



Challenges on the European Roadmap towards Fusion Electricity

Tony Donné
Programme Manager EUROfusion

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the EU Domestic Agency
for ITER: Focus on
procurements



30 Research Units (+ numerous Third Parties) in 28 European countries working together to achieve the ultimate goal of the Fusion Roadmap



FUSION WORKS

The sun and the stars shine thanks to fusion reactions taking place in their core.

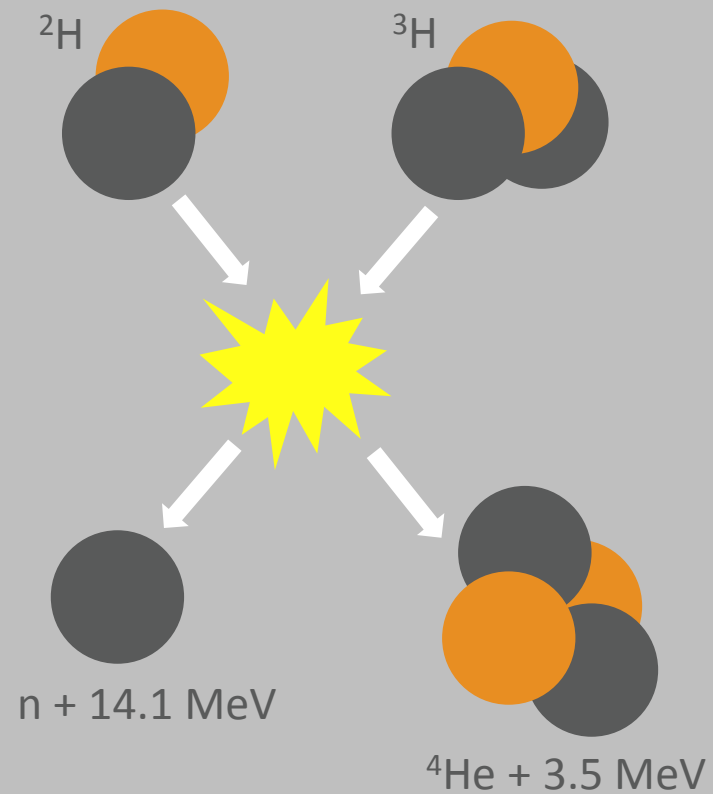


Image: NASA



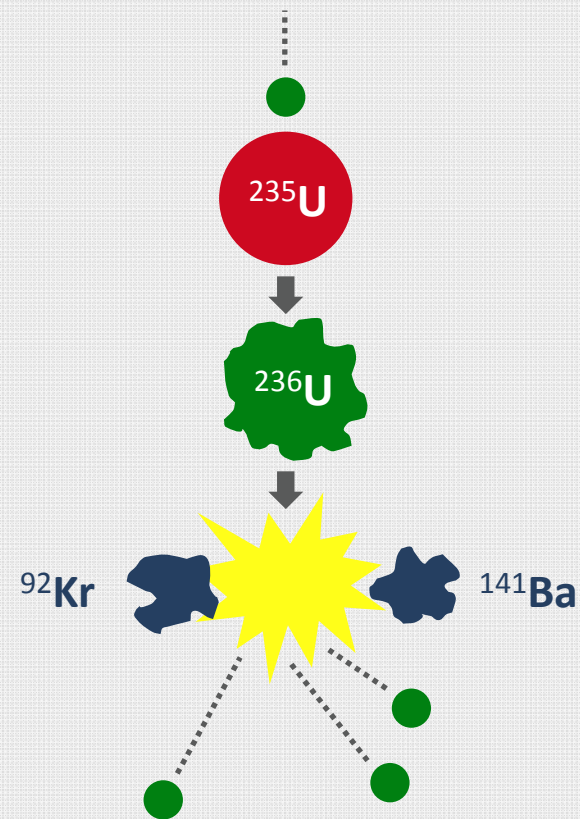
FUSION

Two small nuclei bind making a bigger one.



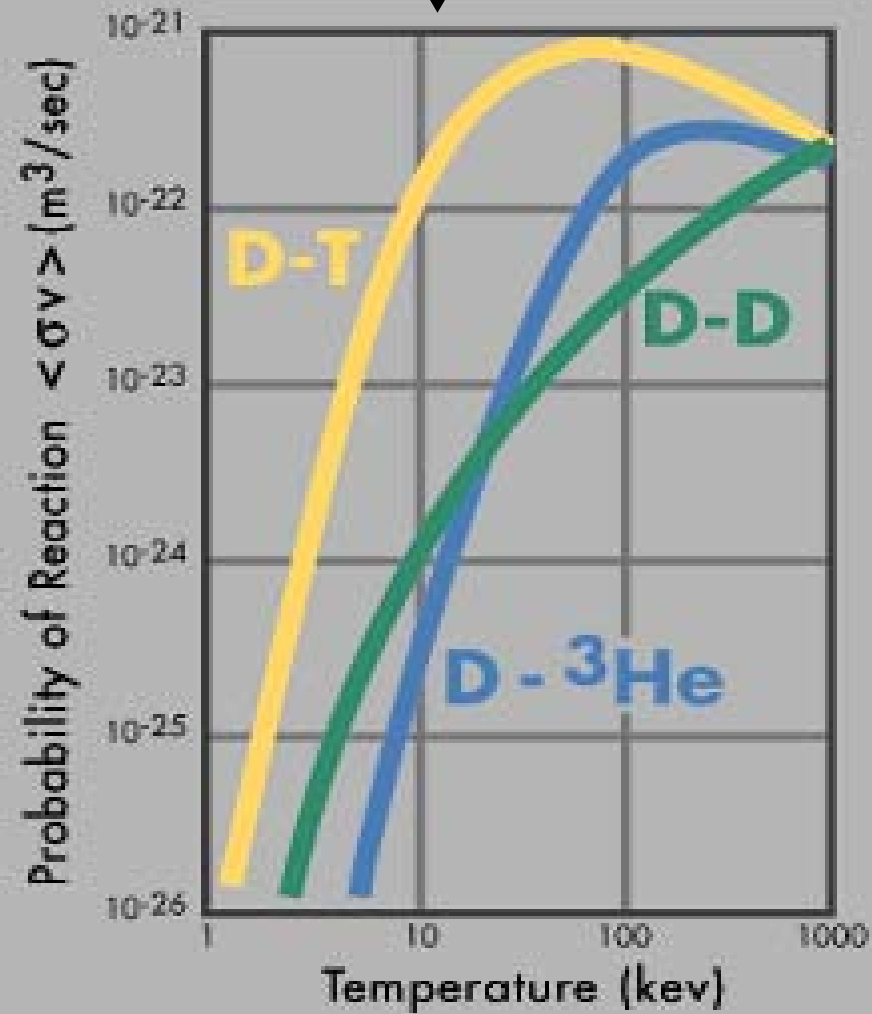
FISSION

One large nucleus breaks up into smaller ones.



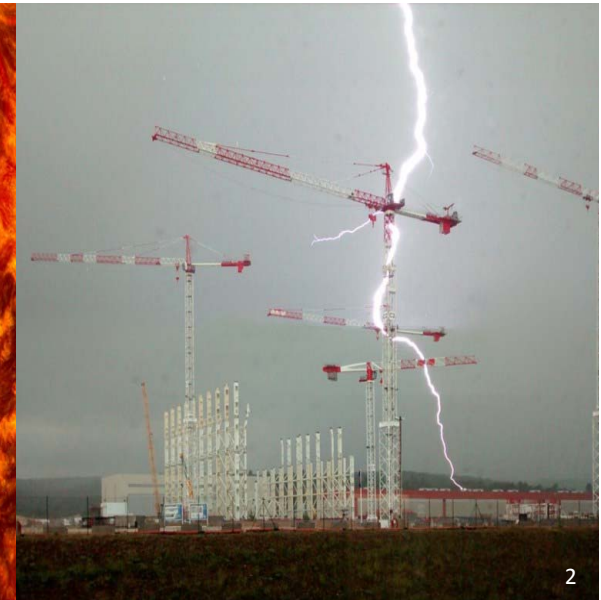
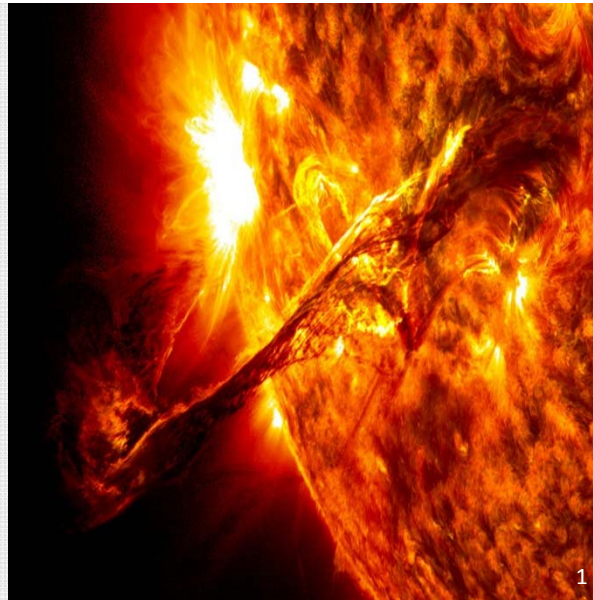


~150 million degrees





PLASMA IS THE MOST COMMON STATE OF MATTER IN THE UNIVERSE. IT MAKES UP 99% OF ALL OBSERVABLE MATTER.



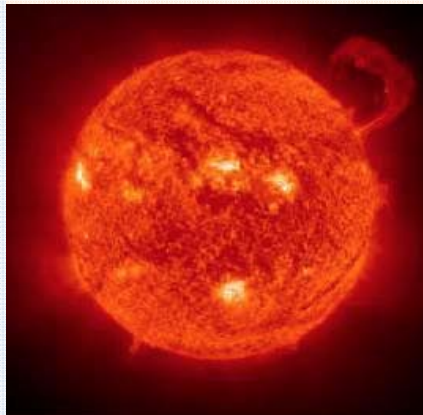
100 million degrees are required to overcome the repulsion between nuclei. Inside a deuterium-tritium fusion reactor matter enters the state of **plasma**.



PLASMA CONFINEMENT IS THE KEY TO ACHIEVING FUSION

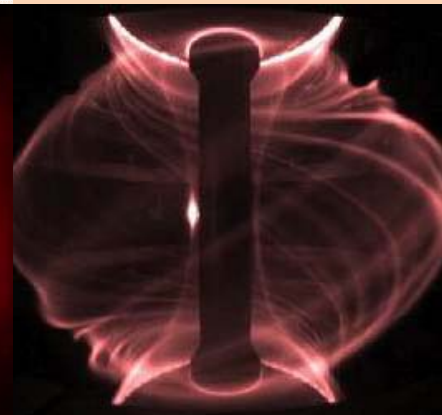
Stars are so massive that they rely on

gravitational confinement

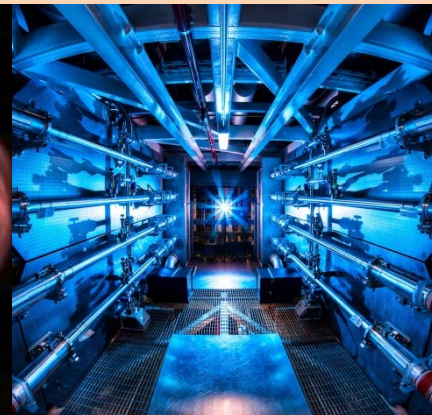


On Earth nuclear fusion does not happen naturally, so we rely mainly on two approaches

magnetic confinement



inertial confinement

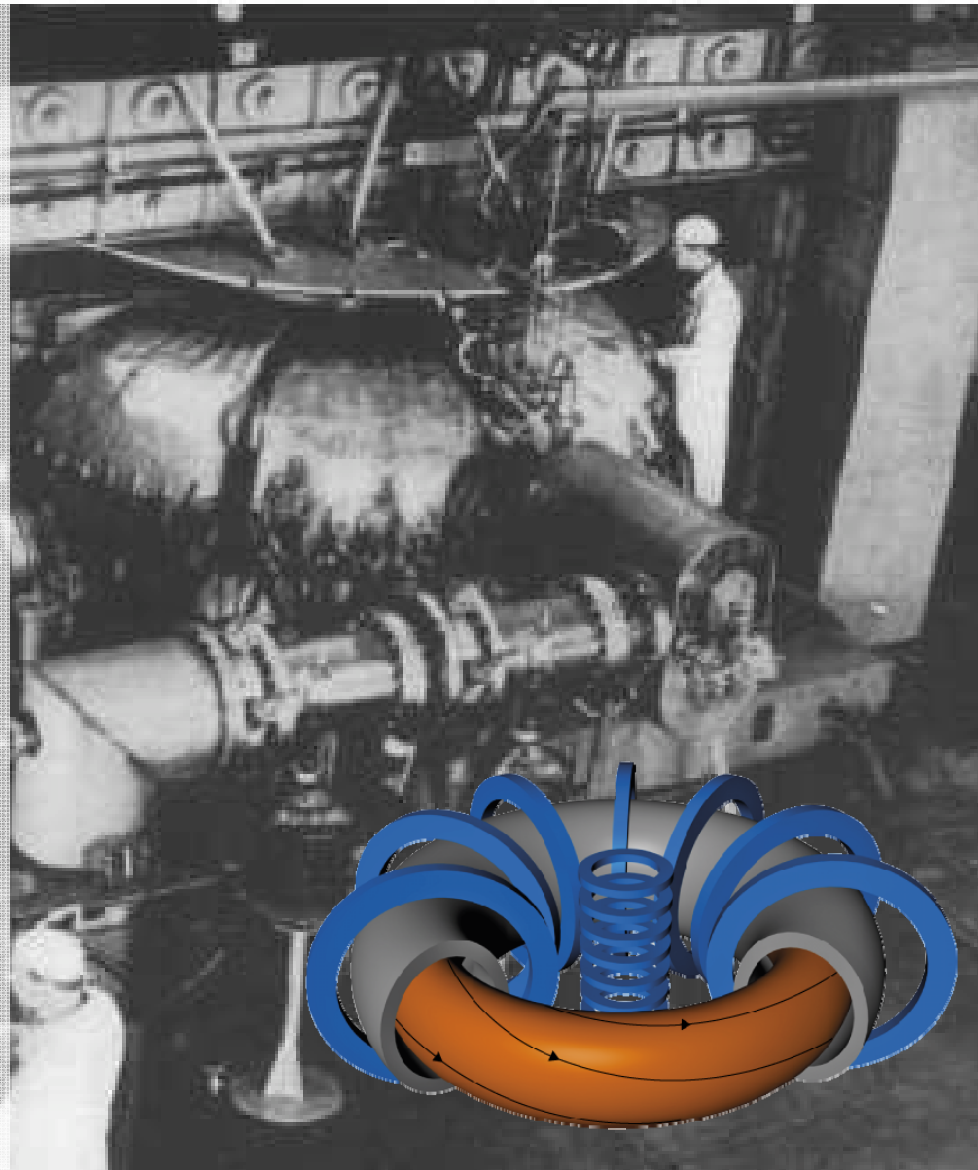


Images(left to right): NASA, CCFE, green picture replace with https://en.wikipedia.org/wiki/National_Ignition_Facility#/media/File:Preamplifier_at_the_National_Ignition_Facility.jpg,
image: Lawrence Livermore National Laboratory, CC BY-SA 3.0, <http://tinyurl.com/hj7qvan>



THE TOKAMAK

- Pioneered in the Soviet Union in the 1950s and 1960s
- Improved plasma confinement by adding a second magnetic field
- T3 device at Kurchatov Institute, Moscow achieved breakthrough in fusion performance – 1968
- Joint European Torus (Culham, UK) is now the largest tokamak operating (since 1983)





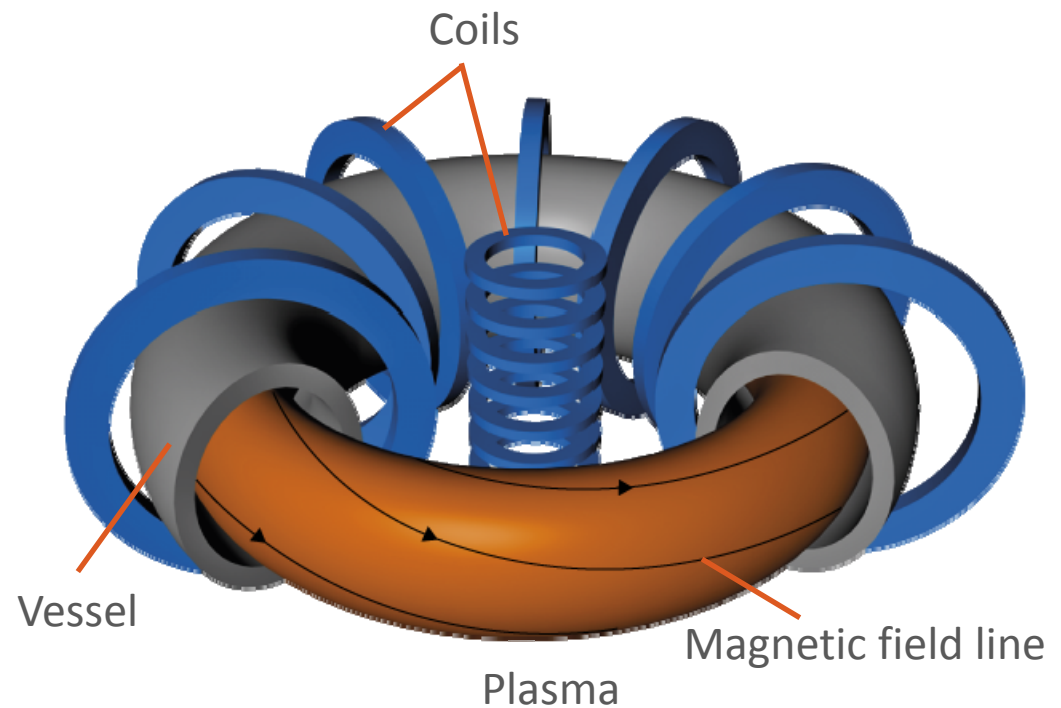
BASICS OF A TOKAMAK

It consists of

Metallic vessel to contain the plasma

Magnetic field coils to

- guide the plasma particles
- generate a current in the plasma
- shape the plasma

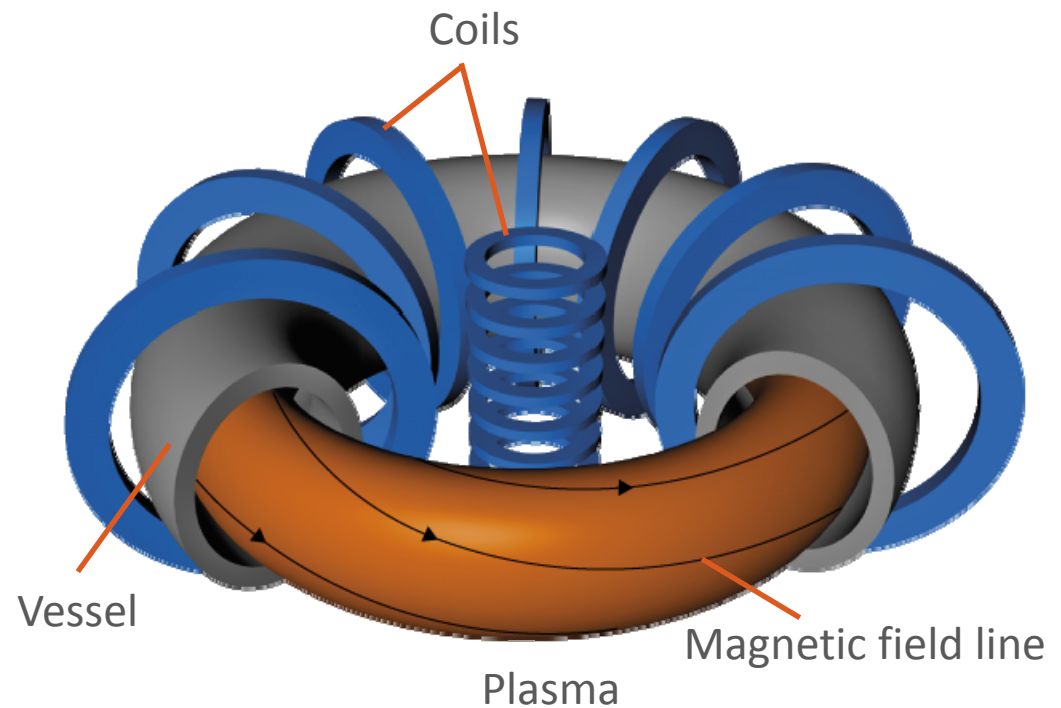




MAGNETIC CONFINEMENT

The combination of the magnetic fields naturally forms a cage-like structure, consisting of a series of nested rings.

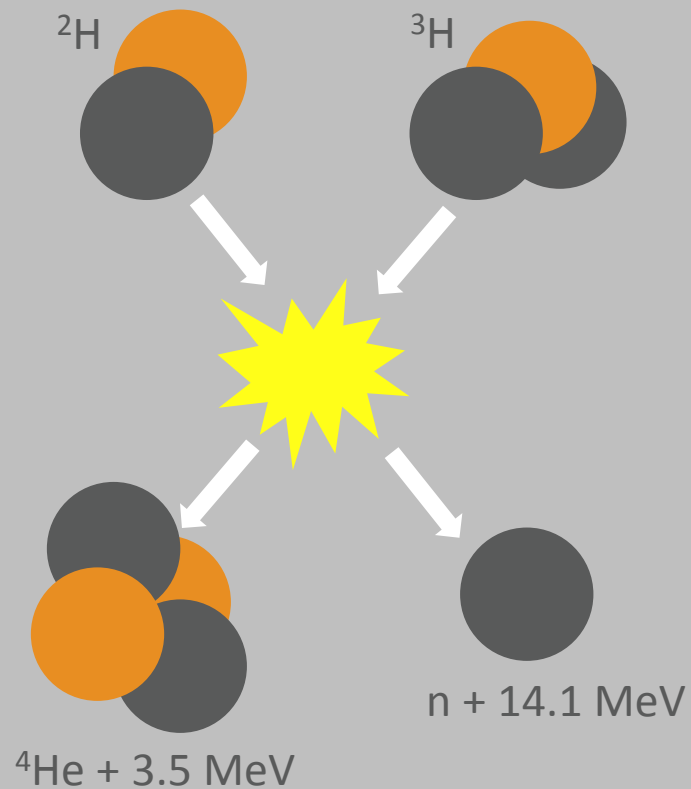
Since particles of the plasma follow the magnetic field lines, they remain confined in the vicinity of the surface of a ring.





FUSION

Two small nuclei bind making a bigger one.



${}^4\text{He}$ is charged and heats the plasma

Neutrons leave the magnetic confinement and penetrate into the wall:

- ☺ Heats the wall ➤ Electricity
- ☺ Can be used to breed tritium
 $n({}^6\text{Li}, {}^4\text{He}){}^3\text{T}$
- ☺ Can be used for diagnostics

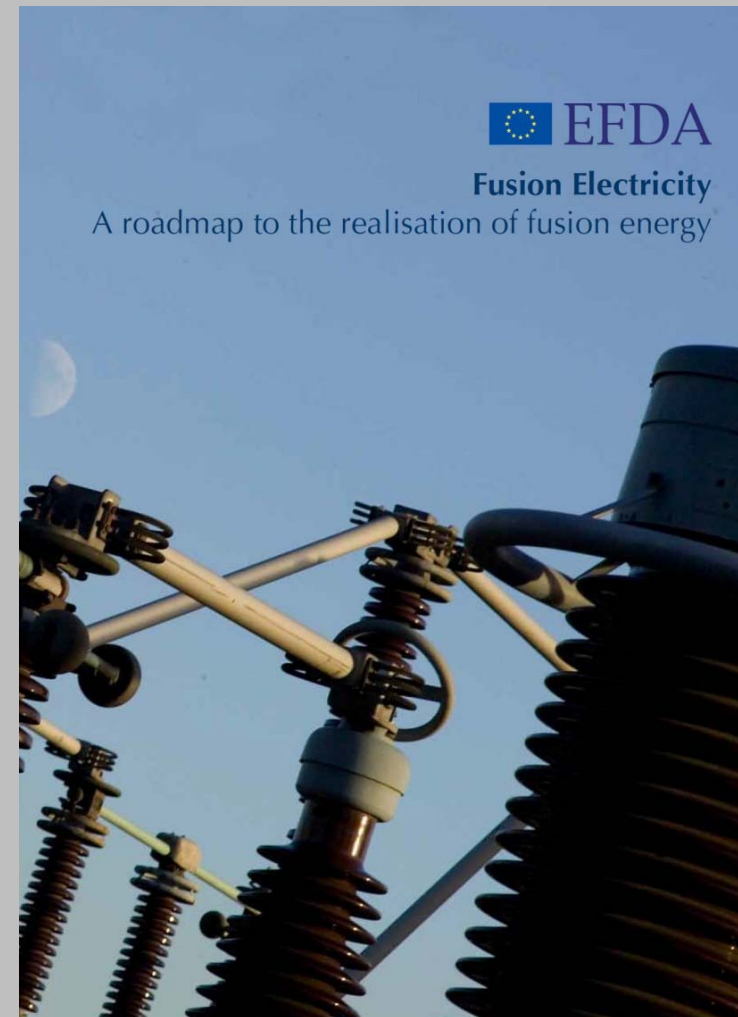
- ☹ They activate the wall

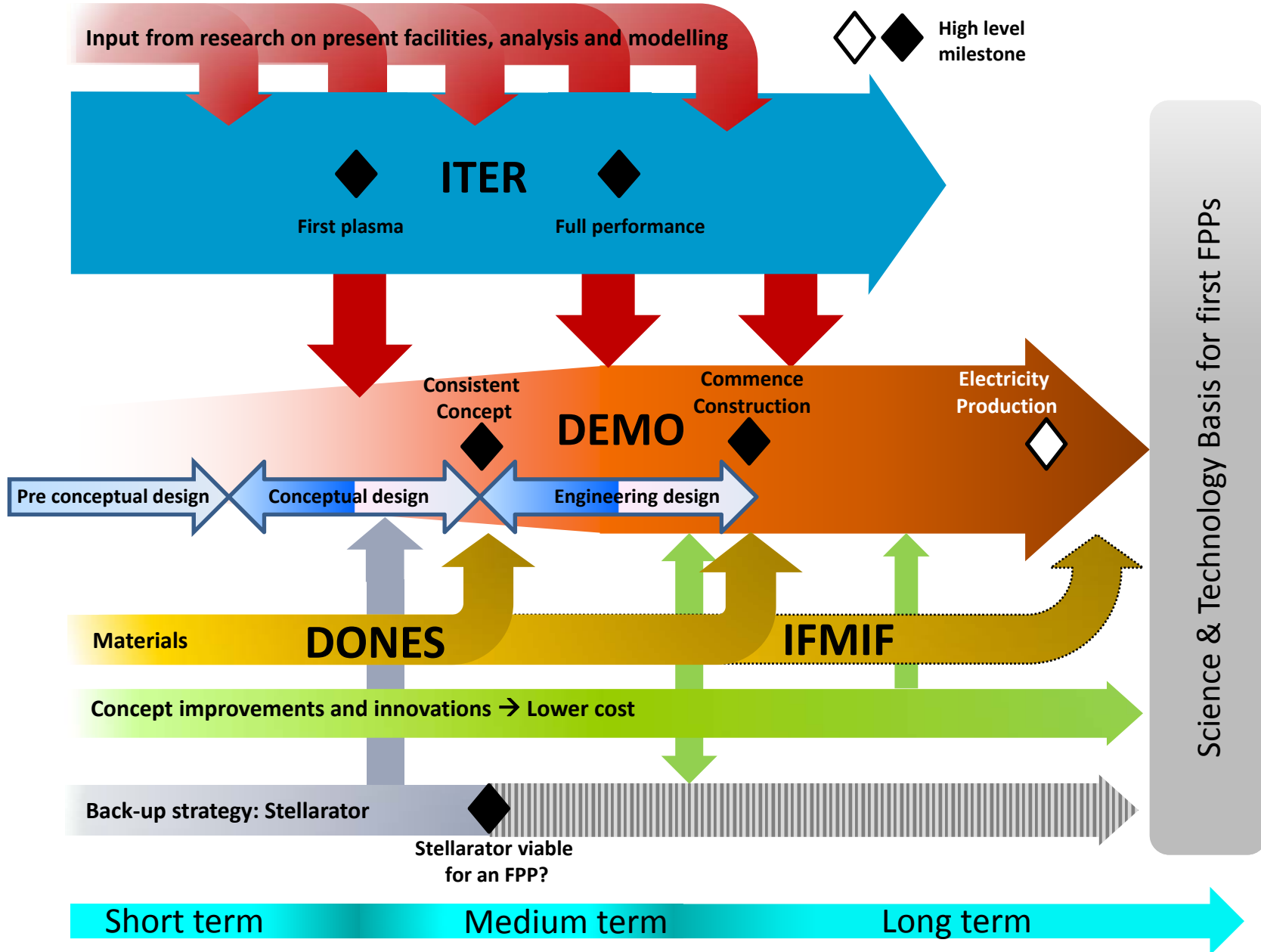


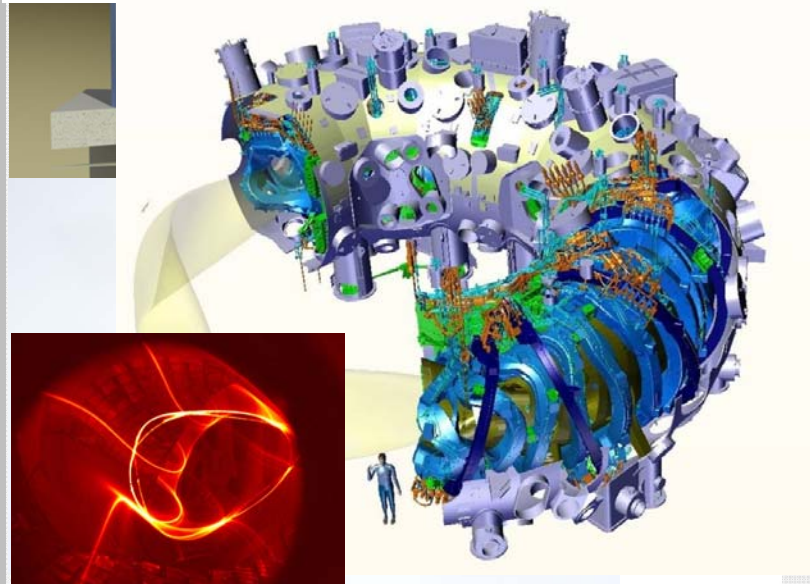
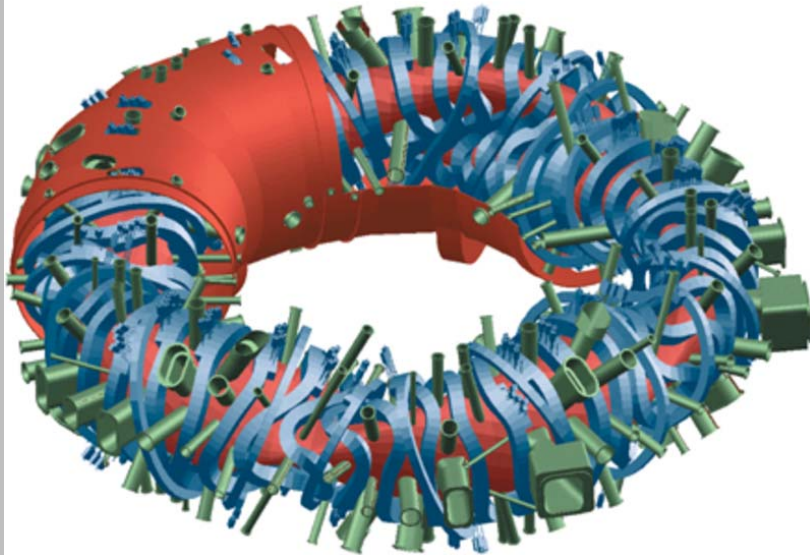
FUSION ROADMAP

DEMONSTRATE FUSION ELECTRICITY BY
THE MIDDLE OF THE CENTURY

- Founded on a number of technical assessment reports
- Provides coherent EU programme with a clear objective
- Avoids open-ended R&D









MST: Medium Size Tokamaks

Three European devices have been selected for input to the Fusion Roadmap in parallel with JET. These devices are:

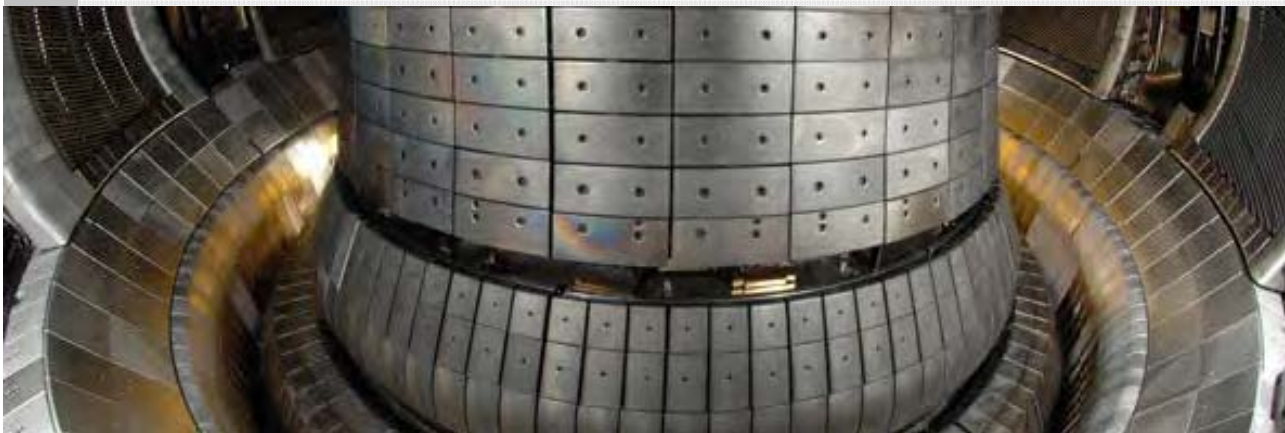


MAST Upgrade

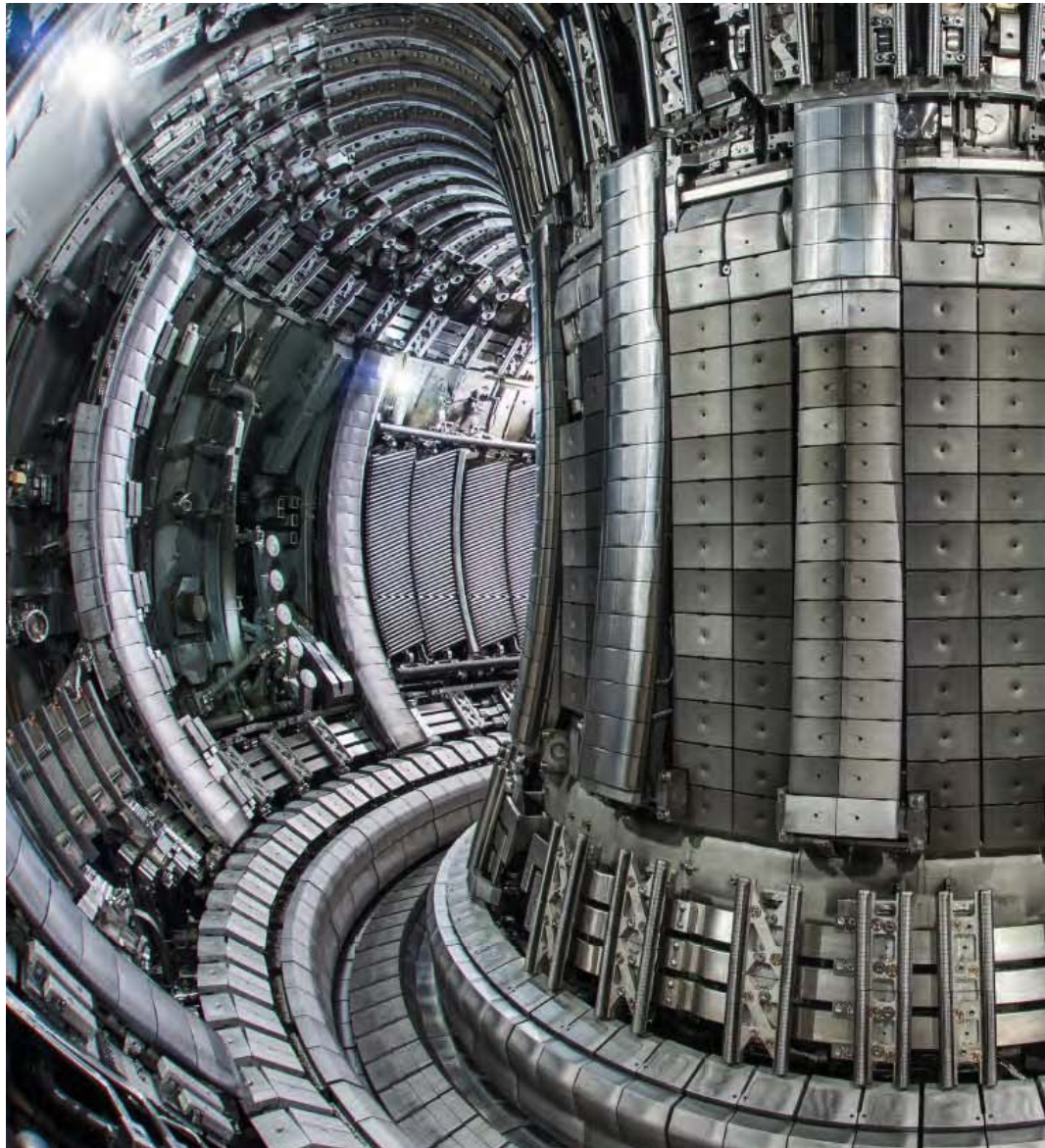


TCV

ASDEX Upgrade



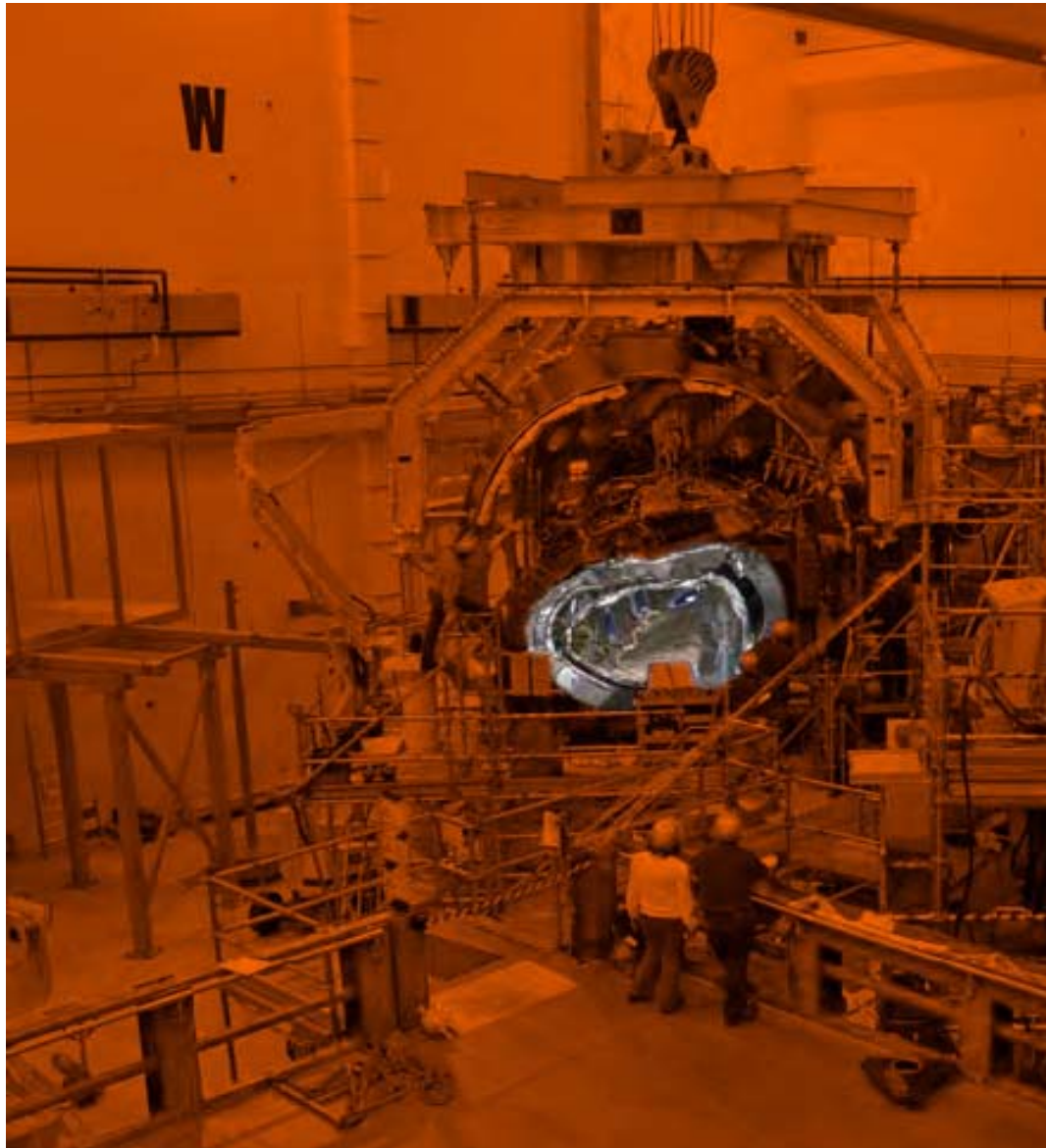
Images (left to right, to down) CCFE, www.ccf.ac.uk; Swisse Plasma Centre, <http://spc.epfl.ch>; Max Planck institute for Plasmaphysics, www.ipp.mpg.de
Image: Max Planck institute for Plasmaphysics, www.ipp.mpg.de, modified



JET – THE WORLD’S LARGEST TOKAMAK

This device is used by researchers from more than 40 European laboratories, co-ordinated by EUROfusion. Hosted and operated by Culham Centre for Fusion Energy in the UK.





WENDELSTEIN 7-X

New stellarator in Greifswald, Germany. Operating from 2015.



Experimental demonstration of closed flux surfaces

© M. Otte, IPP



The realisation of fusion electricity is feasible

EUROfusion coordinates the Fusion R&D in 28 European countries

75% of the EUROfusion effort is dedicated to supporting research for ITER

About 20% is being devoted to the conceptual design of the demonstration reactor

