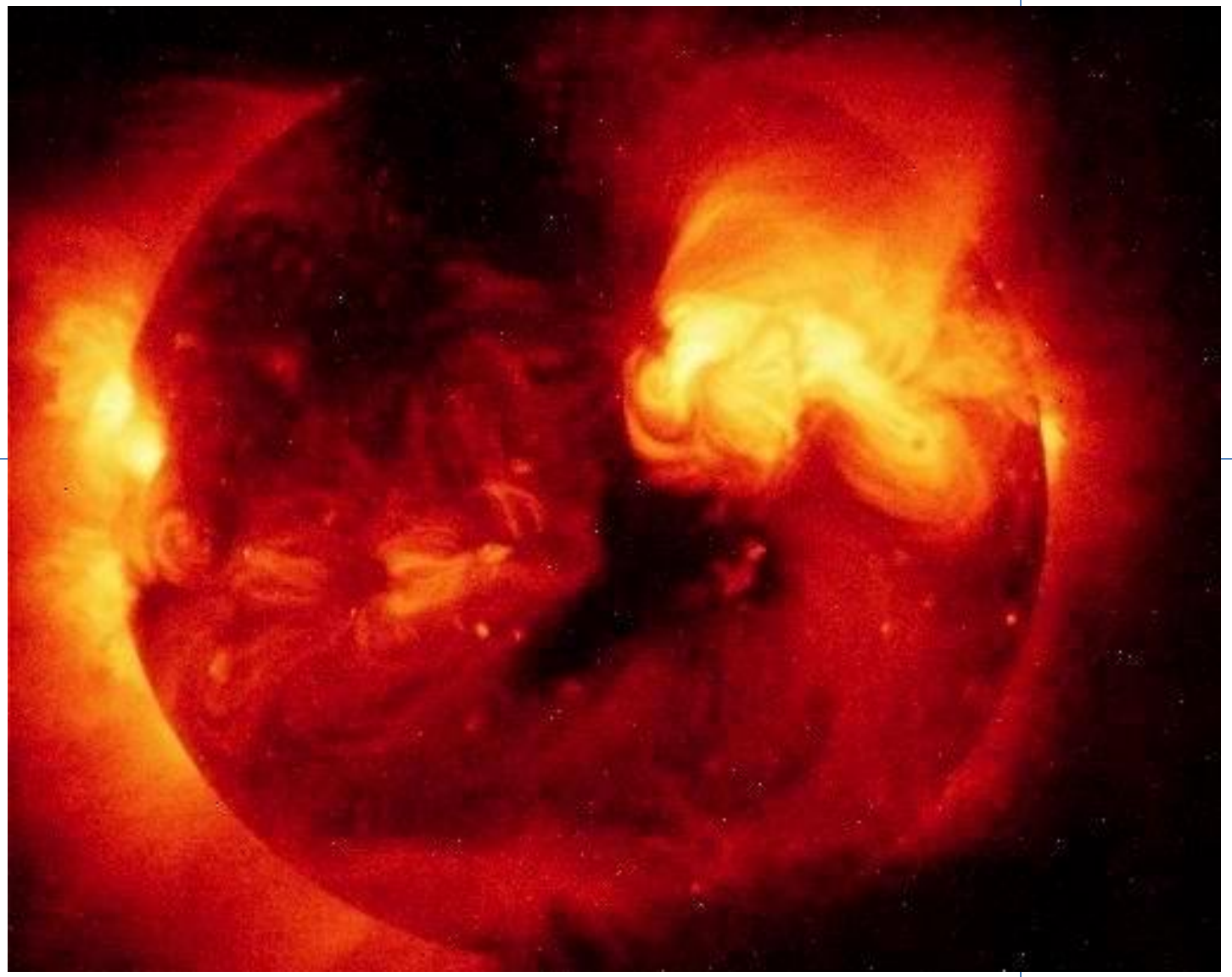
Fusion



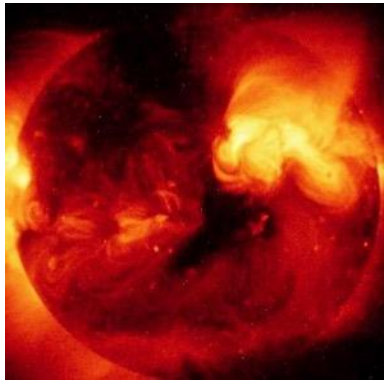
Reproduce the Sun on the Earth

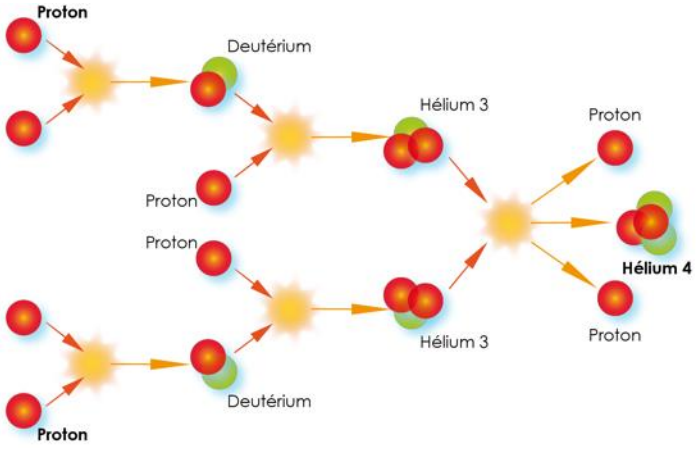
Generate large amounts of energy

Convert this energy into electricity

An energy source that is
- **abundant**
- **safe**
- **respectful of the environment**

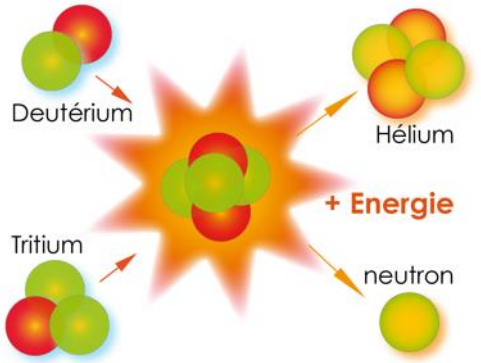
Fusion Reactions





Hydrogen ➔ Helium

Low probability



Deuterium + Tritium ➔ Helium + neutron

Fusion reaction with highest probability

Deuterium (heavy H): from water (H_2O)

1D / 6500H; ~33mg/l

Tritium: radioactive, half-life of 12y, not available in nature

Production of T: Lithium + n ➔ He + T

+ 20 x

≈ 50 x

Electromagnetic force: particles with same charge repell each other

Strong force keeps particles tog

- Responsible for mass

Strong f short range

E passed for the **strong force** to op. Energy must be given to particles. Fuel must be heated

100’000’000 degrees

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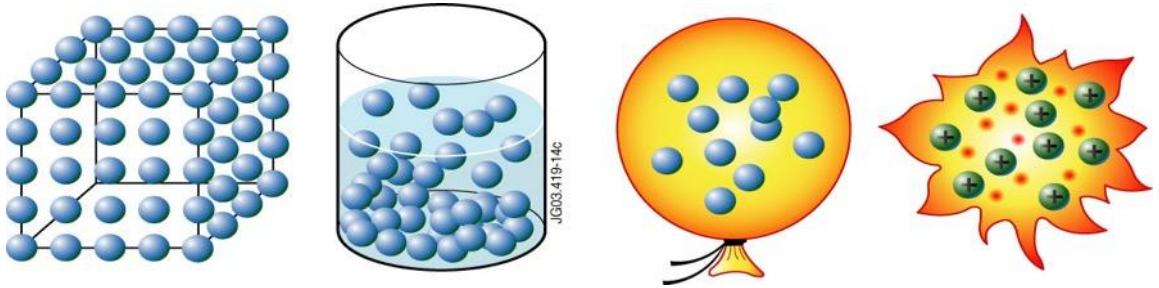
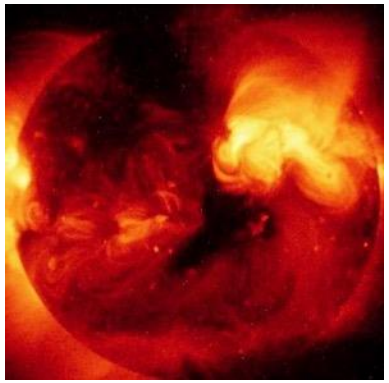
Plasma

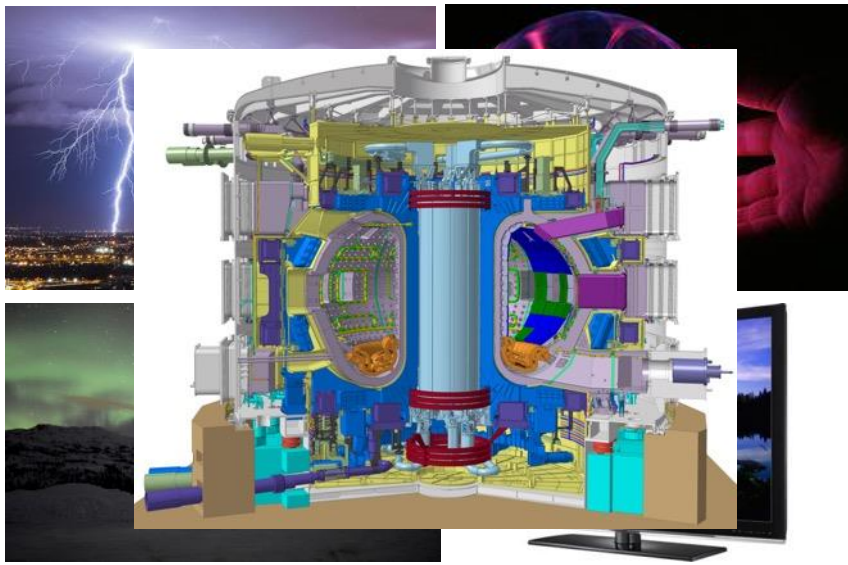
4th state of matter





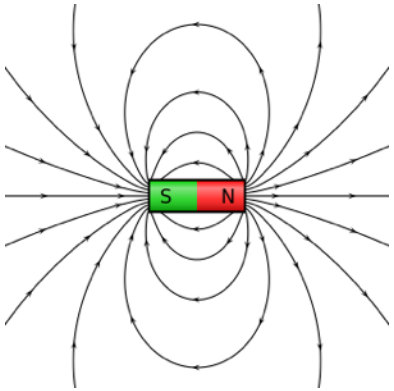
Temperature : ~15’000’000ºC

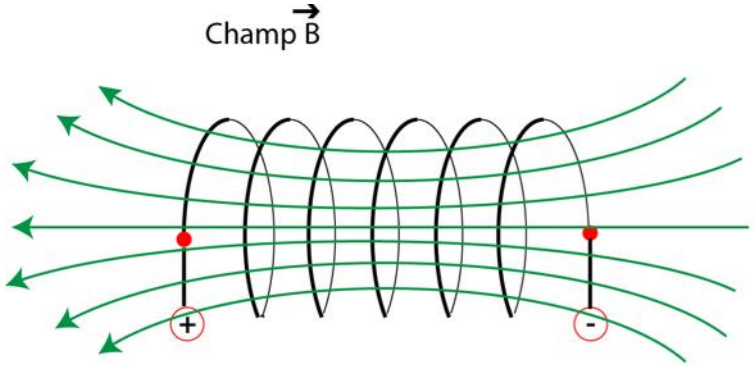
Gravitational force keeps the plasma together



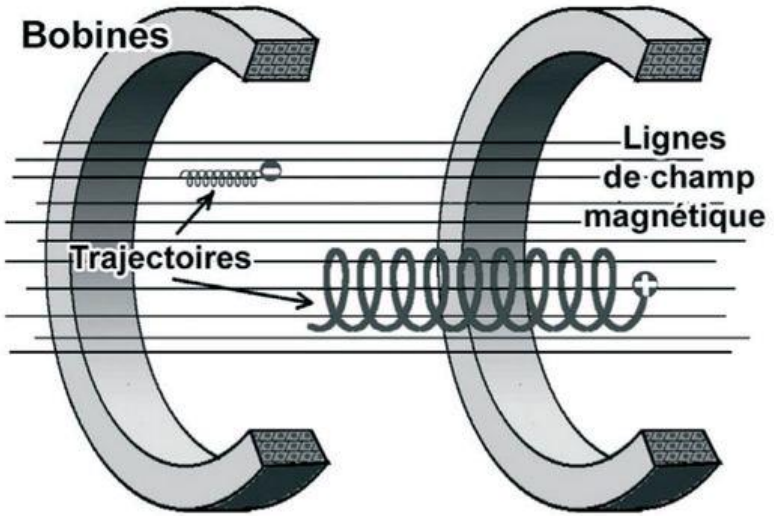
Magnetic Confinement – Tokamak

Magnetic field of a magnet, a coil





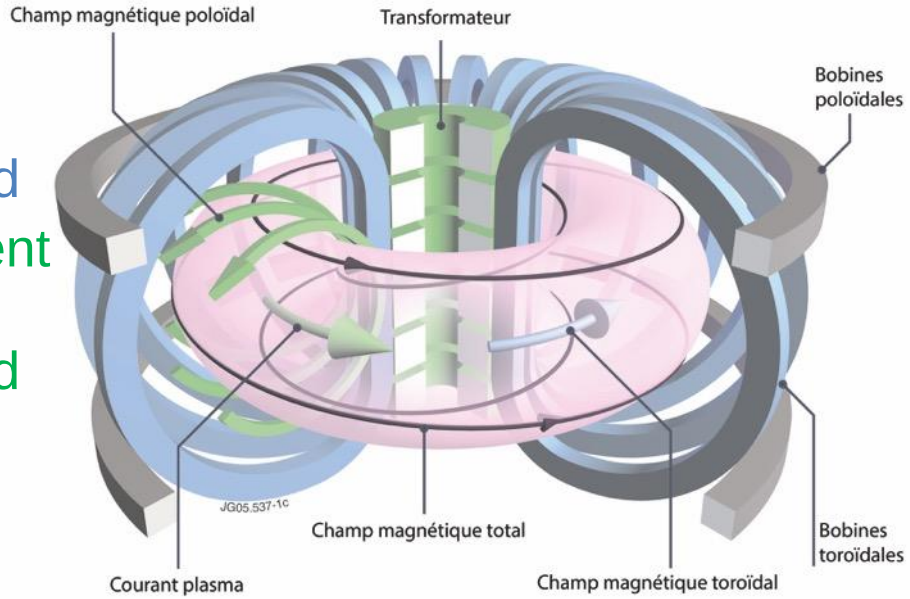
Charged particles follow the magnetic field lines

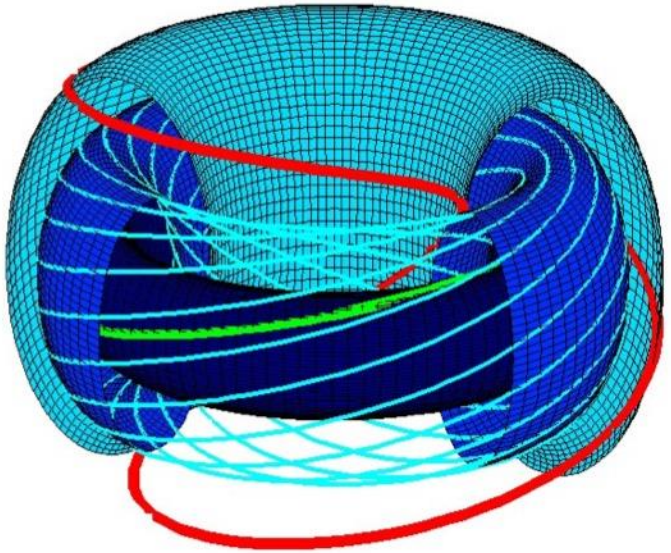


Tokamak

Toroidal magnetic field

Plasma current ➔ Poloidal magnetic field





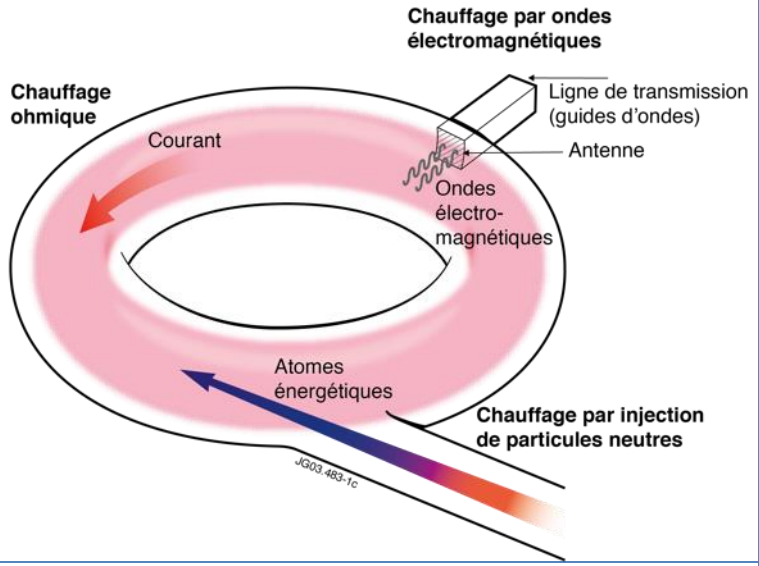
Magnetic fields create a **magnetic cage**

Particles are trapped in thin, nested layers

Tokamak – Heating and Diagnostics

Plasma heating

- El. current
- Energetic particles
- Microwaves

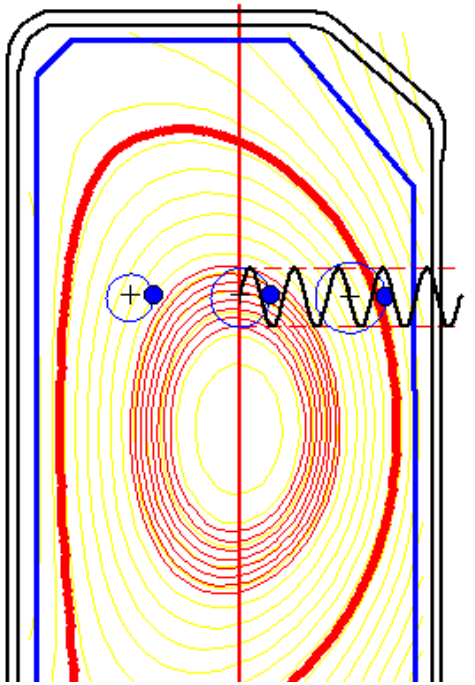


ECRH

Electronic Cyclotron Resonance Heating

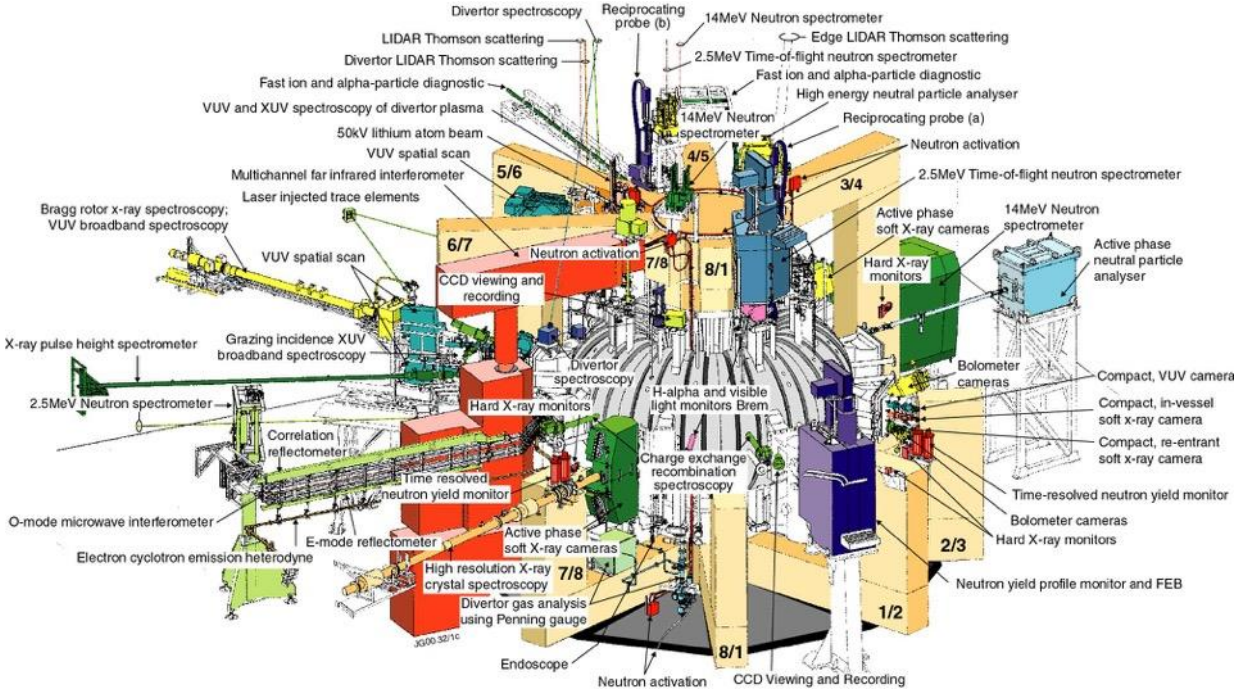
Local Heating

Modification of temperature profiles, beneficial for the plasma



Diagnostics – measurement systems

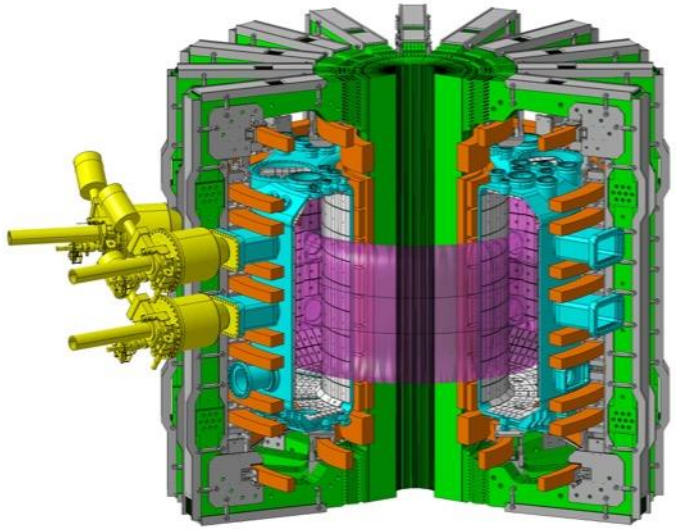
- Mesurement of plasma radiation
  - Visible
  - X-rays
- Laser – plasma interactions
- Particle beams



TCV tokamak

Tokamak
à Configuration
Variable

16 magnetic coils,
independently driven

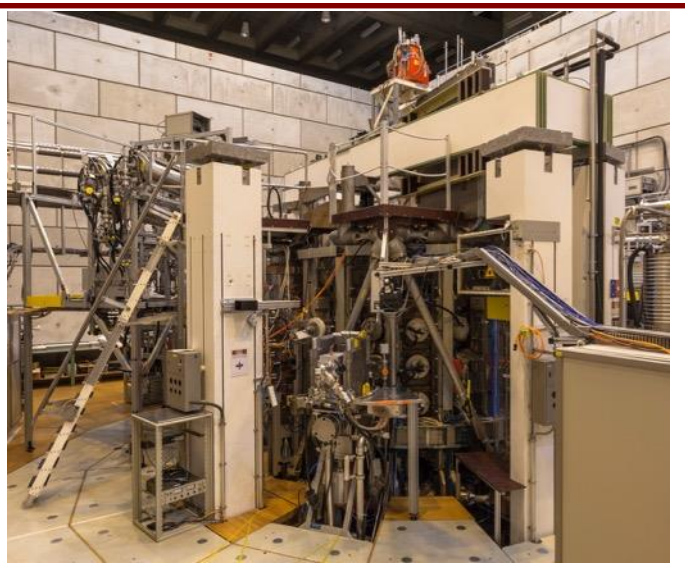


Heating systems

- Neutral beam
- Microwaves

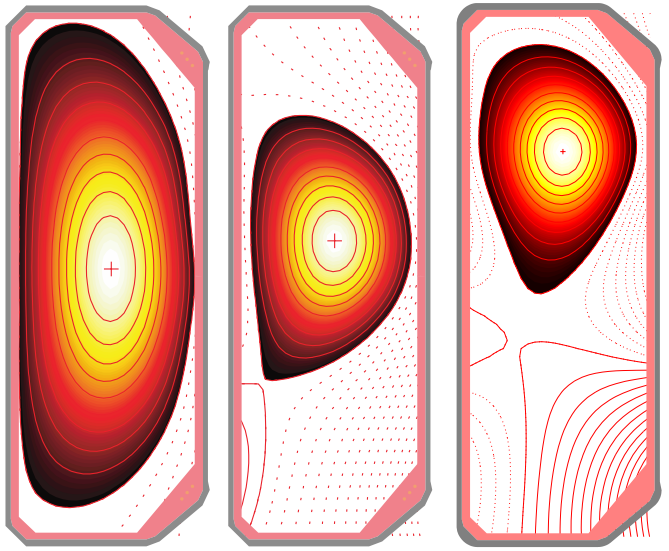
Diagnostics

- Temperature
- Density
- Radiation
- Turbulence



Scientific goals

- Better understanding of Deuterium plasmas
- Innovative plasma shapes
- Influence of plasma shape on its characteristics
- Microwave heating development
- Particle exhaust
- Turbulence characterisation



Plasmas

- Against the wall
- Far from the wall
  - 2 ‘legs’
  - 4 ‘legs’

Present and Future Developments

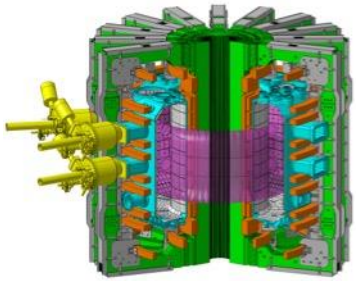
~20 tokamaks worldwide

JET (UK), largest tokamak, produced 16MW of fusion power in 1997

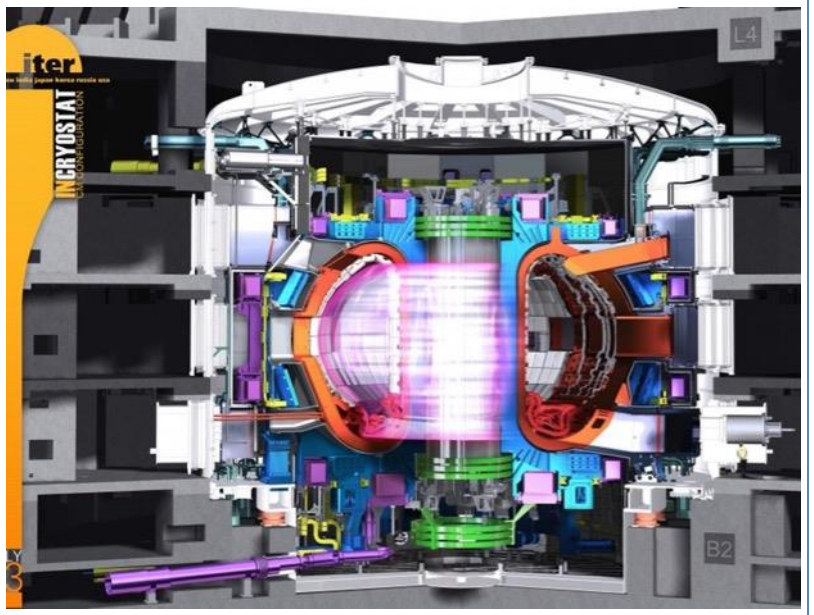
Fusion roadmap of EUROfusion

Provide fusion electricity to the grid around 2050

ITER, DEMO, Medium Size Tokamaks

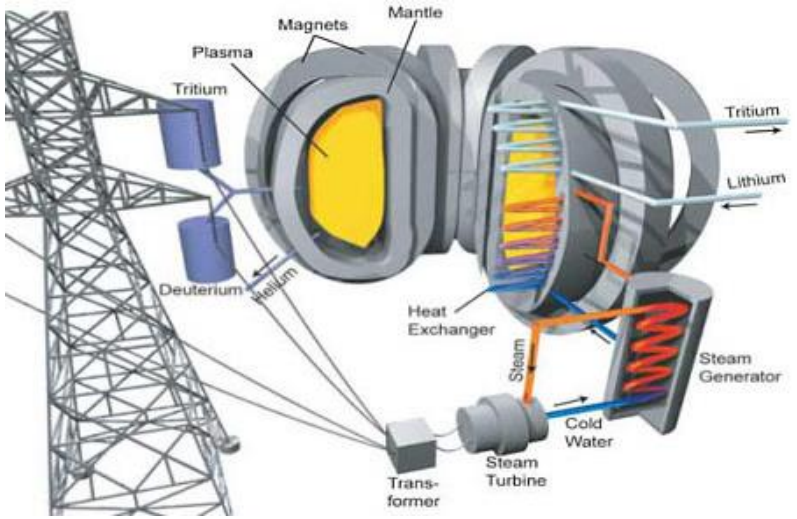


ITER
Under construction
International
Aix-en-Provence
Plasma en 2025
Fusion power:
500MW
500s



DEMO
Electrical power:
500MW - 1GW
24/24, 7/7

Design ongoing



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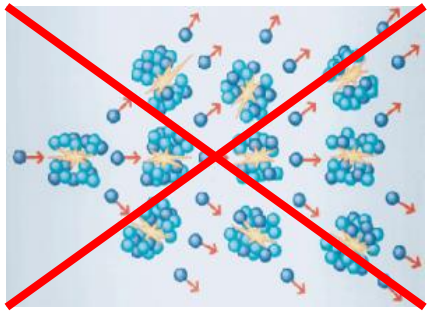
SWISS PLASMA CENTER

Advantages of Fusion

Safety

- No chain reaction, no risk of explosion
- Small amount of fuel in the reactor



Respect of environment

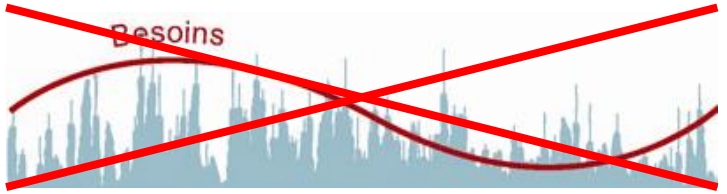
- No CO_2, green house gas emissions
- No radioactive waste that require long duration storage

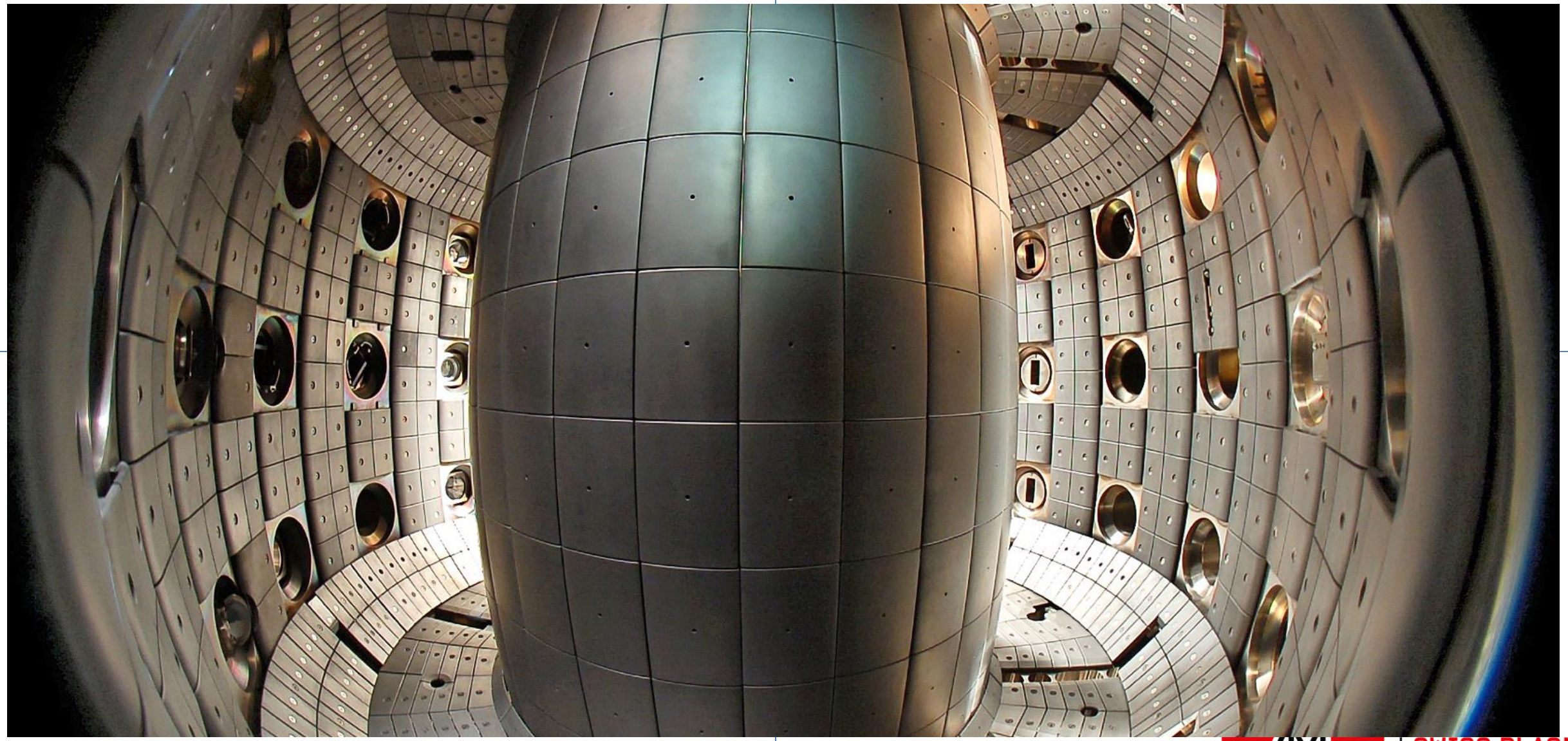
Fuel abundancy and distribution

- Almost unlimited Deuterium and Lithium reserves
- Worldwide distribution
- Reactions efficiency (MJ/g)

Operation

- Continuous



Fusion contributes to sustainable development

Inside the TCV tokamak