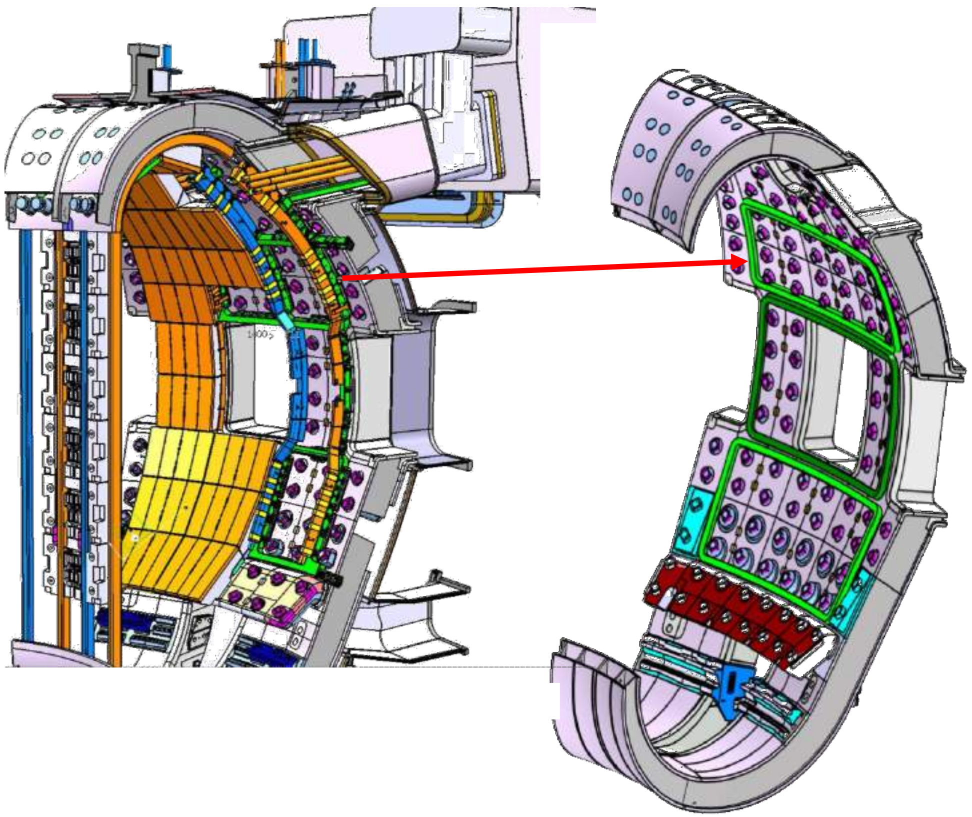


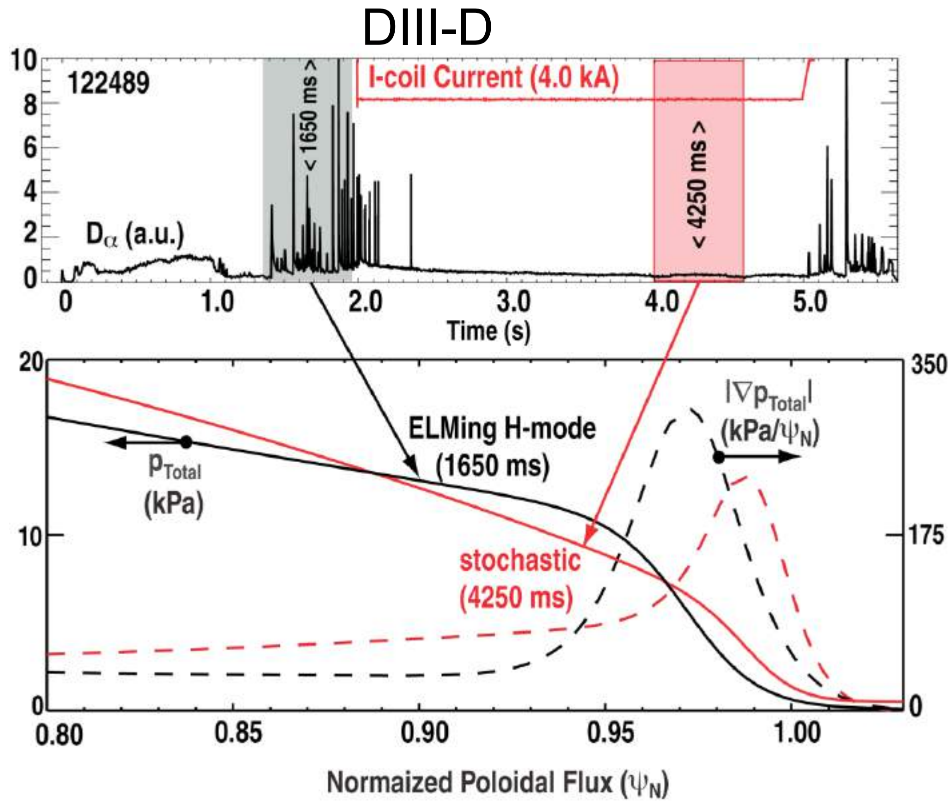
Signs of turbulence suppression; plasma eruptions and exhaust in MAST



Tackling plasma eruptions

A system of coils perturbs the confining magnetic field, reducing pressure gradient



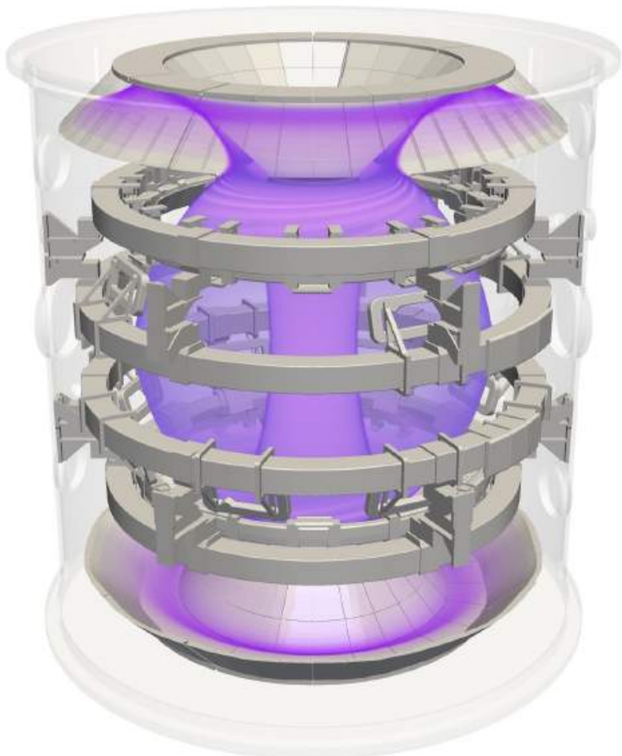


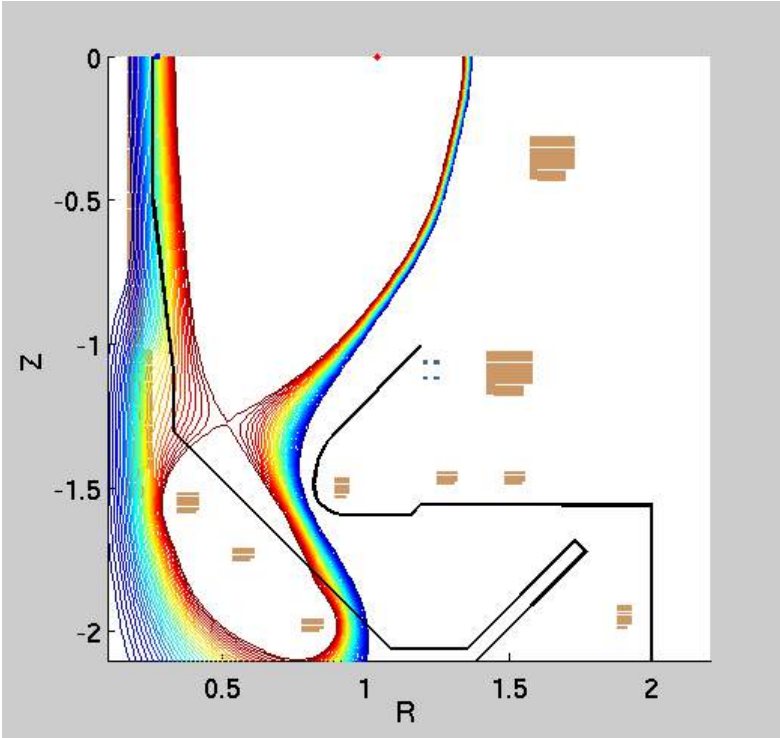
T. E. Evans, et al., Phys. Plas 13 (2006) 056121

- Only works under certain conditions: not understood
- The physics of plasma interacting with such magnetic fields is subtle

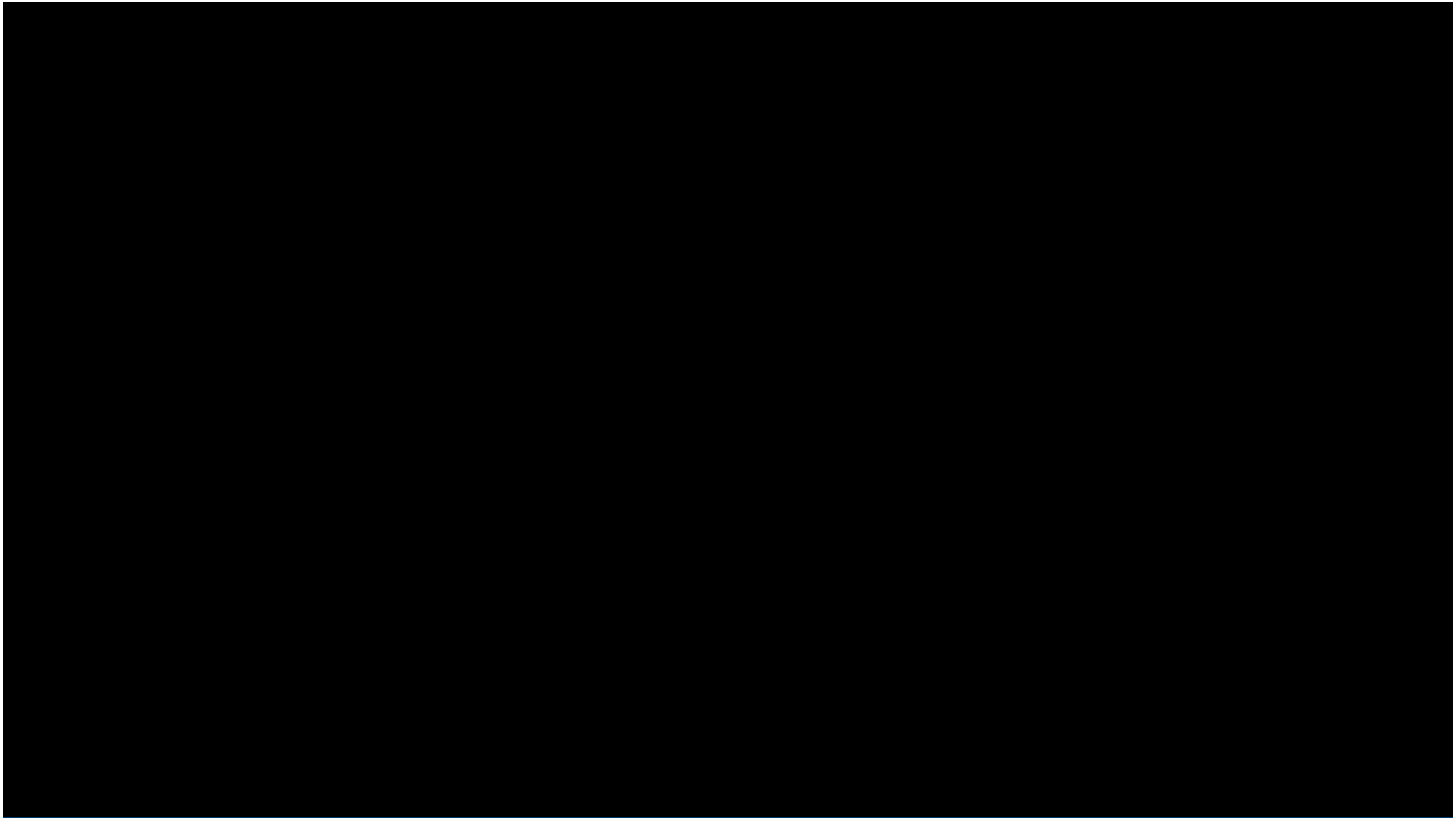
MAST Upgrade – Tackling Plasma Exhaust

- Suppressing turbulence could provide a route to more compact fusion
- But only if the exhaust can be handled
- This is a major motivation for the ~£50M upgrade to MAST

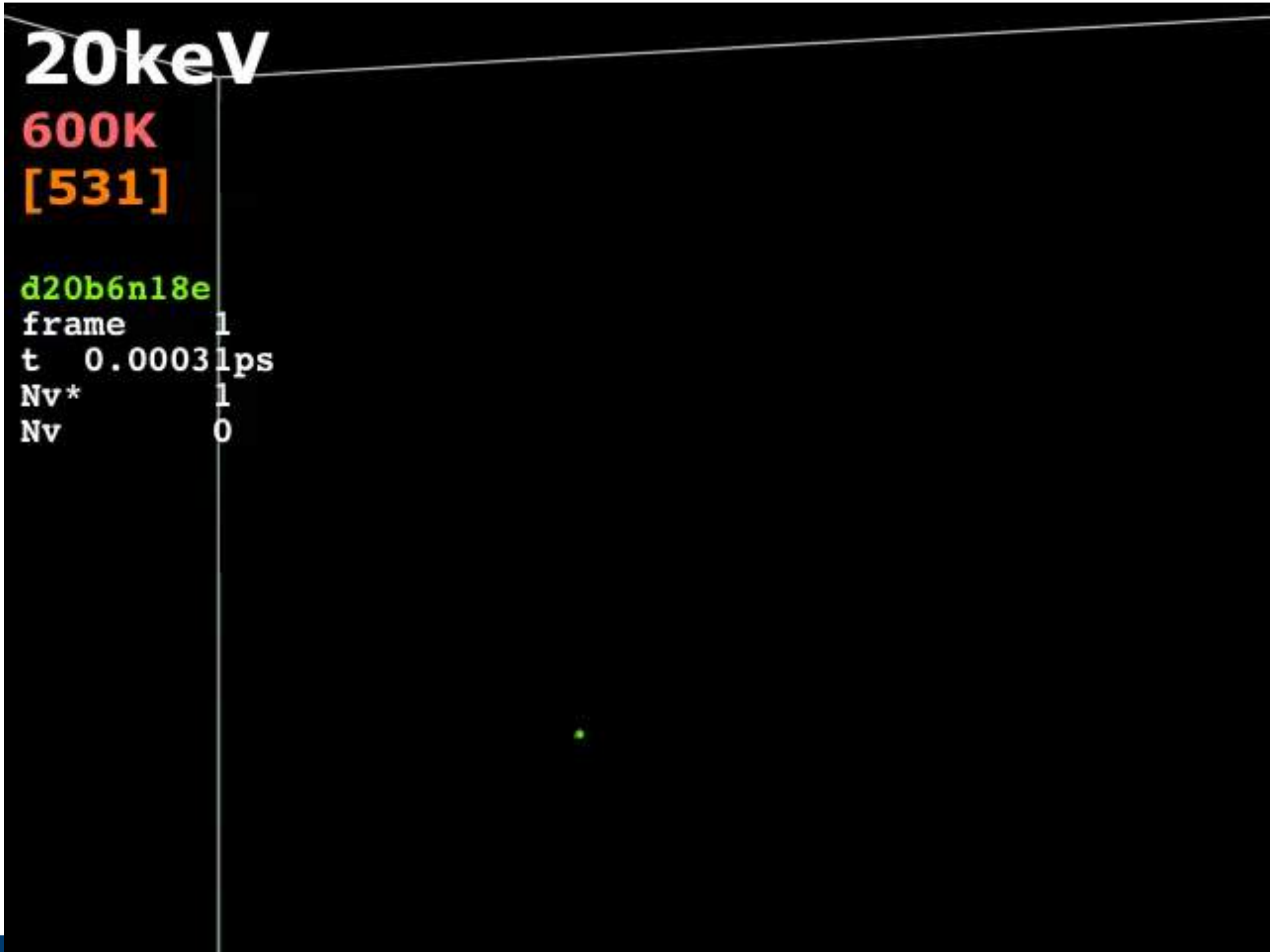




Construction of MAST Upgrade

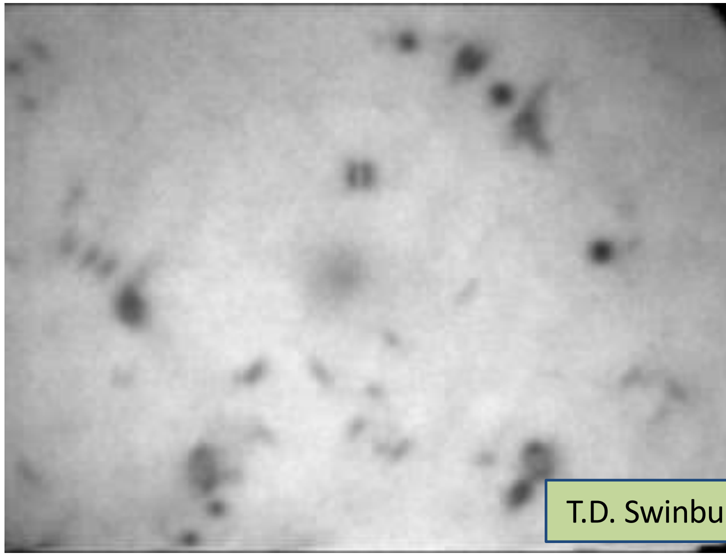


High energy neutrons induce a cascade of damage in materials



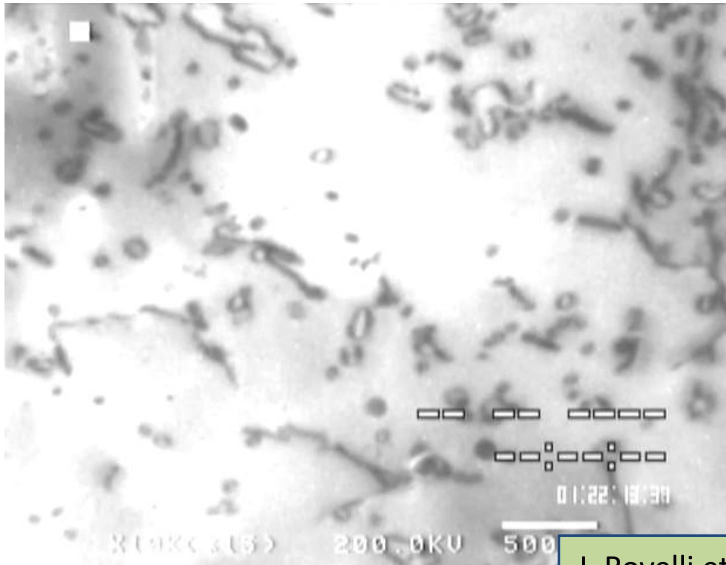
Calder, University of Liverpool

Direct observations of defects



Dynamics of defects as W is irradiated at low temperature

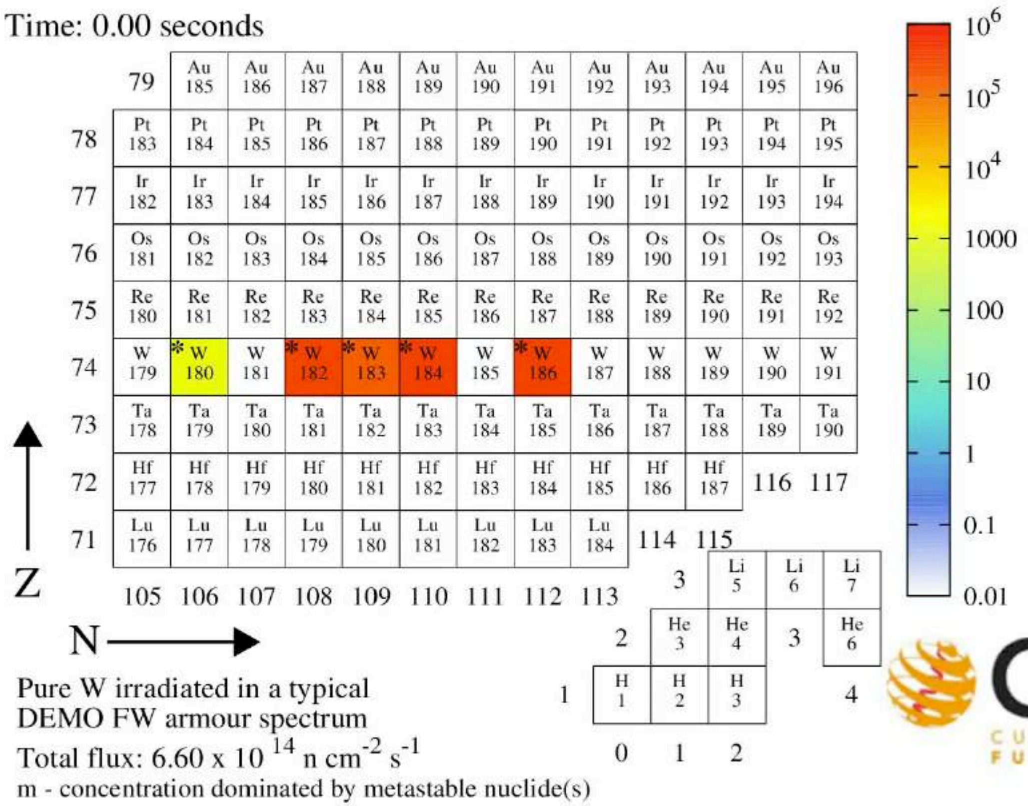
T.D. Swinburne et al., New J. Phys. 19 (2017) 073024

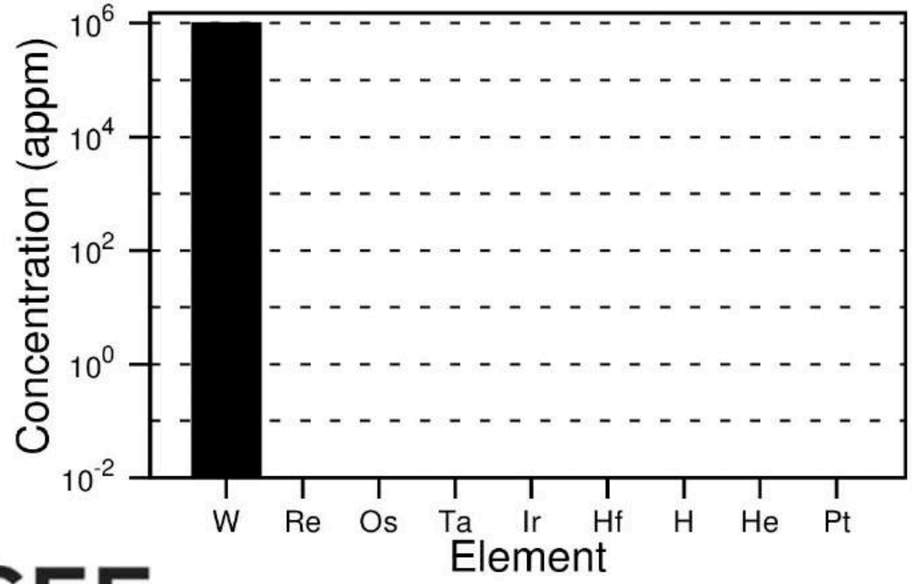


High temperature annealing of defects

I. Rovelli et al., J. Mech. Phys. Solids 103 (2017) 121

Transmutation of Tungsten in DEMO





CCFE
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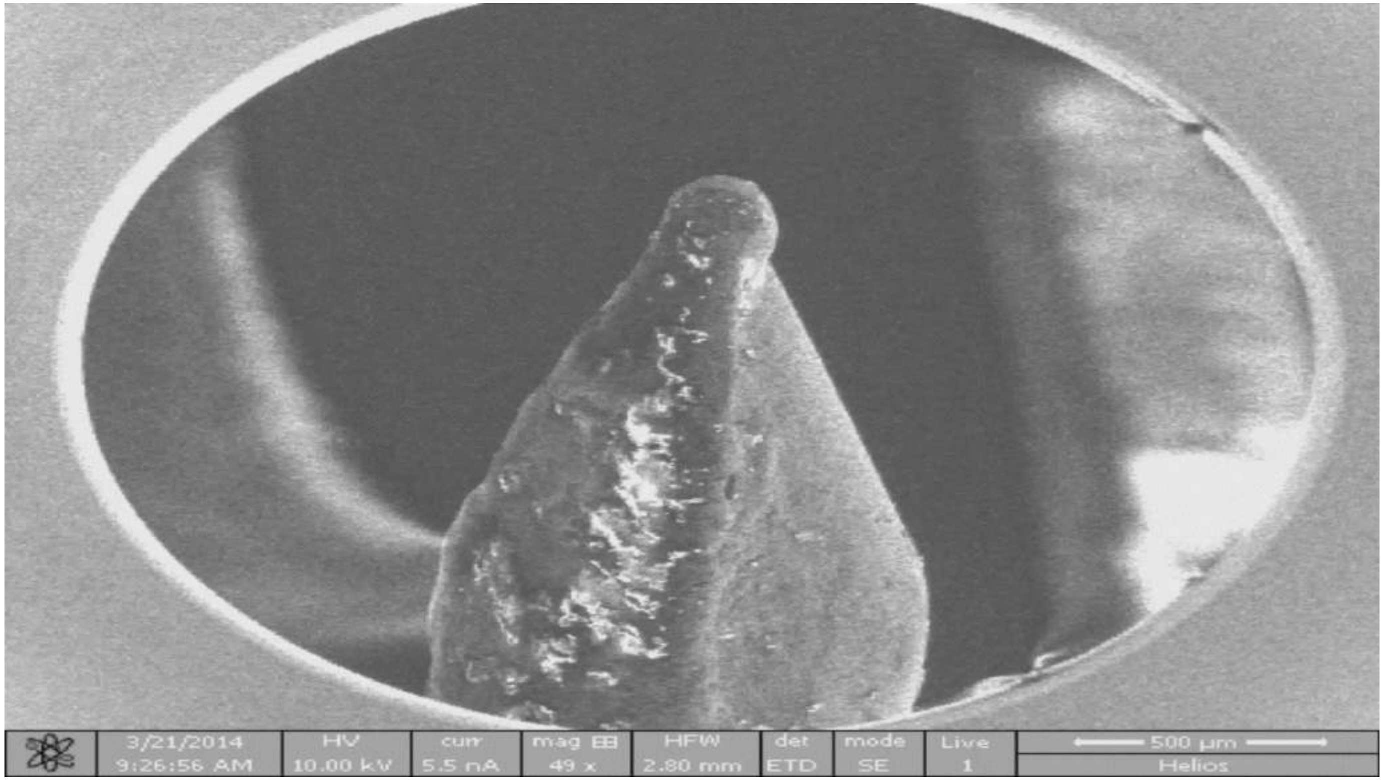
Materials Research Facility at Culham

Universities	~50 MBq	UKAEA	~4 TBq	Sellafield
Very low activity	(e.g. Oxford)	Medium activity, structural	(Co^{60})	Most active, fuel cycle



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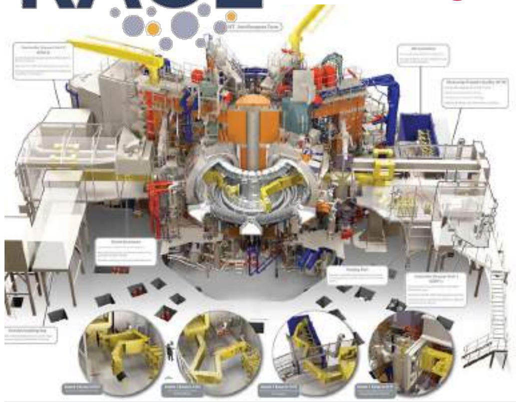
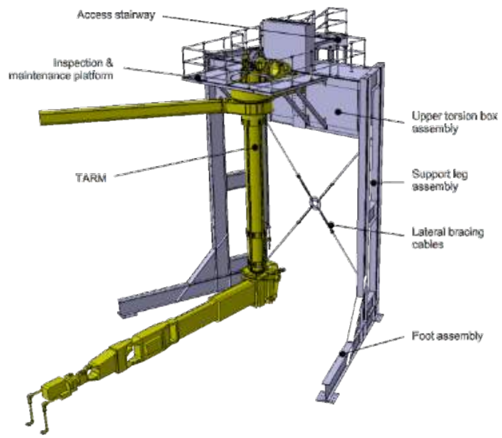
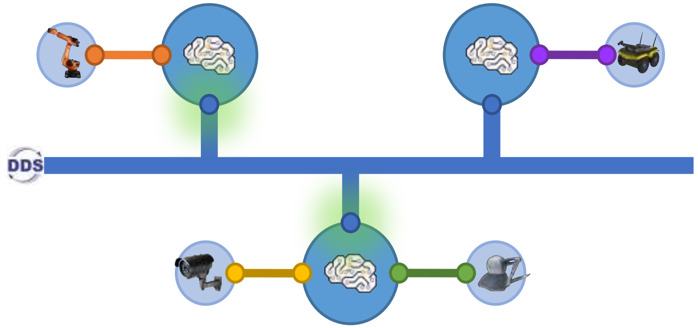
Building on expertise in JET robotics



↑ JET Remote Handling System: systems overview; JET boom in situ; JET RHS control room in operation

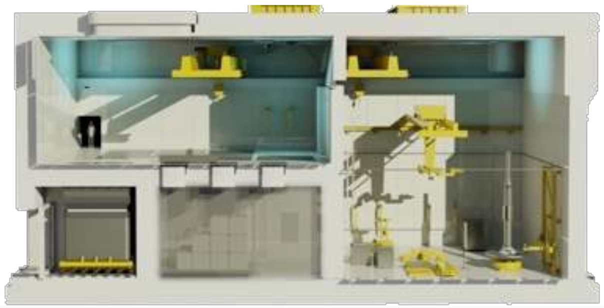


↑ TARM: unique flagship



↑ CorteX: system of systems control including augmented reality and AI

ESS windowless hot cell →



Autonomous vehicle living lab →

With ITER construction well under way, we are taking significant steps towards commercial fusion energy

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PhD and MSc Fusion Open Day

6th December 2017
Culham Science Centre, Oxfordshire

SHAPE THE ENERGY OF THE FUTURE