Fusion energy - an abundant energy source for the future

Korsholm, Søren Bang

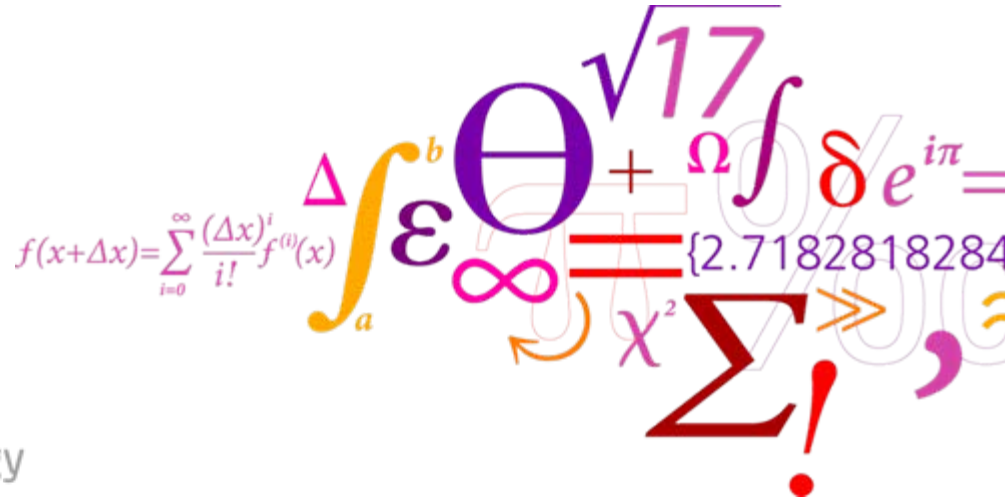
Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

Fusion Energy
– an abundant energy source for the future

Søren Bang Korsholm
Plasma Physics and Technology Programme, Risø DTU
Association Euratom-Risø DTU
sbko@risoe.dtu.dk

European Environment Agency,
Copenhagen 10 November



Risø DTU
National Laboratory for Sustainable Energy

Outline

- Fusion energy basics
- Aspects of resources and environment for fusion
- Status of fusion research
- ITER – the way towards fusion power plants

- Fusion in the energy system

Some pictures and figures of this presentation are courtesy of:
EFDA, EFDA-JET, and ITER.

Fusion in the sun

The energy of the sun is produced by fusion of hydrogen nuclei

$4H + 2e \rightarrow He + 5\gamma + 2\nu$ (+ 26 MeV)

The sun produces fusion energy continuously at a power of $3.6 \cdot 10^{17}$ GW!!!??

In the sun 600 mio. tons of hydrogen is converted into 596 mio. tons of helium every second

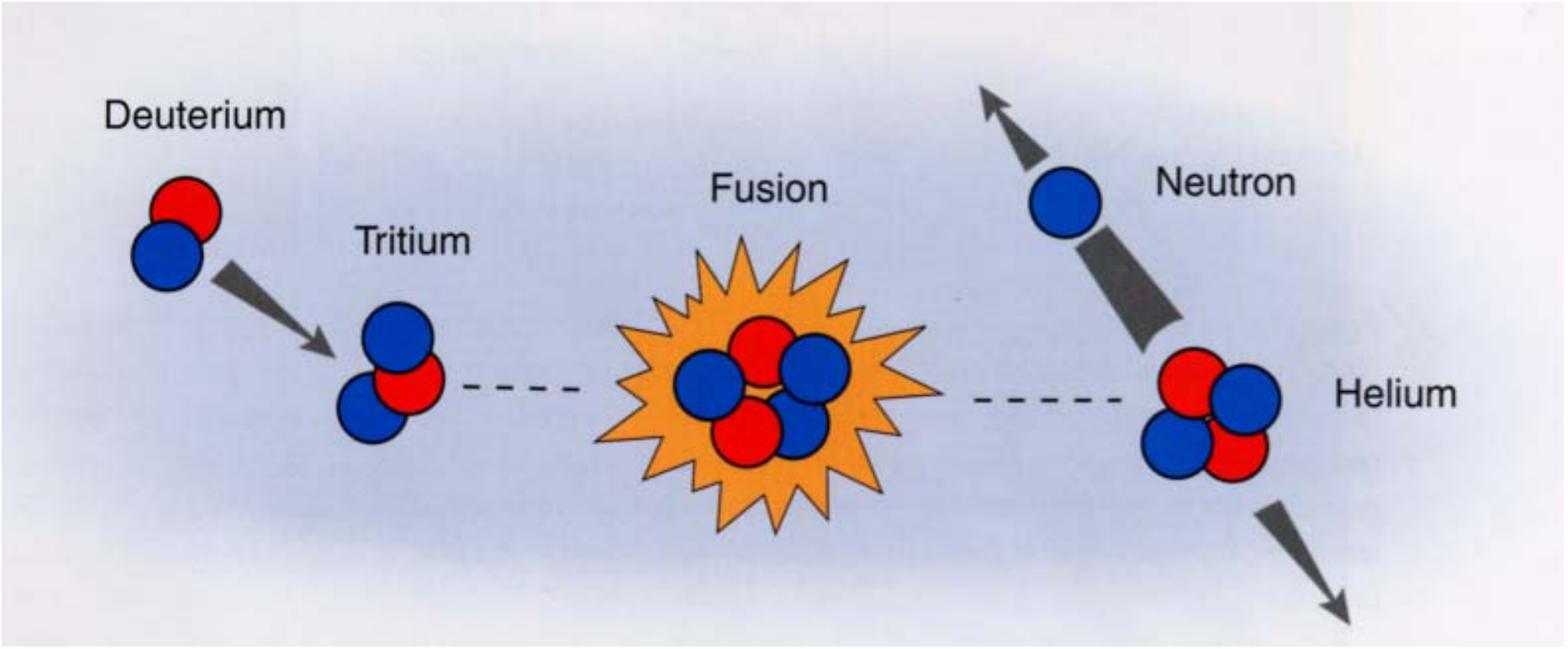
I.e. every second 4.000.000 tons of the solar mass is transformed into energy


Fusion is a universal energy source ...
... that we would like to utilize directly on earth

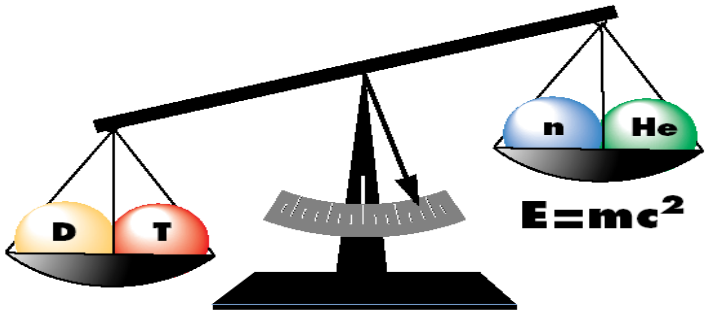
Fusion on Earth

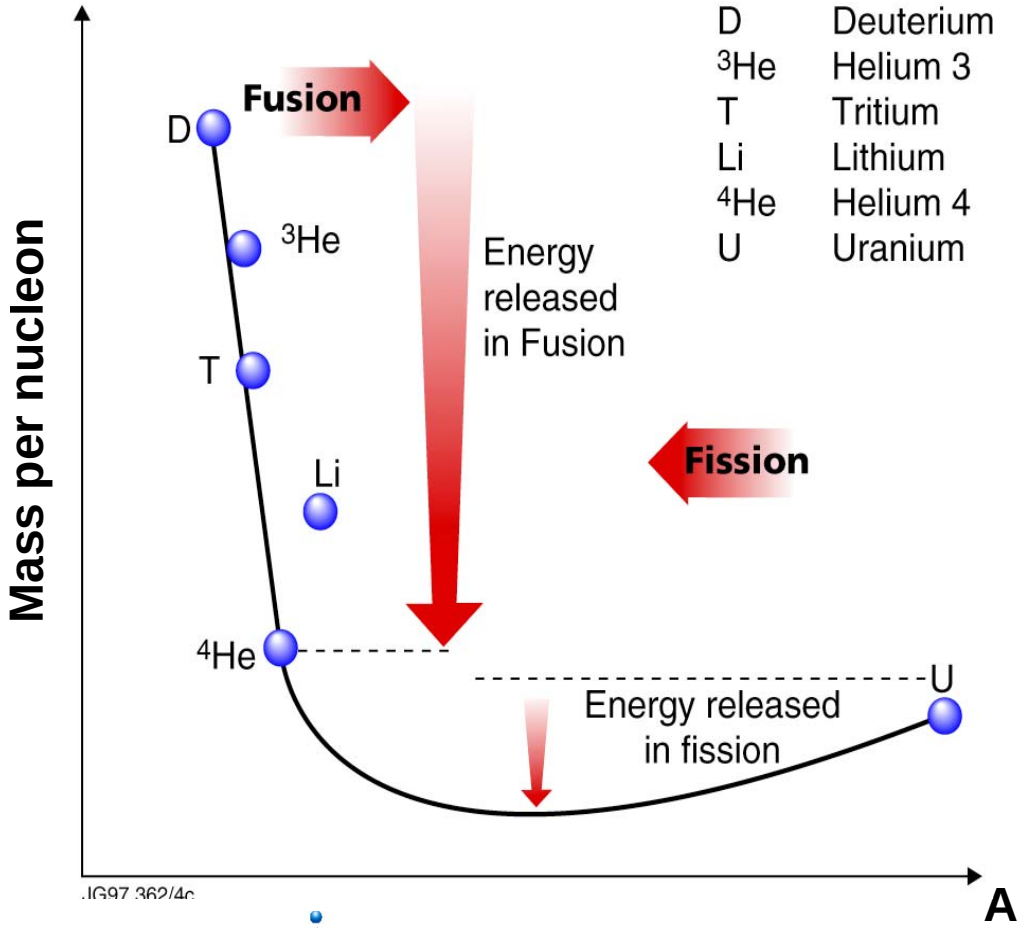
The most viable fusion process is:

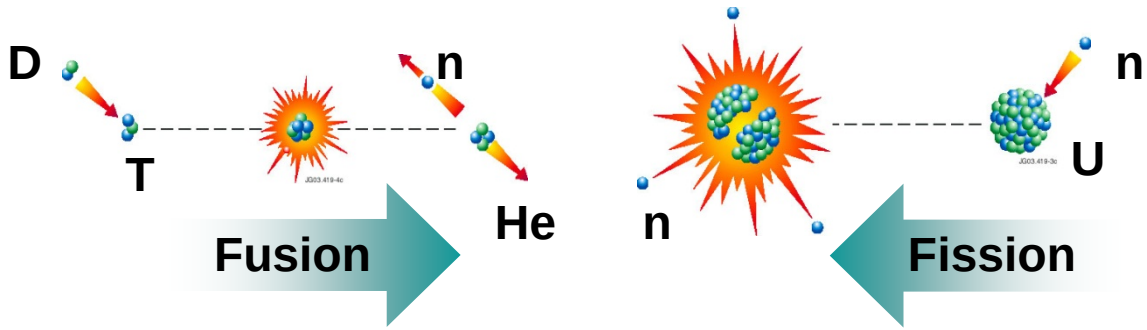
$$D + T \rightarrow He^4 + n + 17{,}6\ MeV$$



Fusion and fission nuclear processes







Energy from fusion

Lifelong energy supply for a Dane

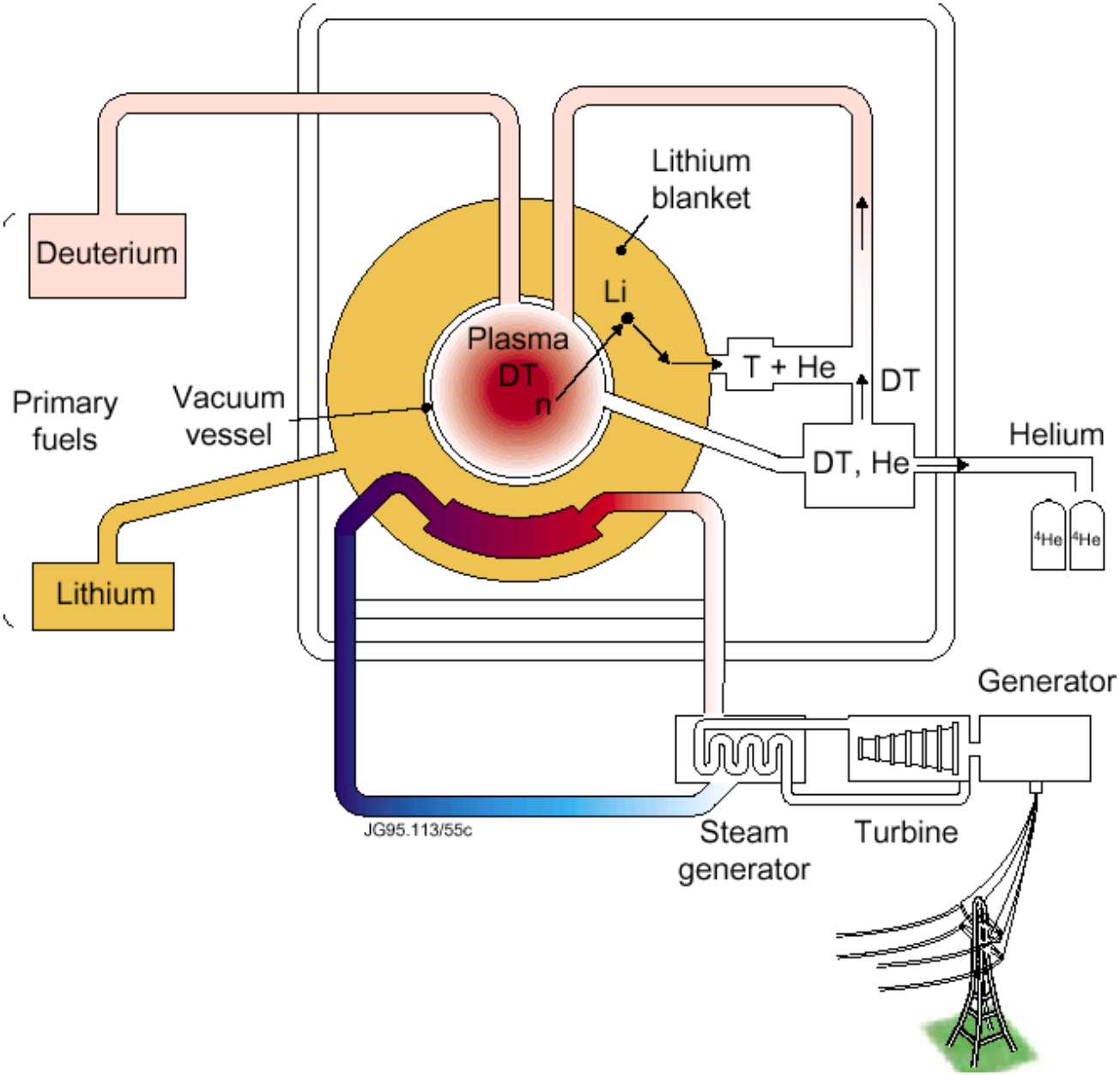
- 10 g deuterium (from 500 L water)
- 15 g tritium (from 30 g lithium)

- Fusion energy in D-content in
  1 L water = burn value of 300 L oil

- A 1 GW_e power plant needs annual supplies of:
  - 2.700.000 tons coal or
  - 1.900.000 tons oil or
  - ¼ tons D+T (450 kg D+Li)

At the present energy consumption, resources for fusion energy are sufficient for more than 10,000,000,000 years

Principle of a fusion power plant

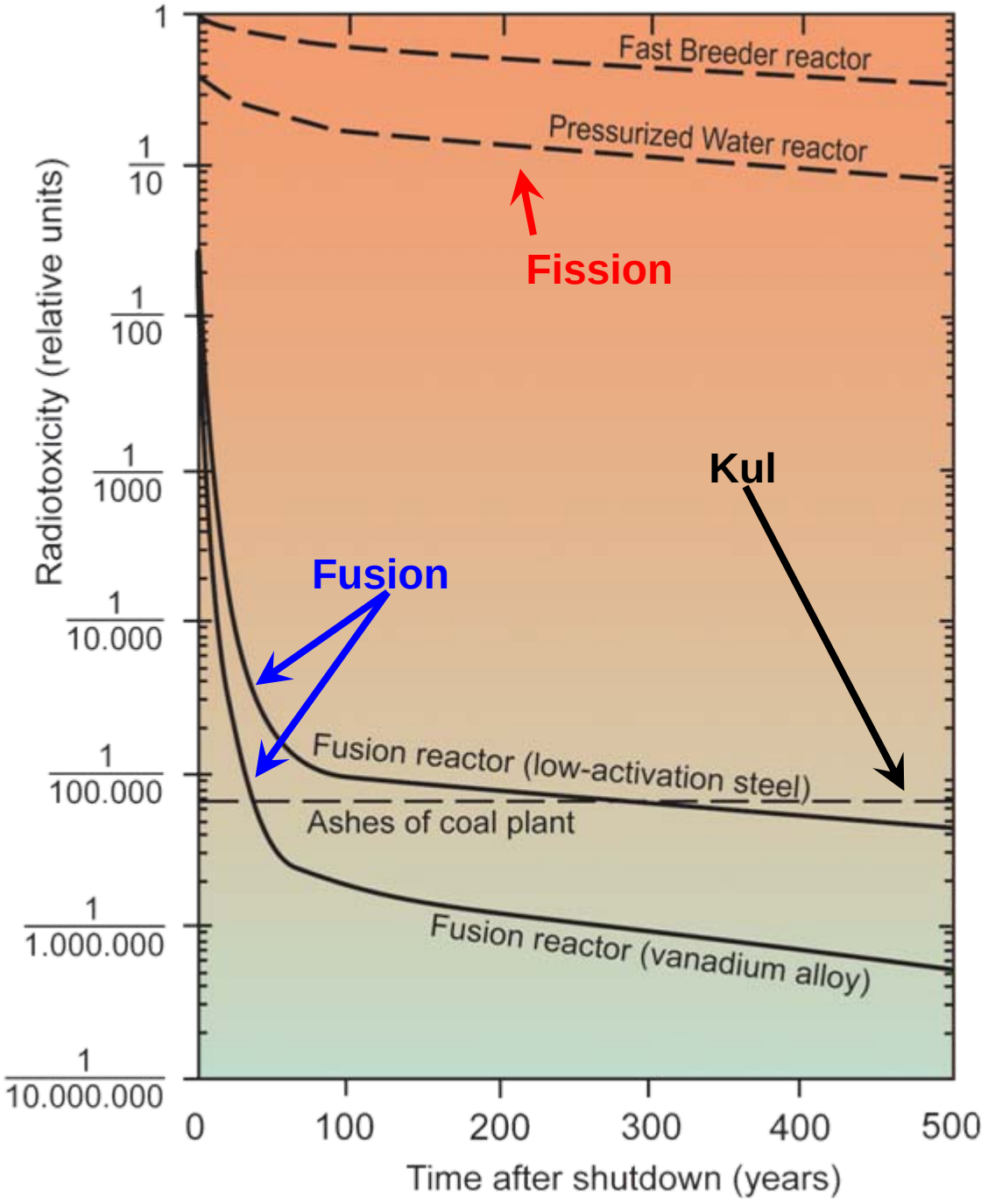


Fusion in an energy system

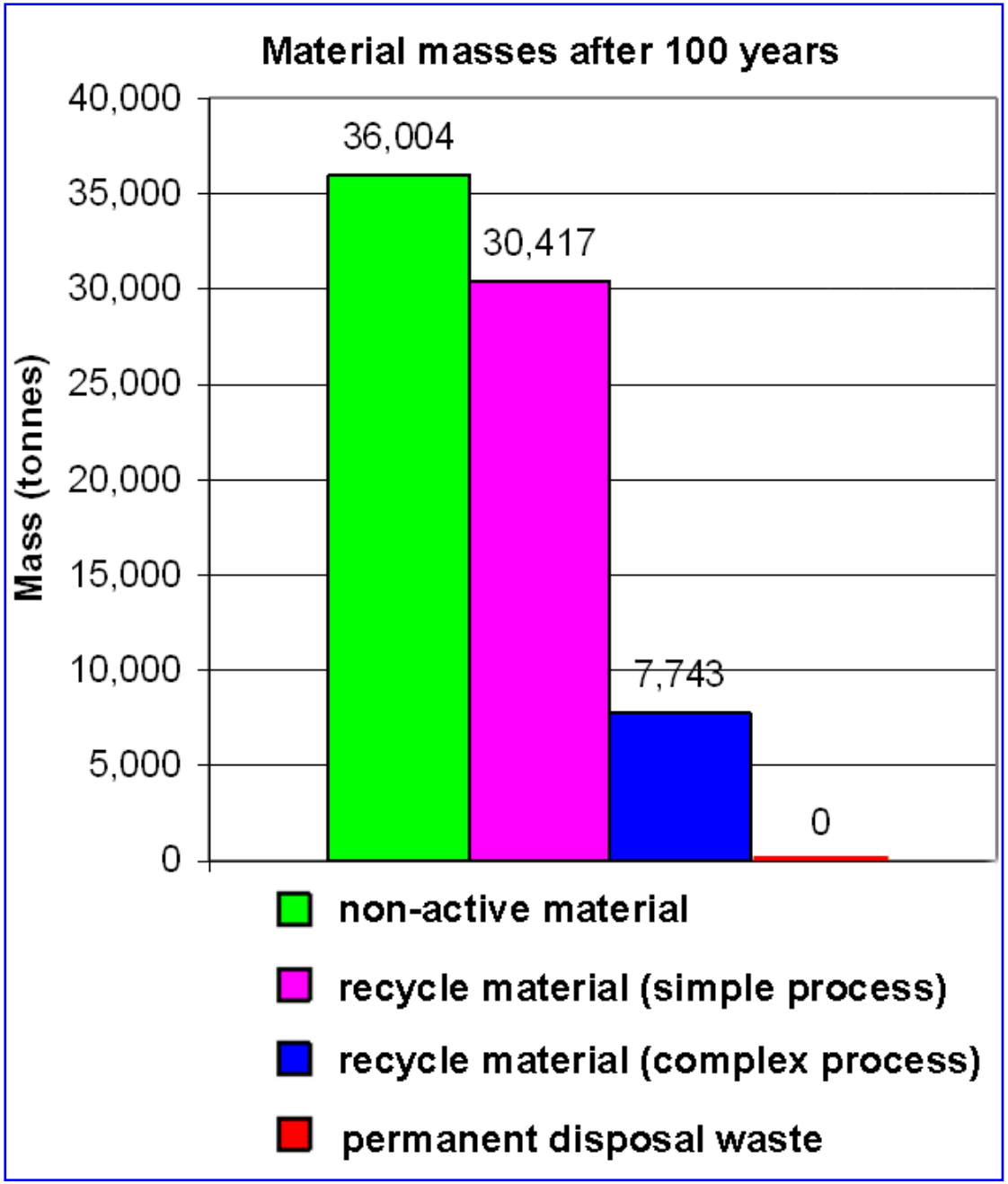
- Economically sound – price similar to other sustainable energy sources
- Units of 1.5 GW electric
- Power plants for base load and primary energy production of:
  - Electricity
  - Hydrogen
- May deliver energy for all sectors incl. transport

Fusion and environment

- No emission of CO_2
- Radioactivity in the reactor decays in about 50 years
- Recyclable components
- No long-term storage of waste



Decommissioning and waste



Categorisation of all material arising from the operation and decommissioning of PPCS model B after 100 years.

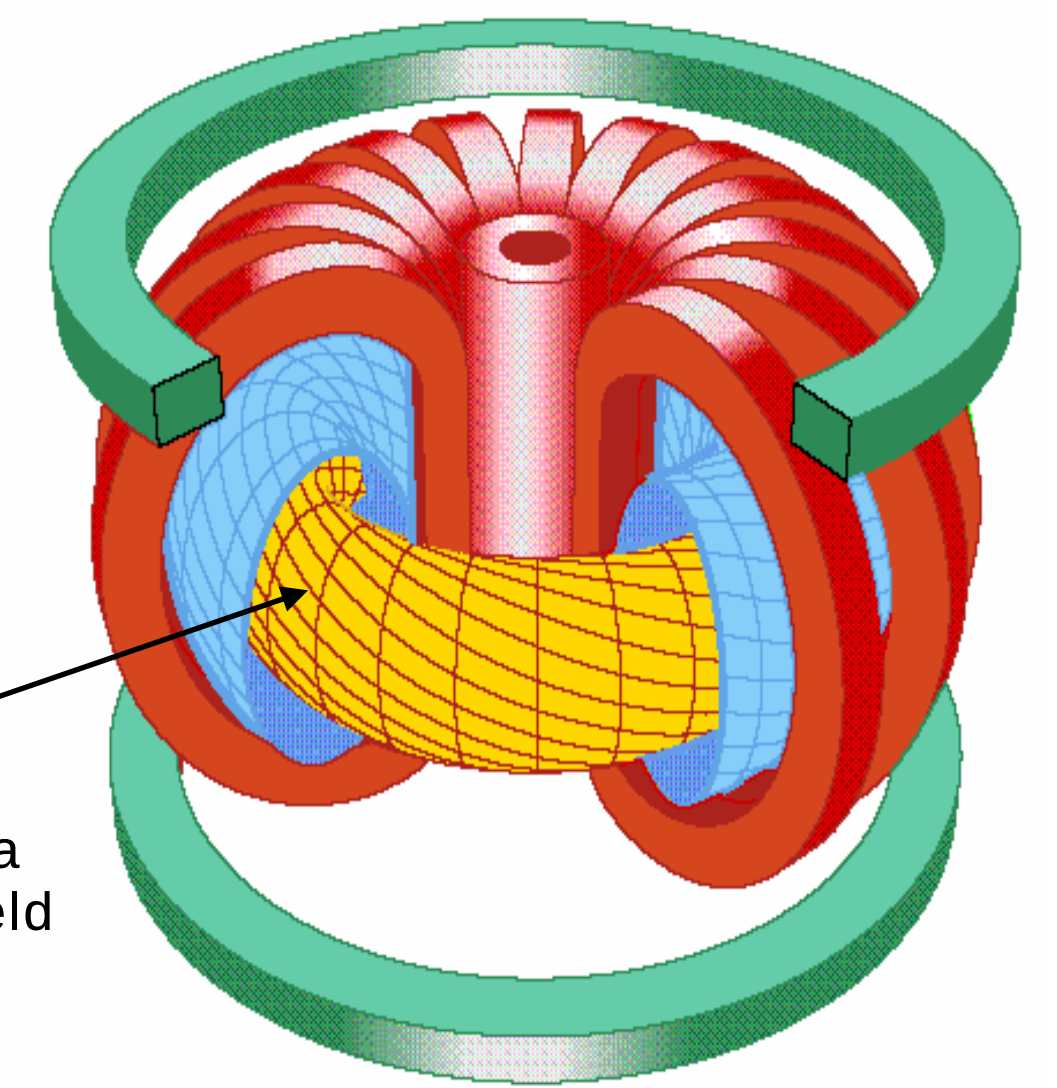
D. Maisonnier et al., Fusion Engineering and Design 75–79 (2005) 1173–1179

Fusion, safety and environment

- No CO_2 emission
- No chain reactions
- No risk of meltdown
  - overheating of fuel $\Rightarrow$ reduced fusion rate
  - 2 g of fuel – fuel needs to be supplied continuously
  - loss of control $\Rightarrow$ immediate cooling of fuel against the wall
- No transport of radioactive fuel or waste
- No production of long-lived radioactive waste (activated waste for less than 100 years)

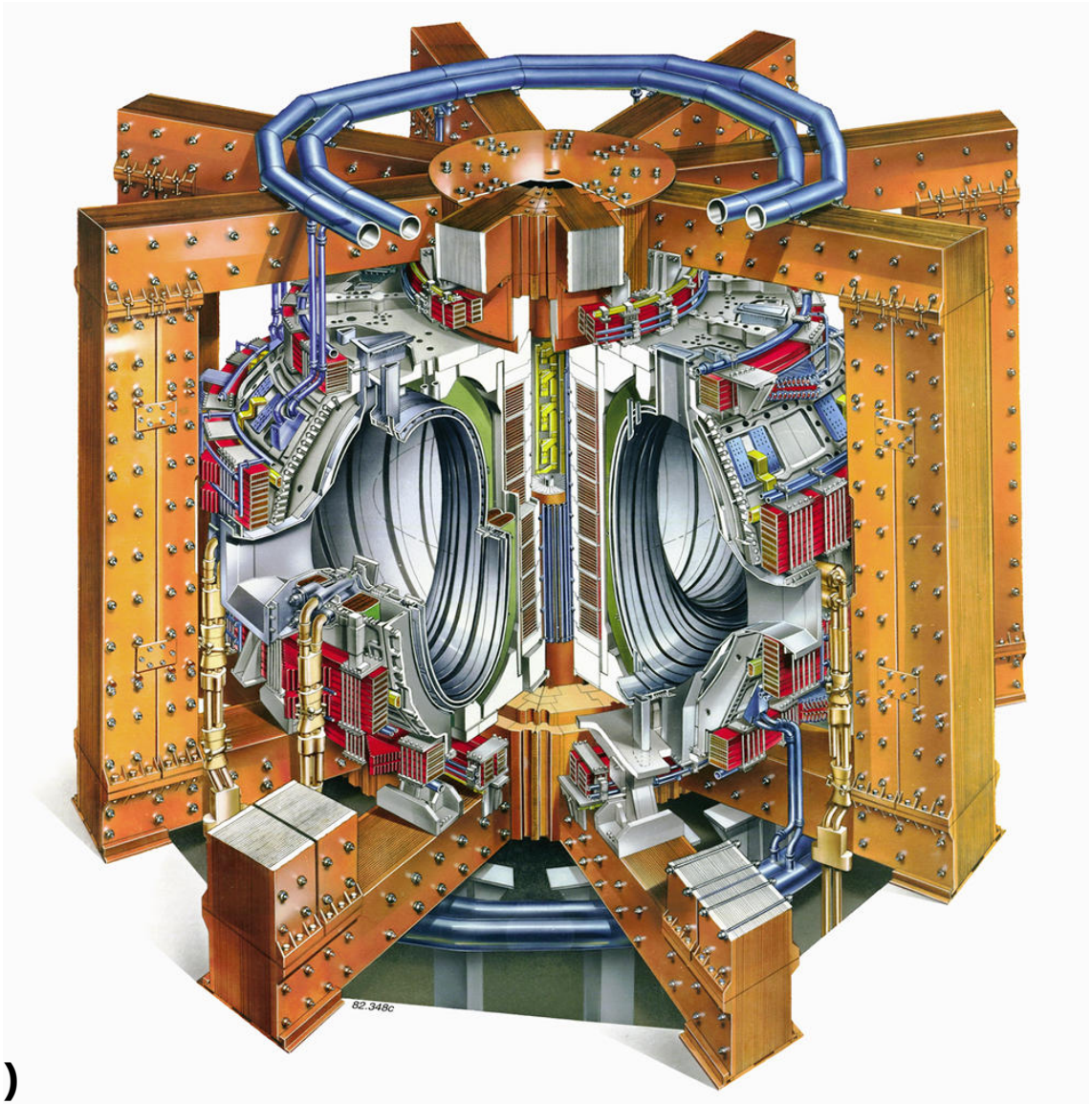
The tokamak

Heating of fuel to 200 million ˚C => plasma



Plasma is confined in a magnetic field

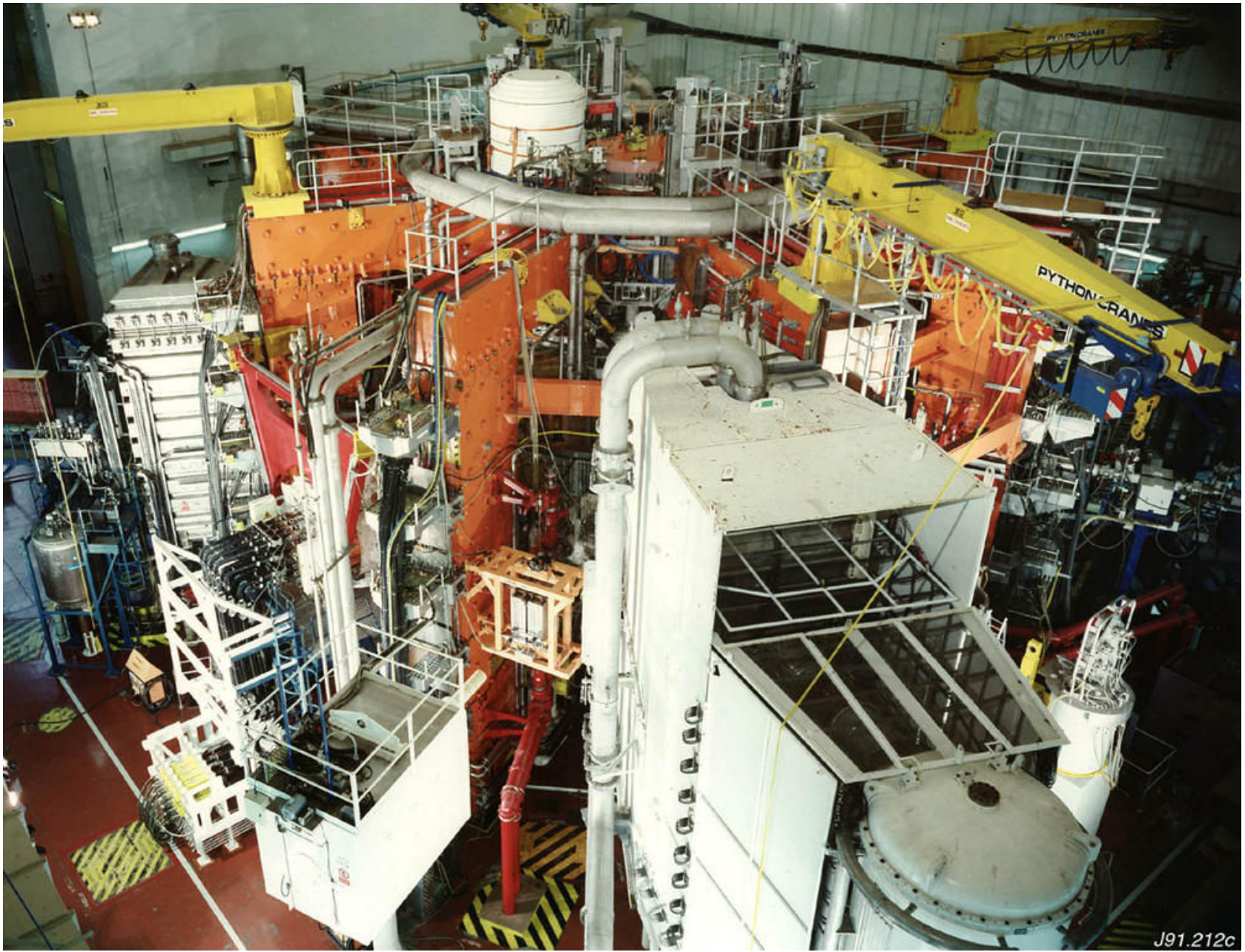
The Worlds largest tokamak: JET (Joint European Torus)



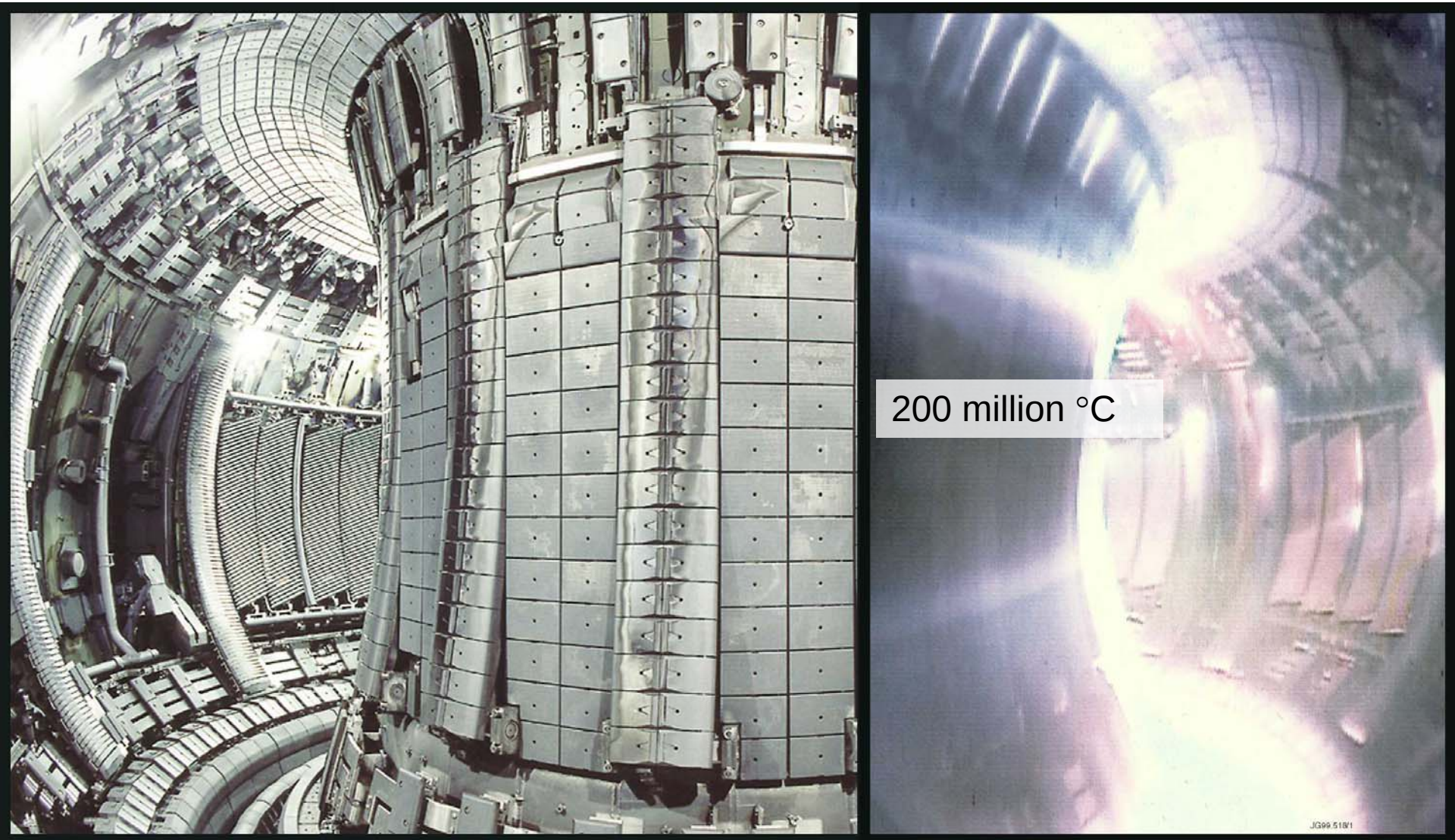
Built 1983,

near Oxford (UK)

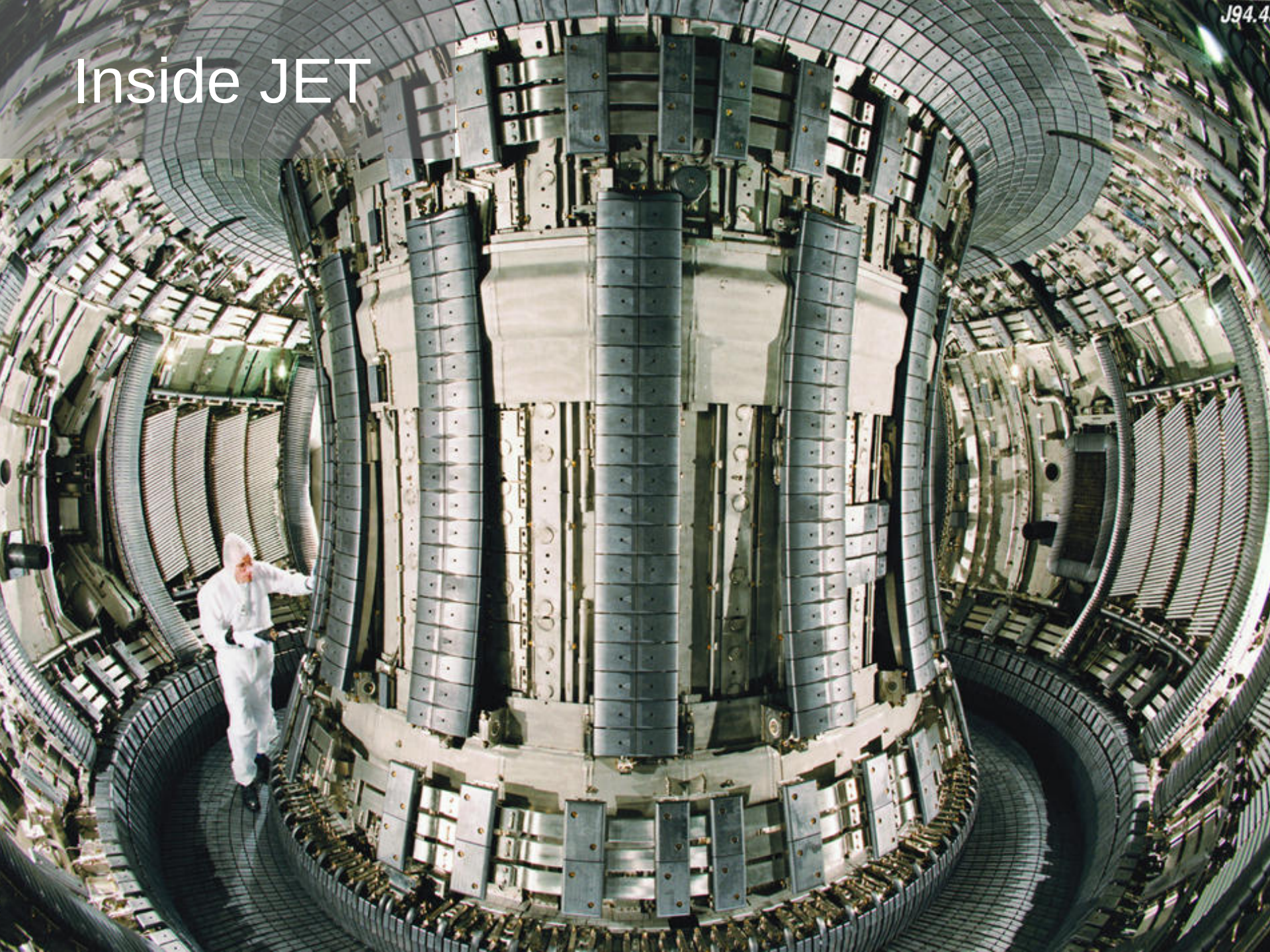
JET torus building - 1991

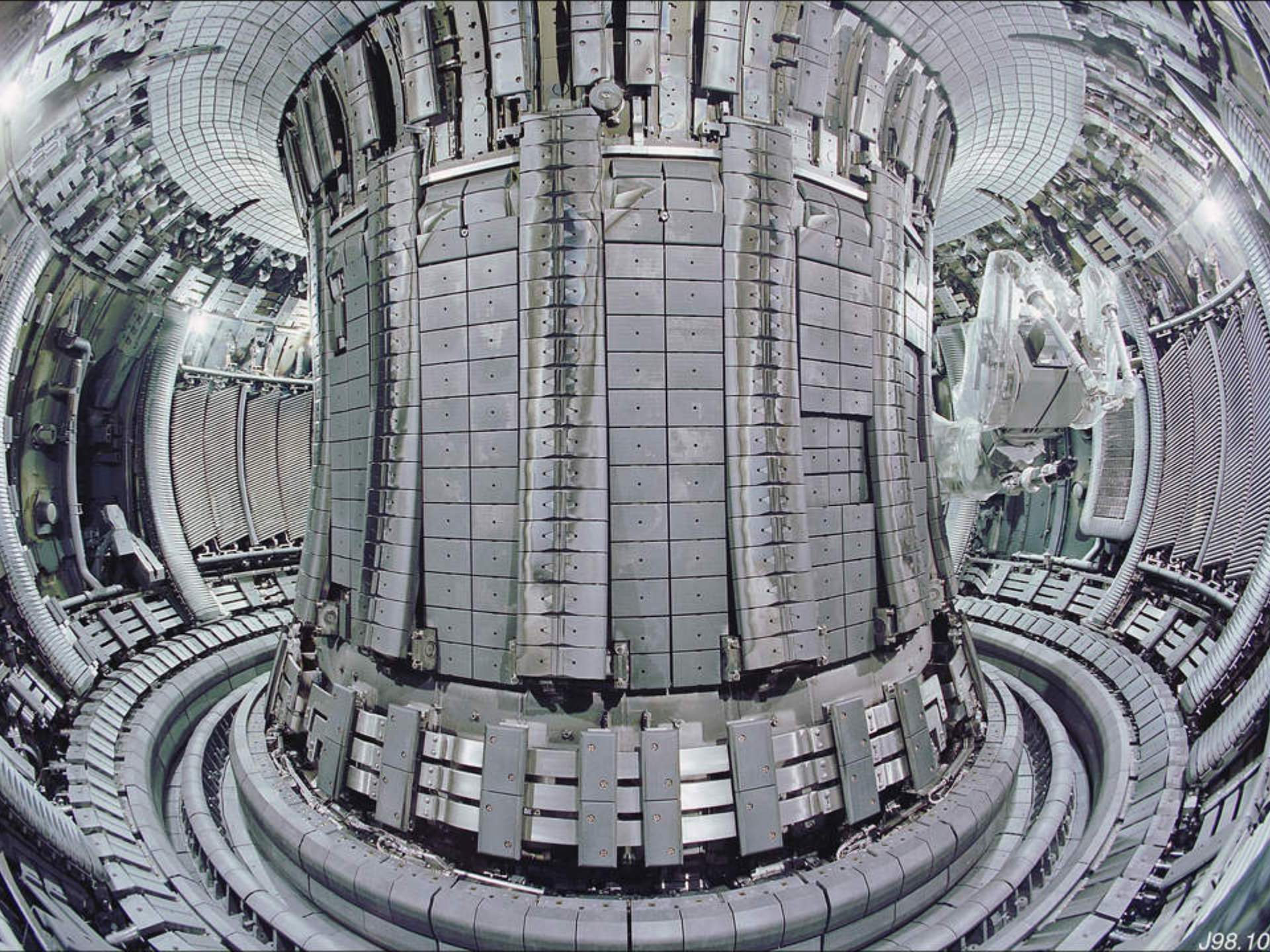


Fusion plasma in JET



Inside JET

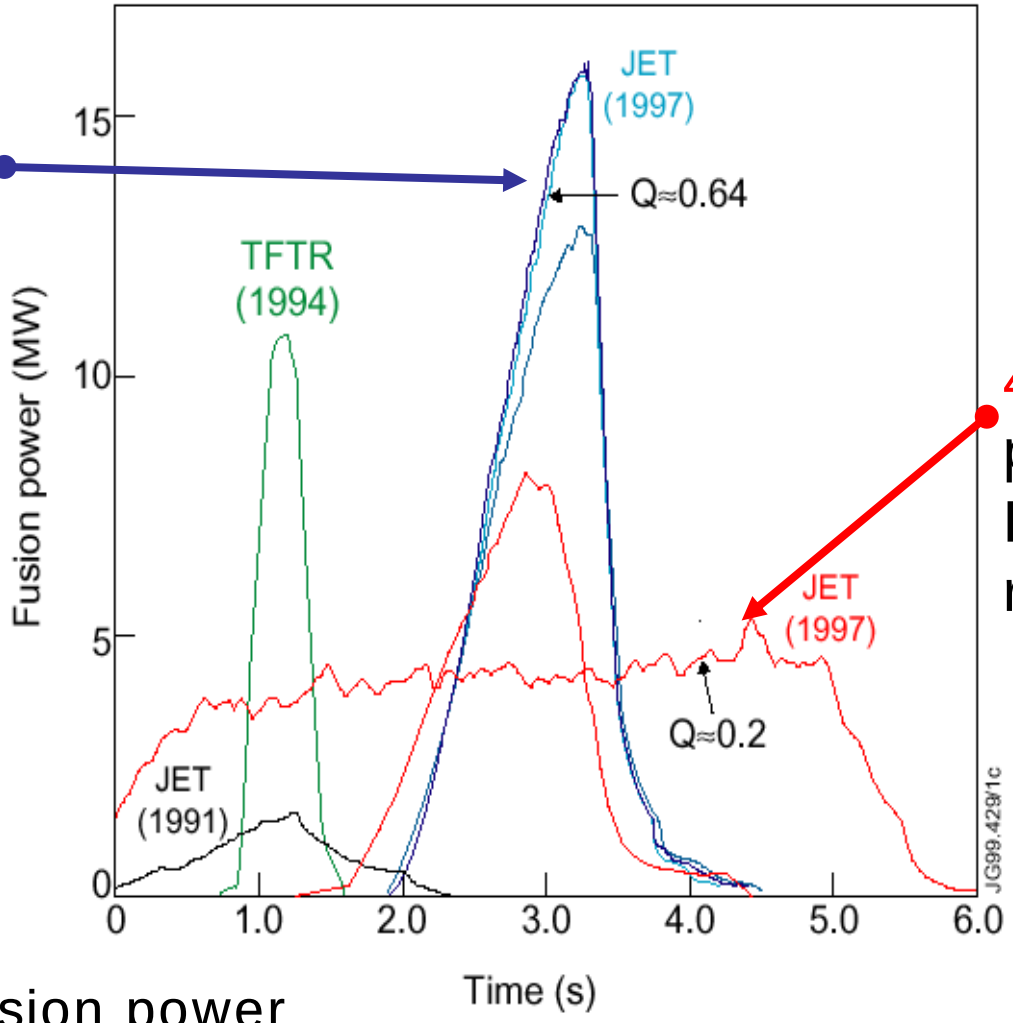



J98.10

Achieved fusion power in D-T plasmas

16 MW fusion power (***record***)

Q~0.64

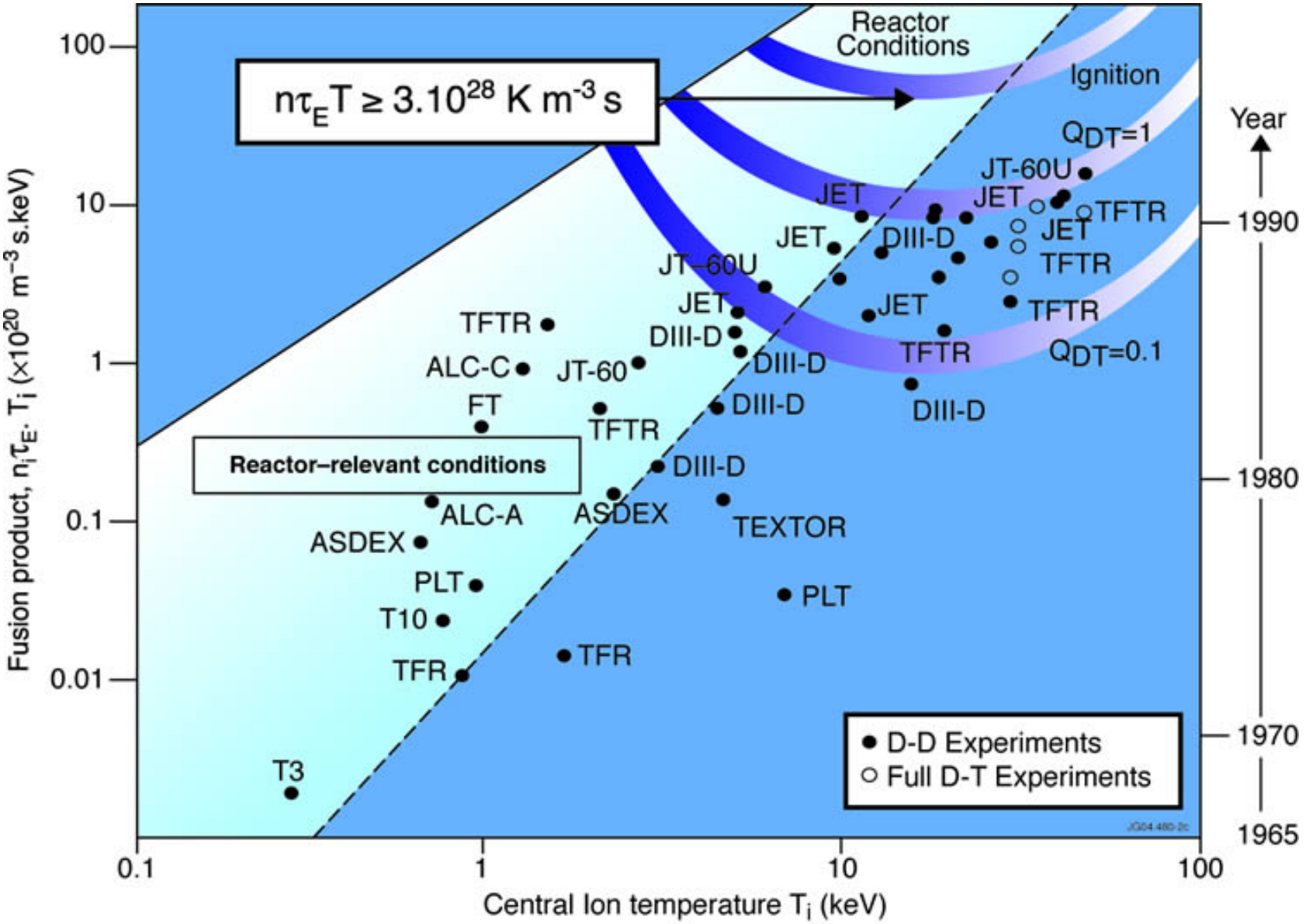


4 MW fusion power. Reference regime for ITER

$$Q = \frac{\text{Fusion power}}{\text{External heating power}}$$

Fusion performance factor

Triple product: $n_i \tau_E T_i$



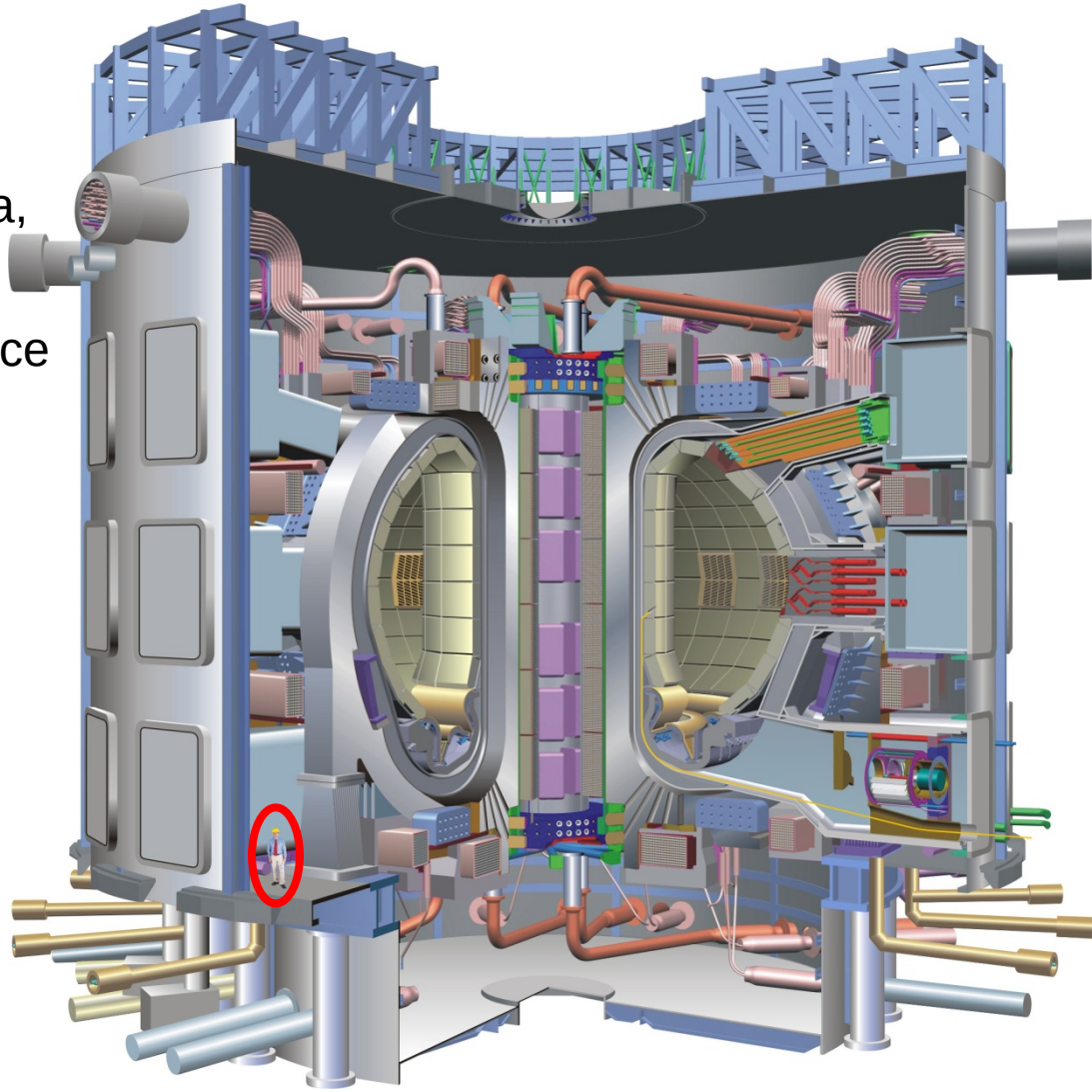
ITER

Decision 28th June 2005:

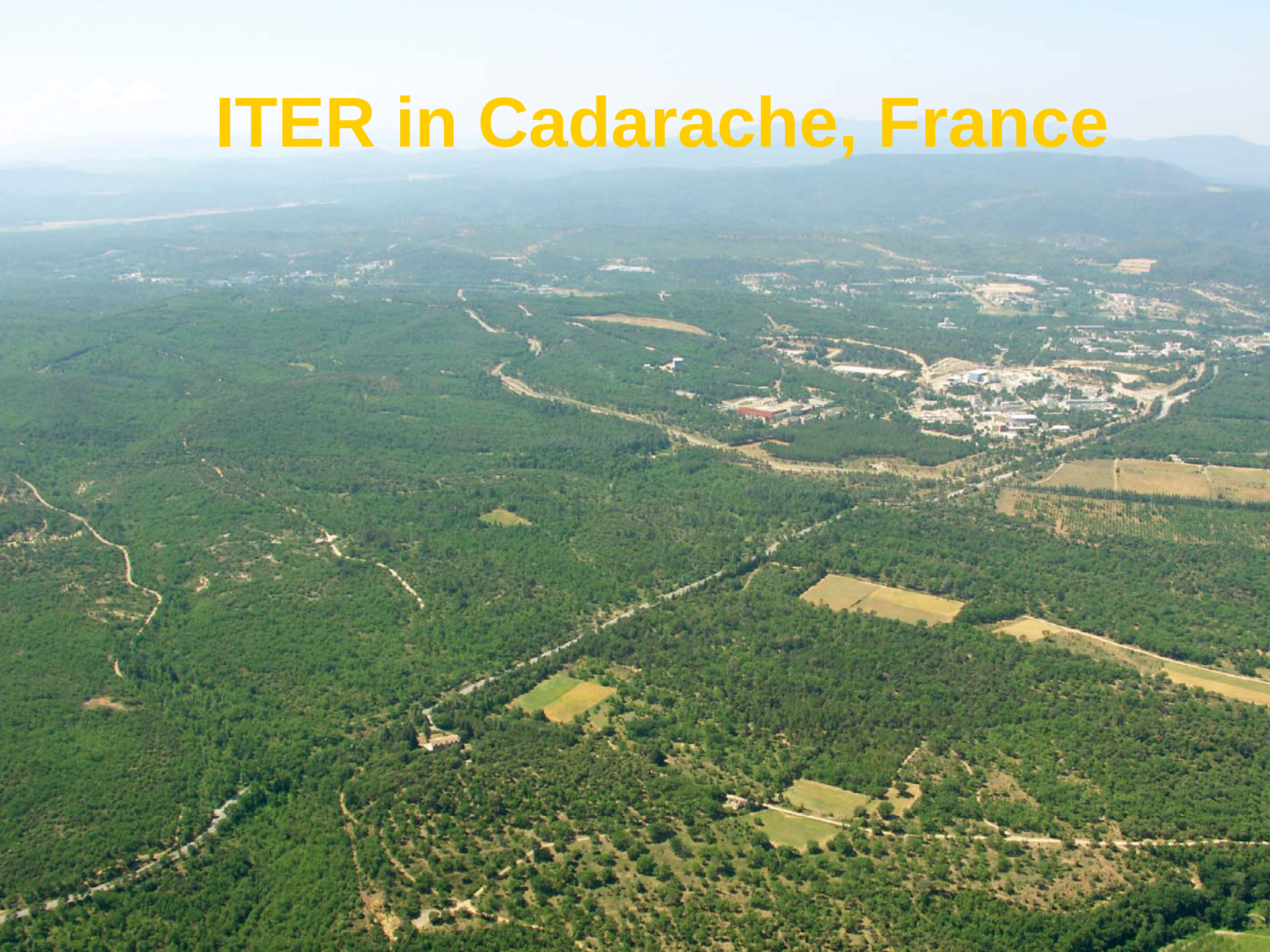
- 7 partners: EU, India, Japan, China, Korea, Russia and USA
- EU host; location in Southern France
- EU delivers 40 % of ITER

Construction

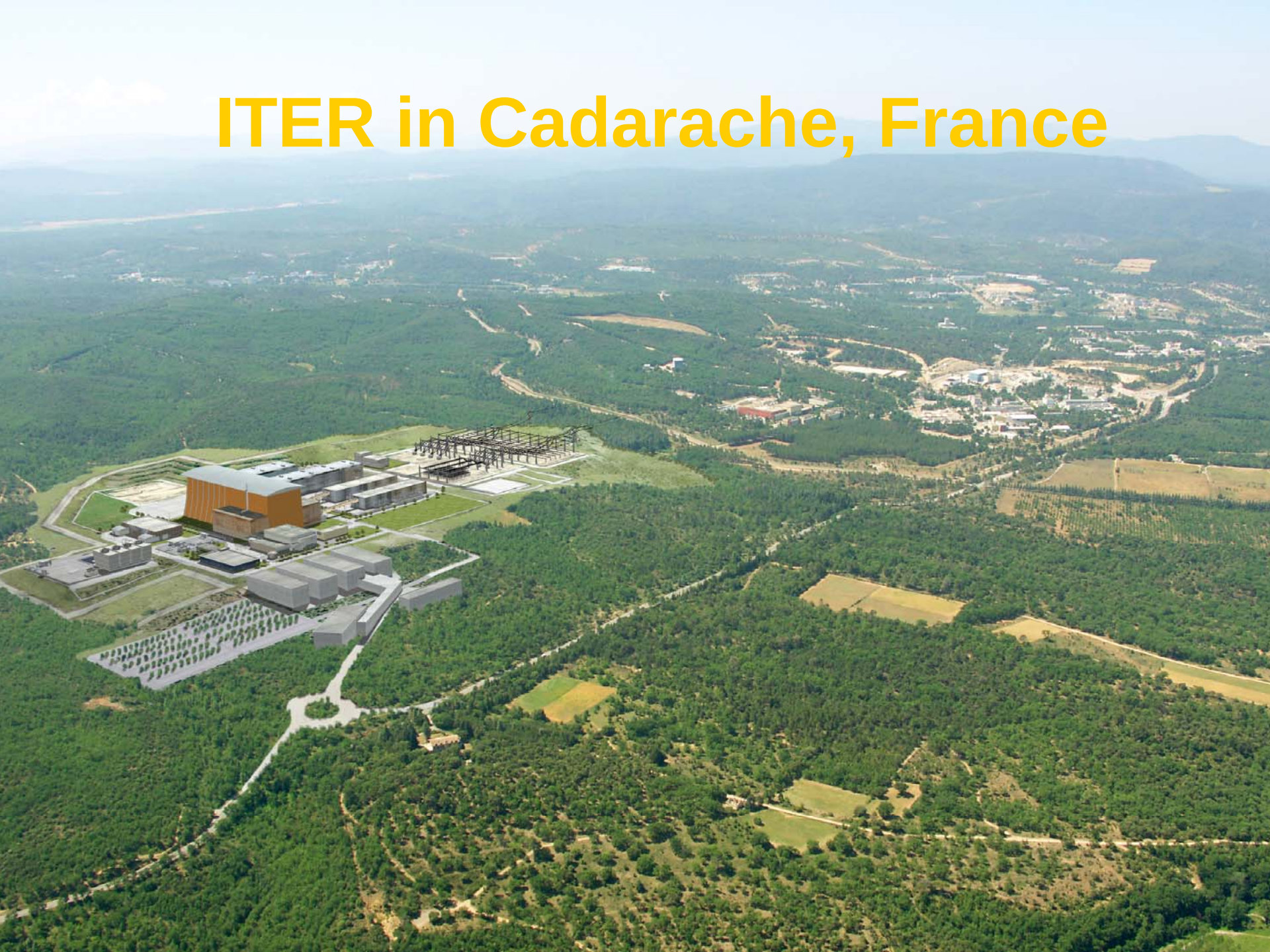
- 5+ billion Euros
- 10 years
- First contracts in 2008
- Ready in 2018



ITER in Cadarache, France



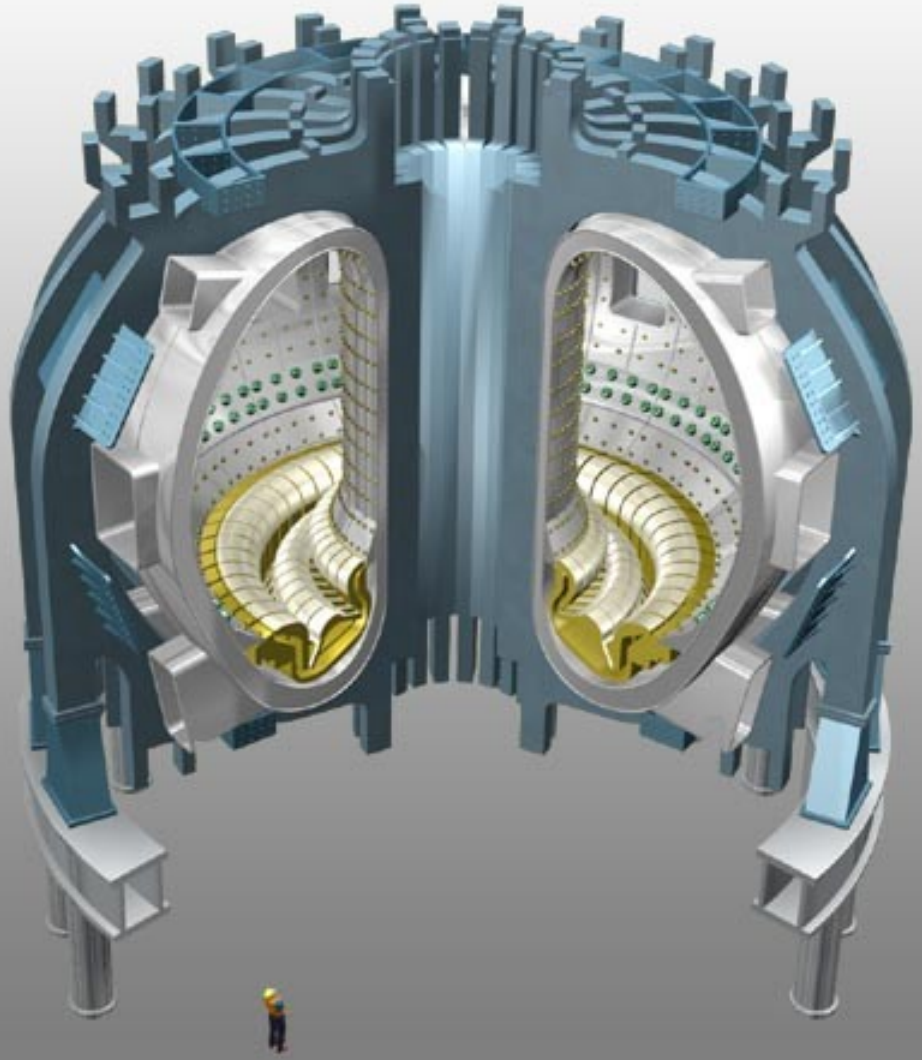
ITER in Cadarache, France

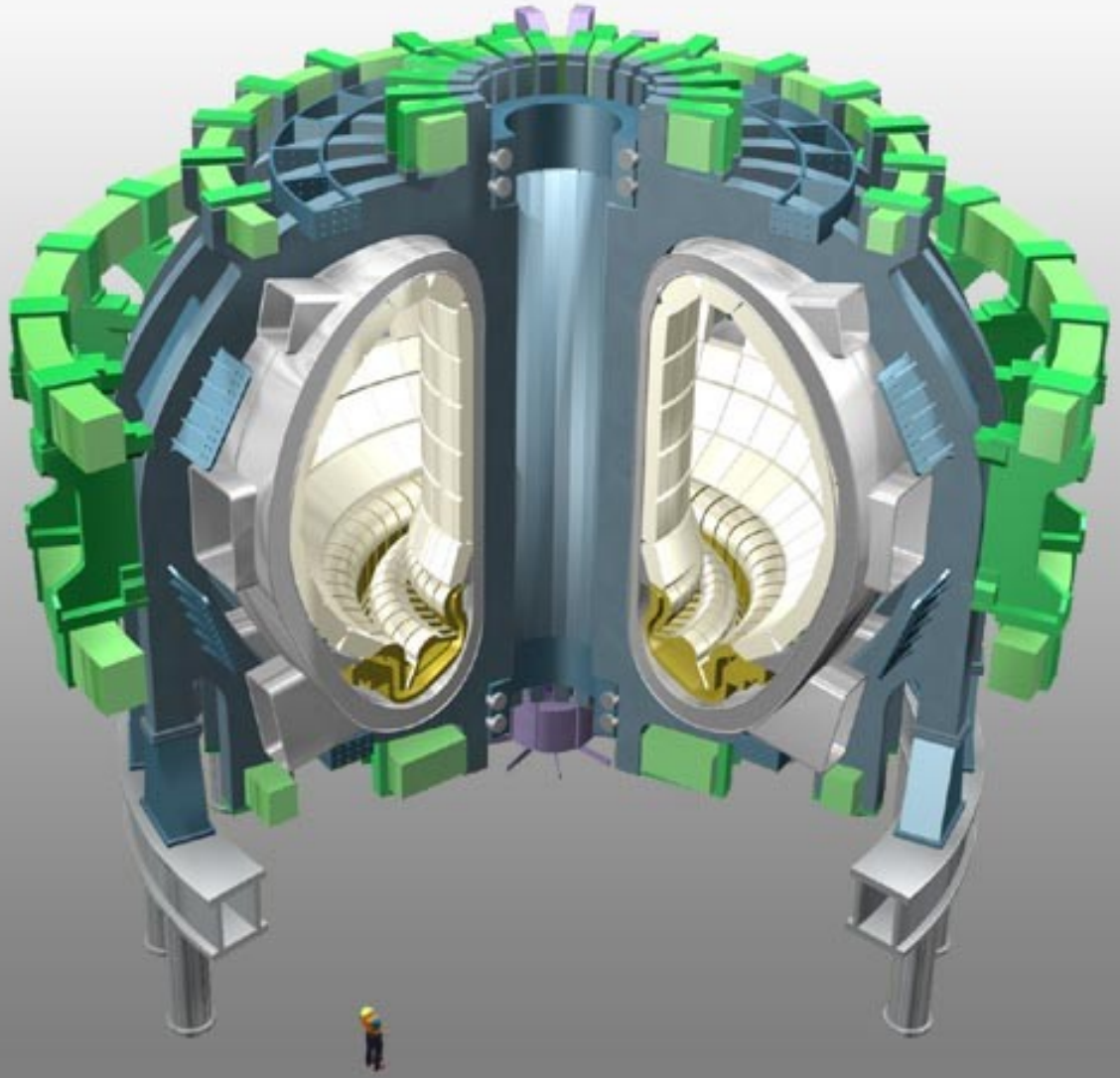


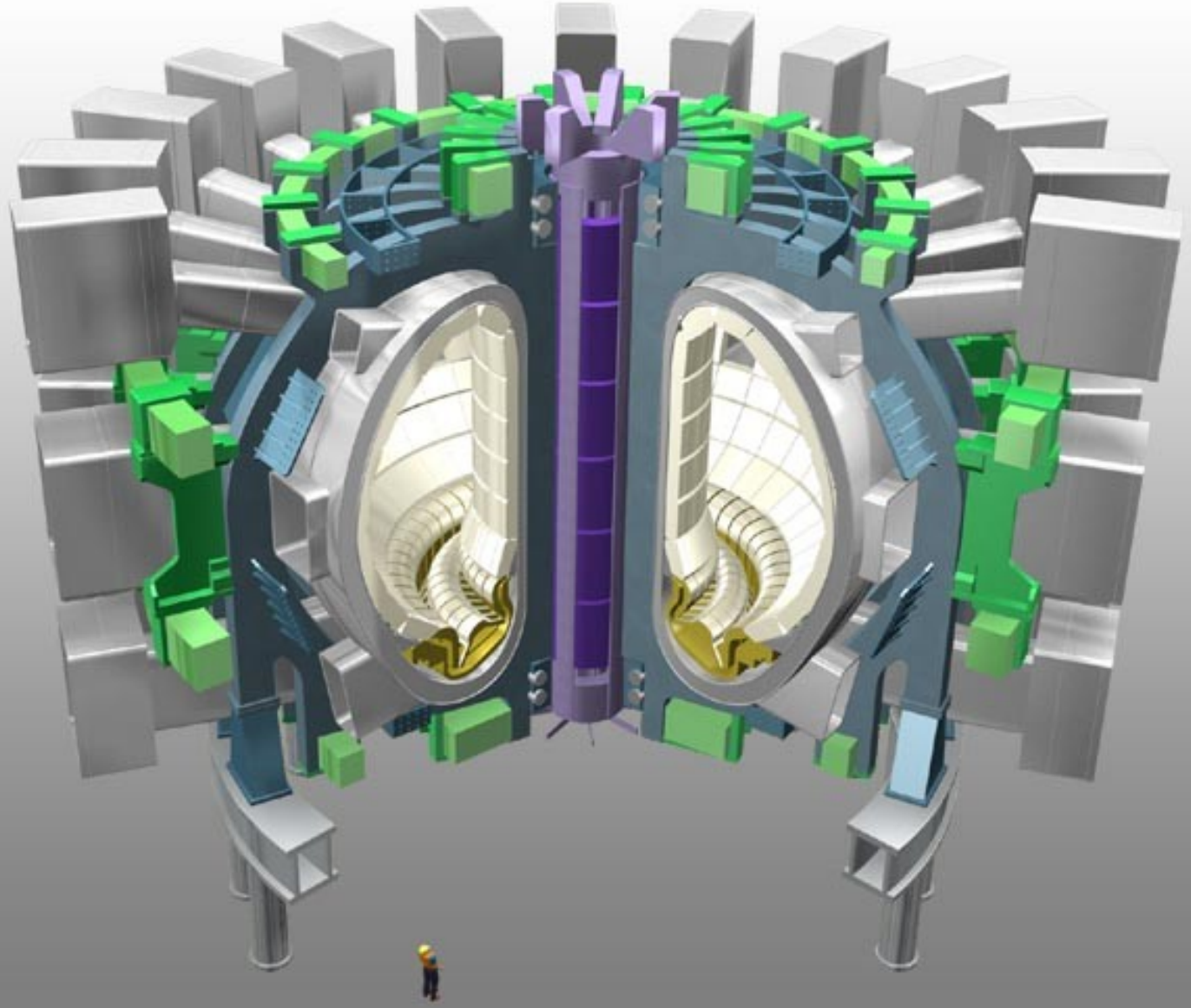
ITER site now – 6th Nov 2009

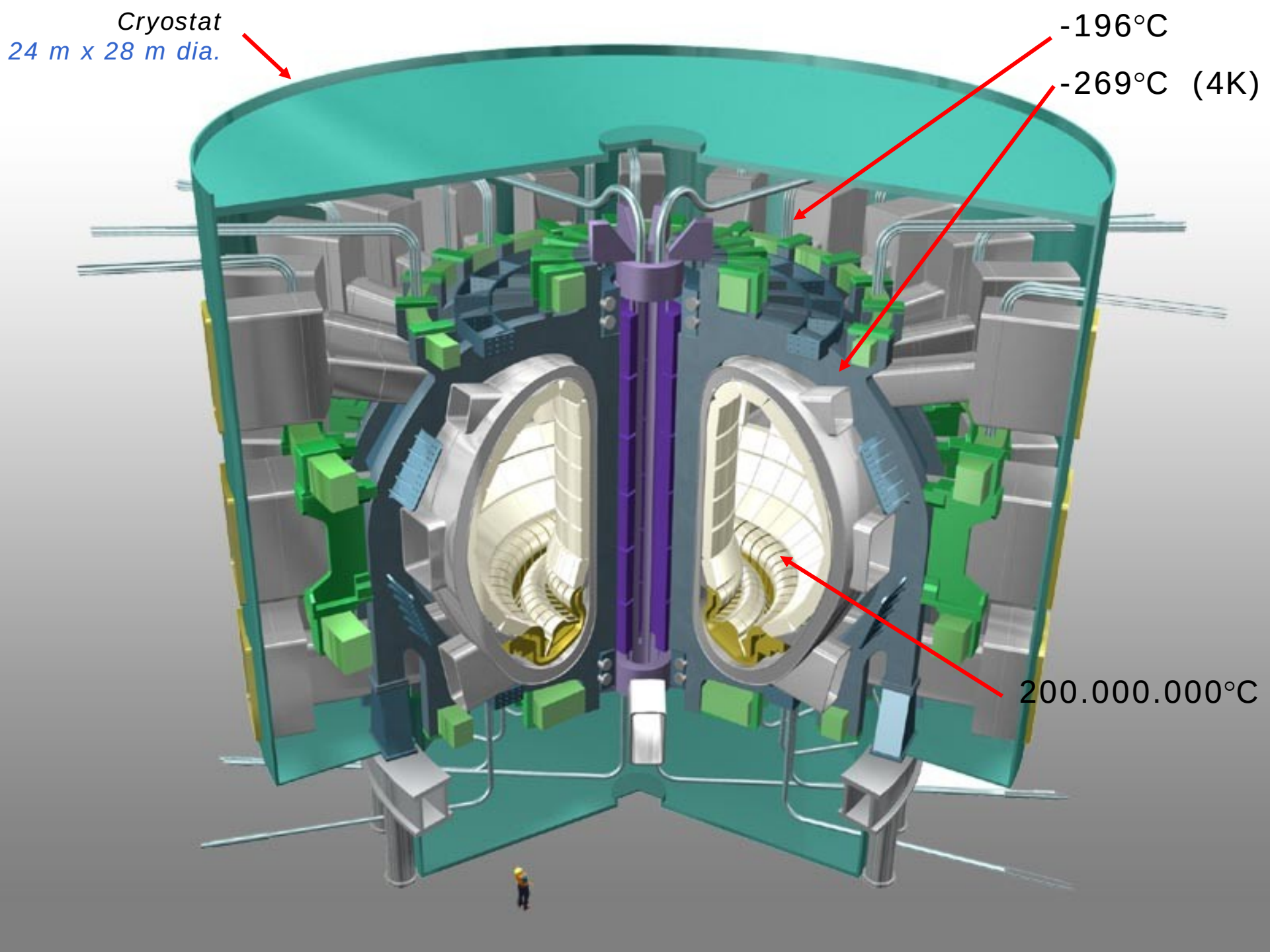
ITER site now – 6th Nov 2009

ITER site now – 6th Nov 2009

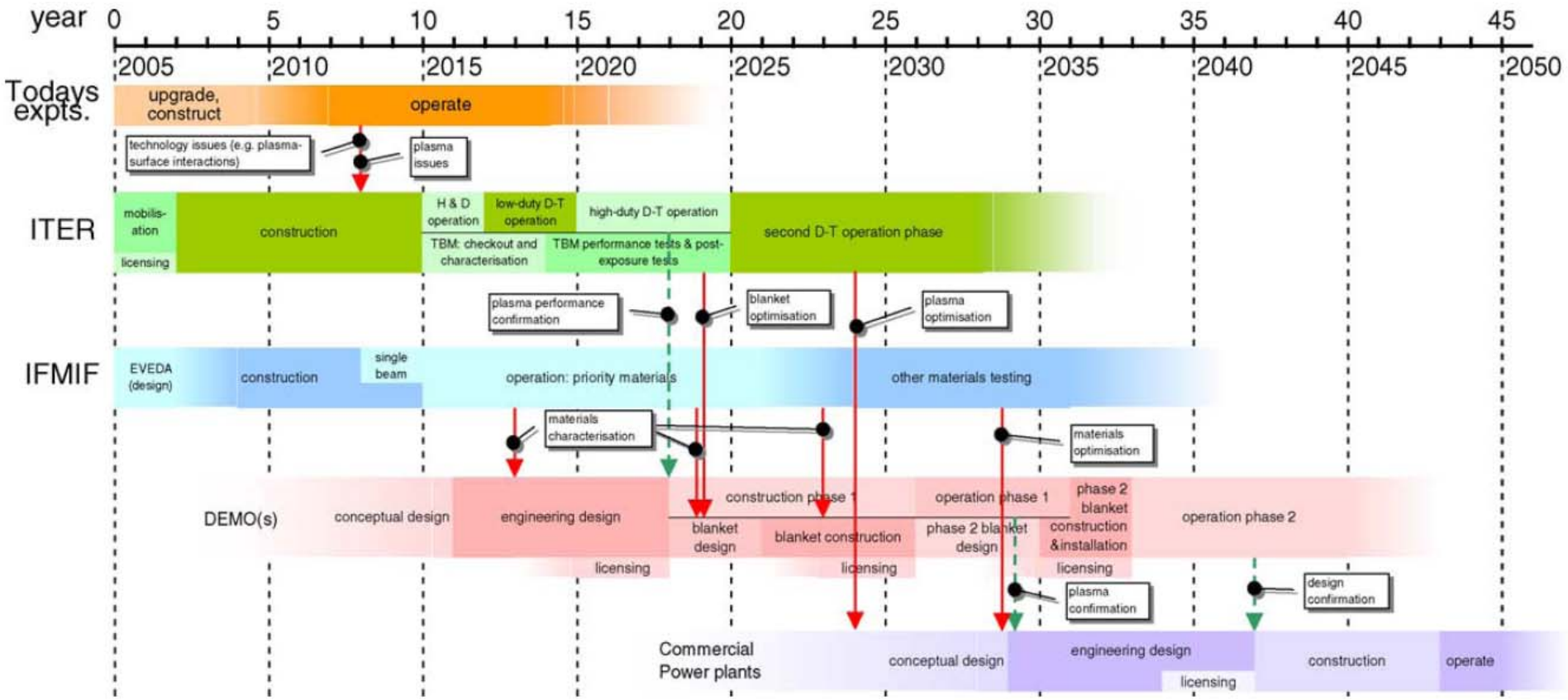







Cryostat
24 m x 28 m dia.
-196°C
-269°C (4K)
200.000.000°C

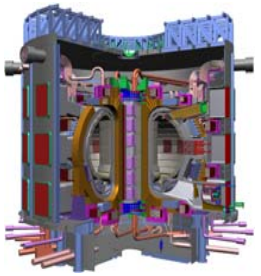
Towards a fusion power plant



Road map to a fusion power plant

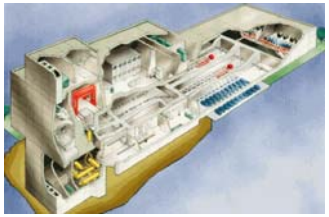
2020 ITER first operation

- Demonstrate fusion as energy source
- Test fusion technologies in an integrated system

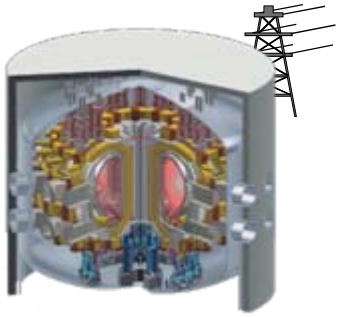


2020 IFMIF first operation

- Qualify materials for high neutron irradiation



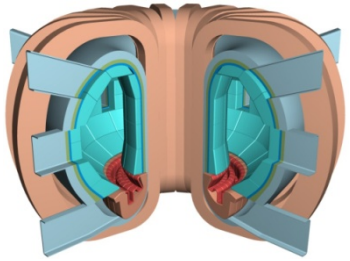
2030 Decision on DEMO



2040 DEMO first operation

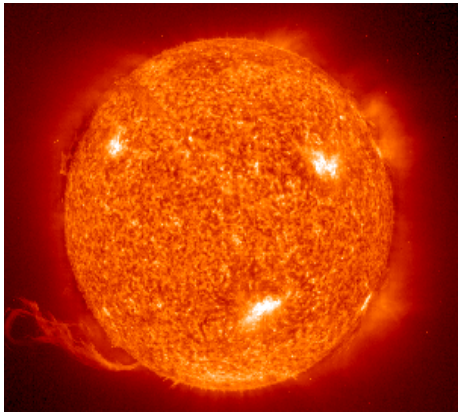
- Prototype fusion power station

2050 First commercial fusion power station



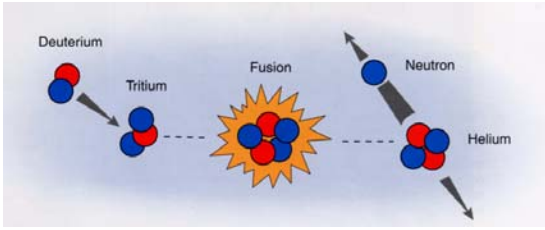
Summary on fusion energy

Fusion of hydrogen to helium is the energy source of the Sun

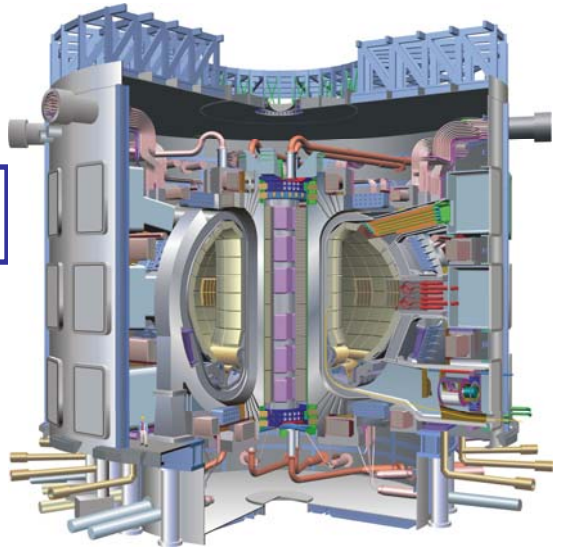


Fusion research aims at an energy source which is

- **sustainable**
- **CO_2 neutral**
- **inexhaustible**



Plan is to utilise fusion energy within 40 years



Links to more information

EU commission:
http://ec.europa.eu/research/energy/fu/article_1122_en.htm

EFDA: http://www.efda.org

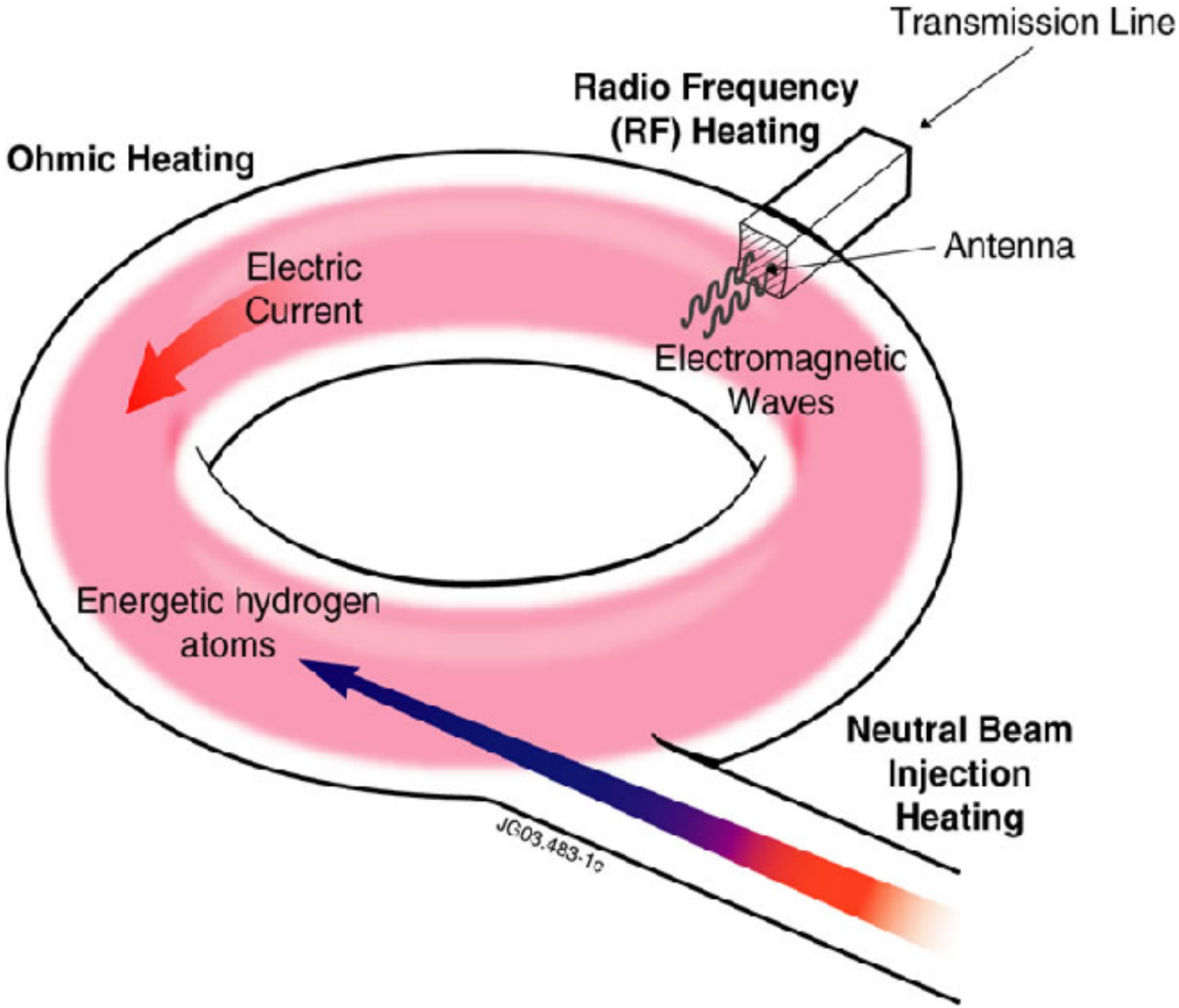
JET: http://www.jet.efda.org

ITER: http://www.iter.org

Risø DTU: http://fusionEN.risoe.dk

Extra slides

Heating methods



Catalytic production of hydrogen

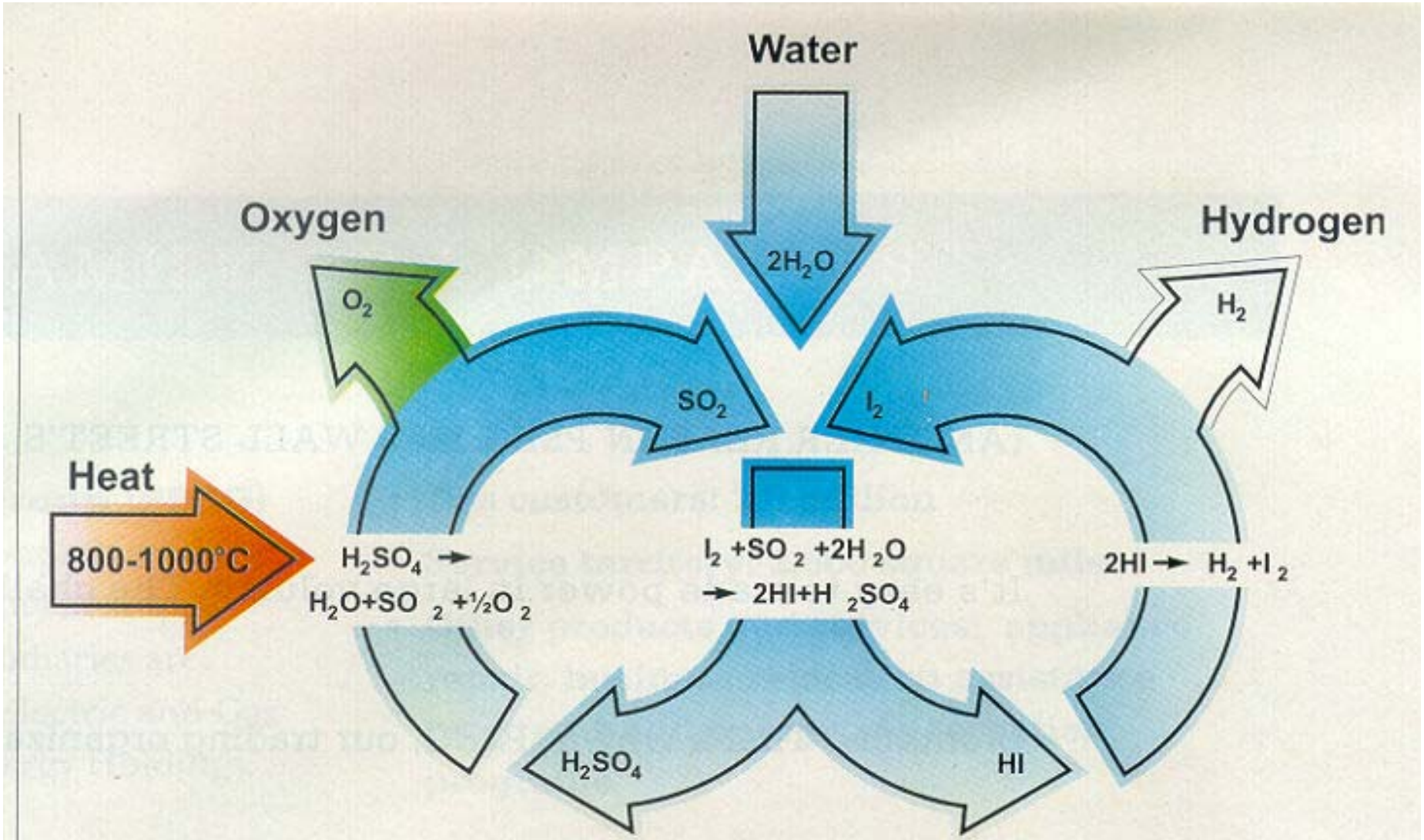


Fig. 2. Iodine-sulfur process for thermochemical production of H_2 (Source: ORNL)