PLASMA HEATING: FROM THE HOTTEST EVER…

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Heating ITER plasma's up to the highest temperatures ever in the universe

The problem

Possible reactions:

$D + D \longrightarrow T + H + 4.0\ MeV$

$D + D \longrightarrow {}^{3}He + n + 3.3\ MeV$

$D + {}^{3}He \longrightarrow {}^{4}He + H + 18.3\ MeV$

$D + T \longrightarrow {}^{4}He(3.5MeV) + n\ (14.1MeV)$

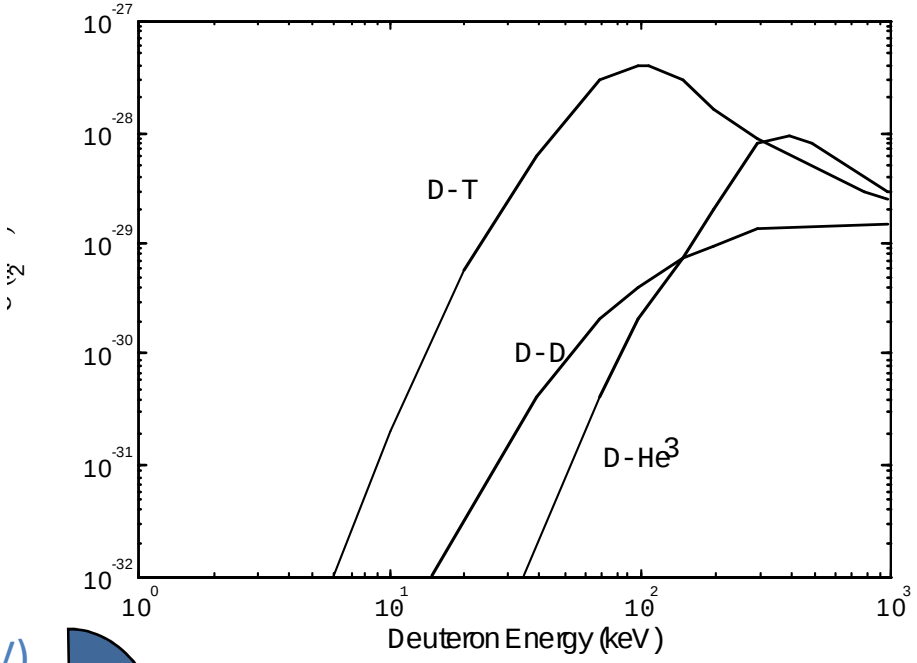
Tritium :

$^{4}He + T \longleftarrow {}^{6}Li + n$

$^{4}He + T + n \longleftarrow {}^{7}Li + n$

1 g D-T produces 26000 kWh of electricity

1g coal produces 3Wh



!!! T (β^-) 12.26y

The conditions …

Problem : Coulomb

Solution : high temperature

But : 150×10^6 K ⇒ PLASMA

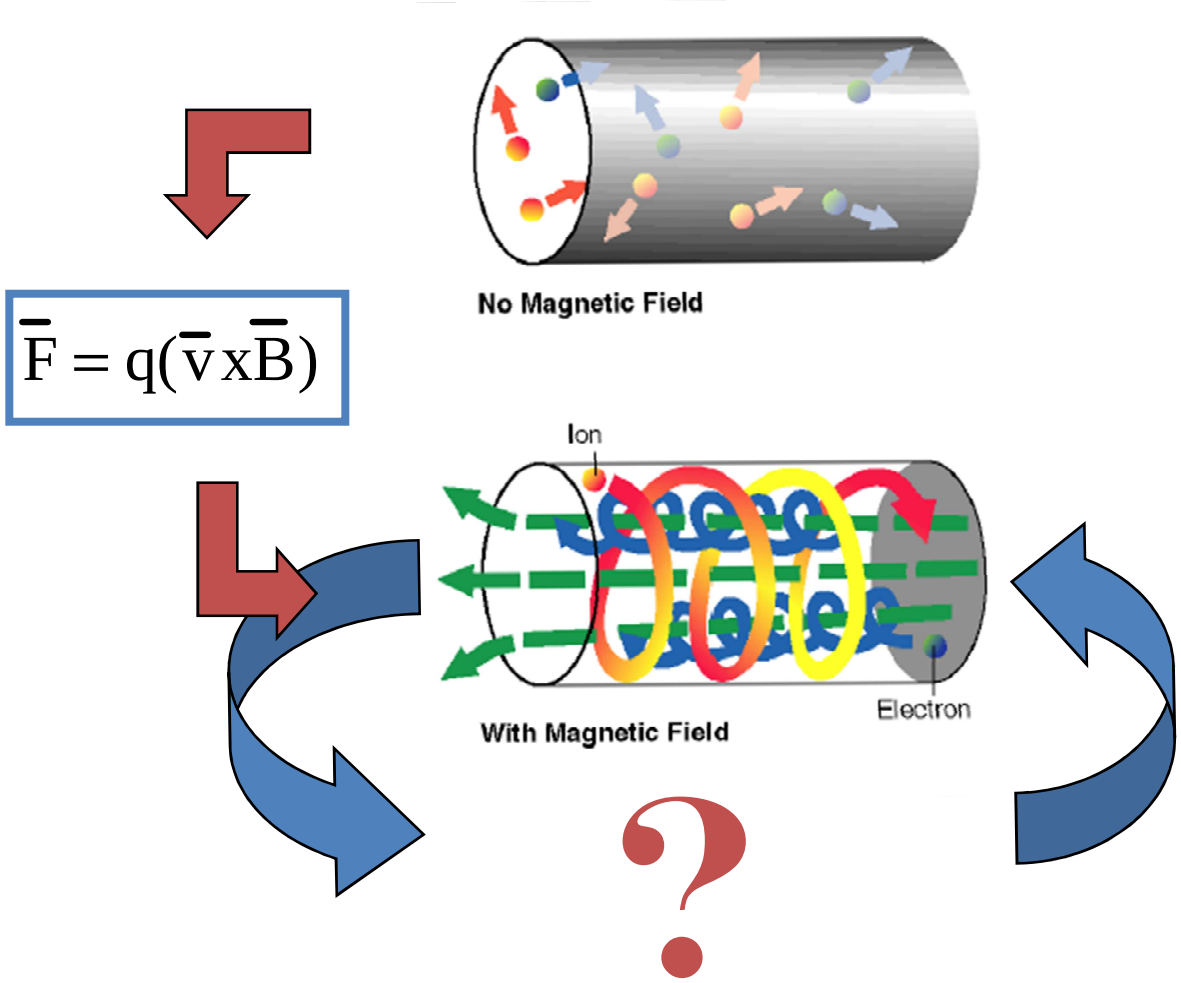
Lawson:

$$n \times \tau_E \times T > 6 \times 10^{28}\ m^{-3}sK$$ (for ignition)

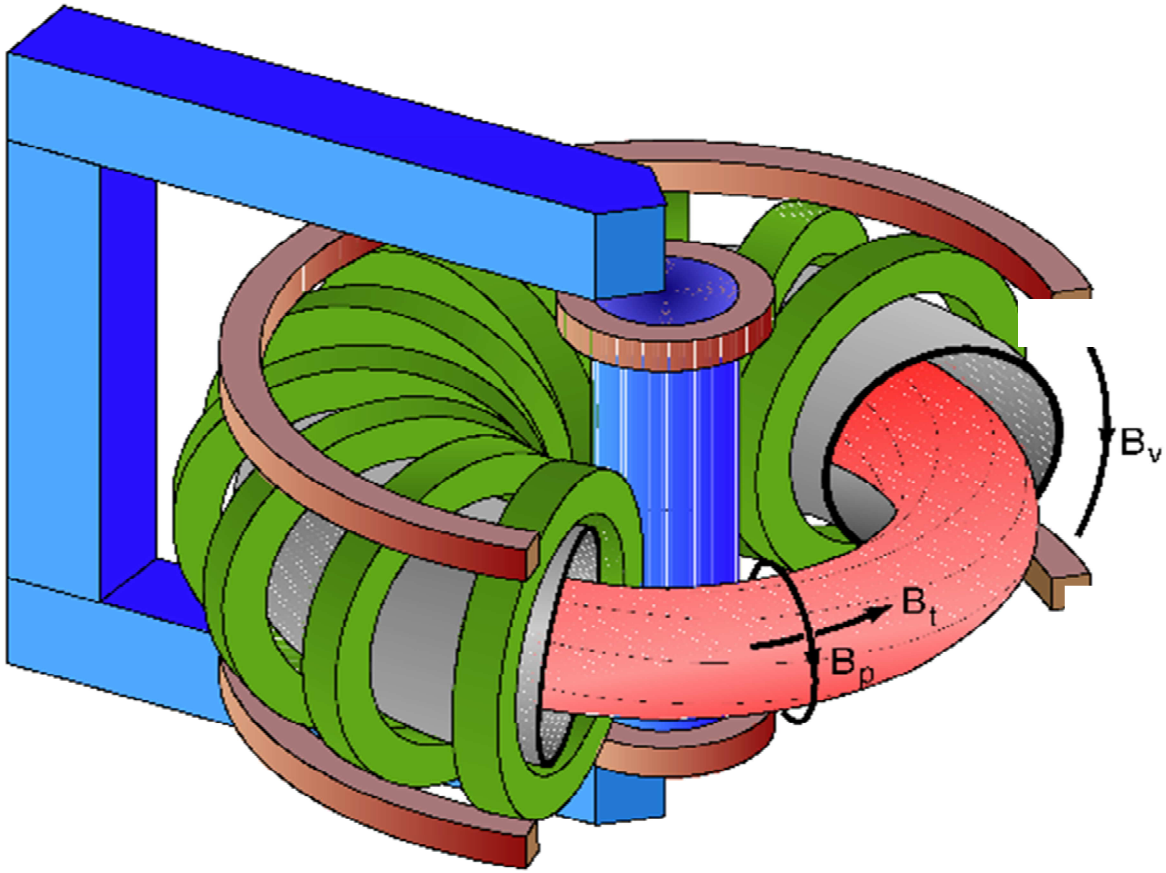
2 strategies: Inertial

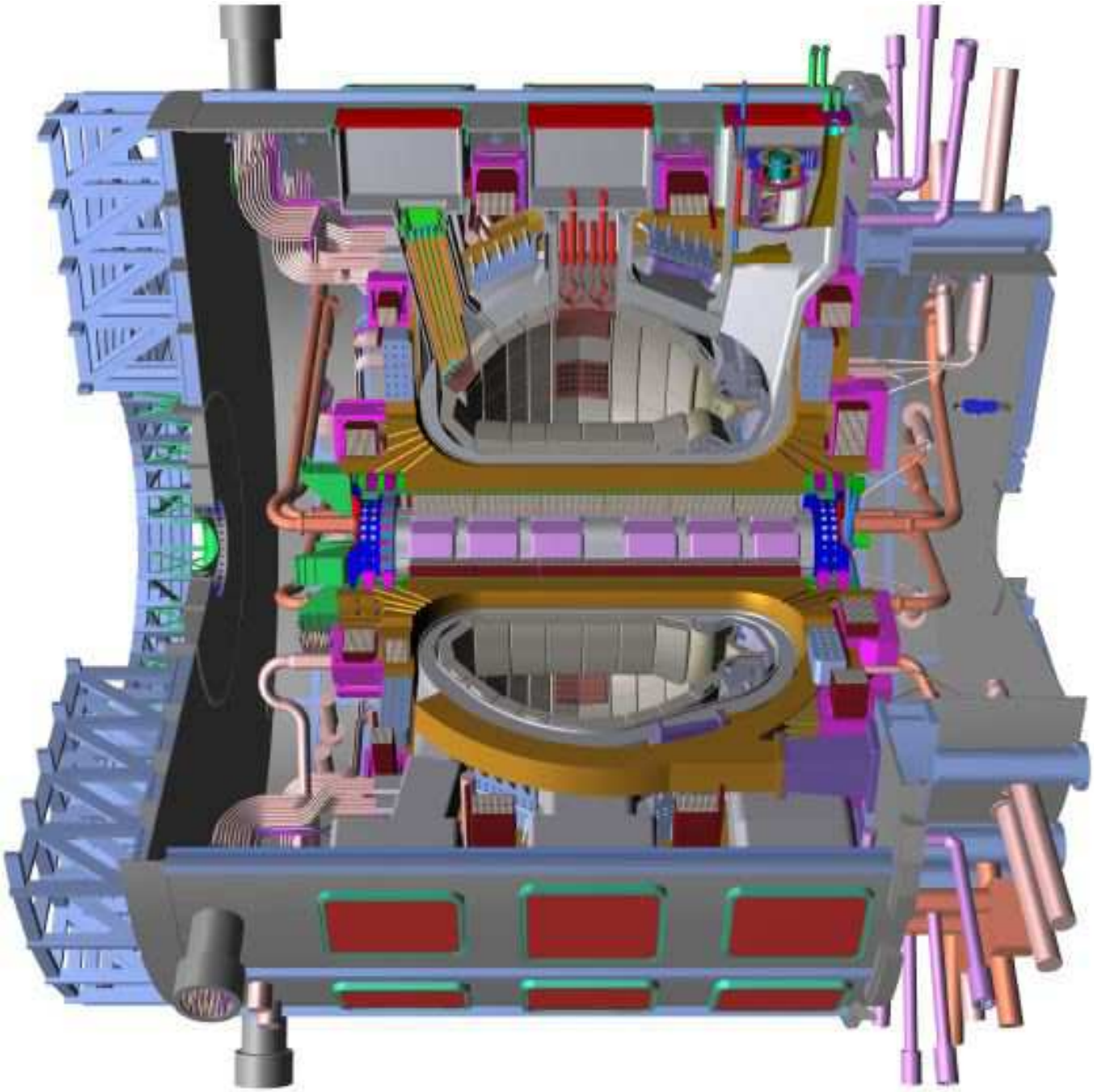
Magnetic

The Tokamak

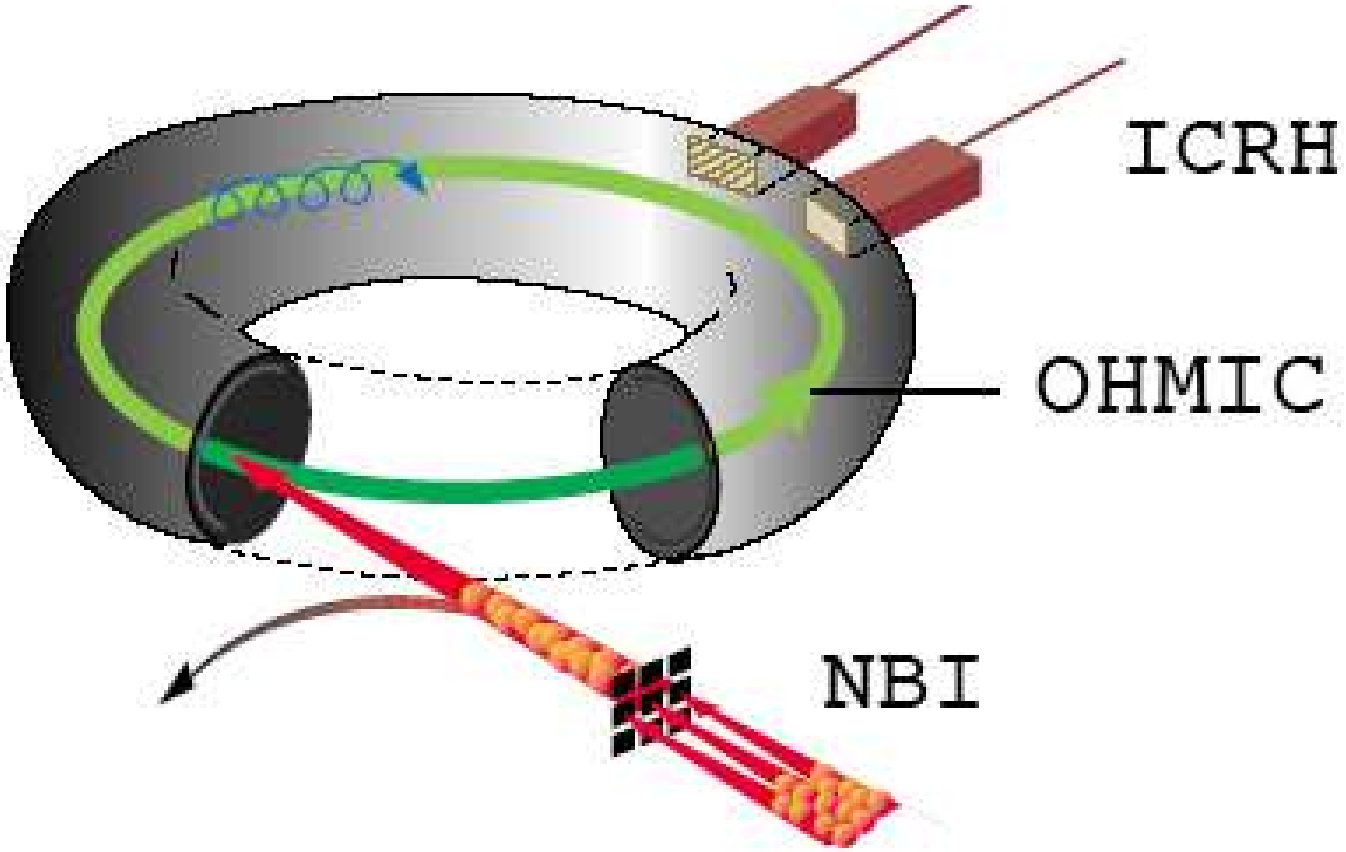

No Magnetic Field
$\bar{F} = q(\bar{v} x \bar{B})$
Ion
Electron
With Magnetic Field
?

The Tokamak





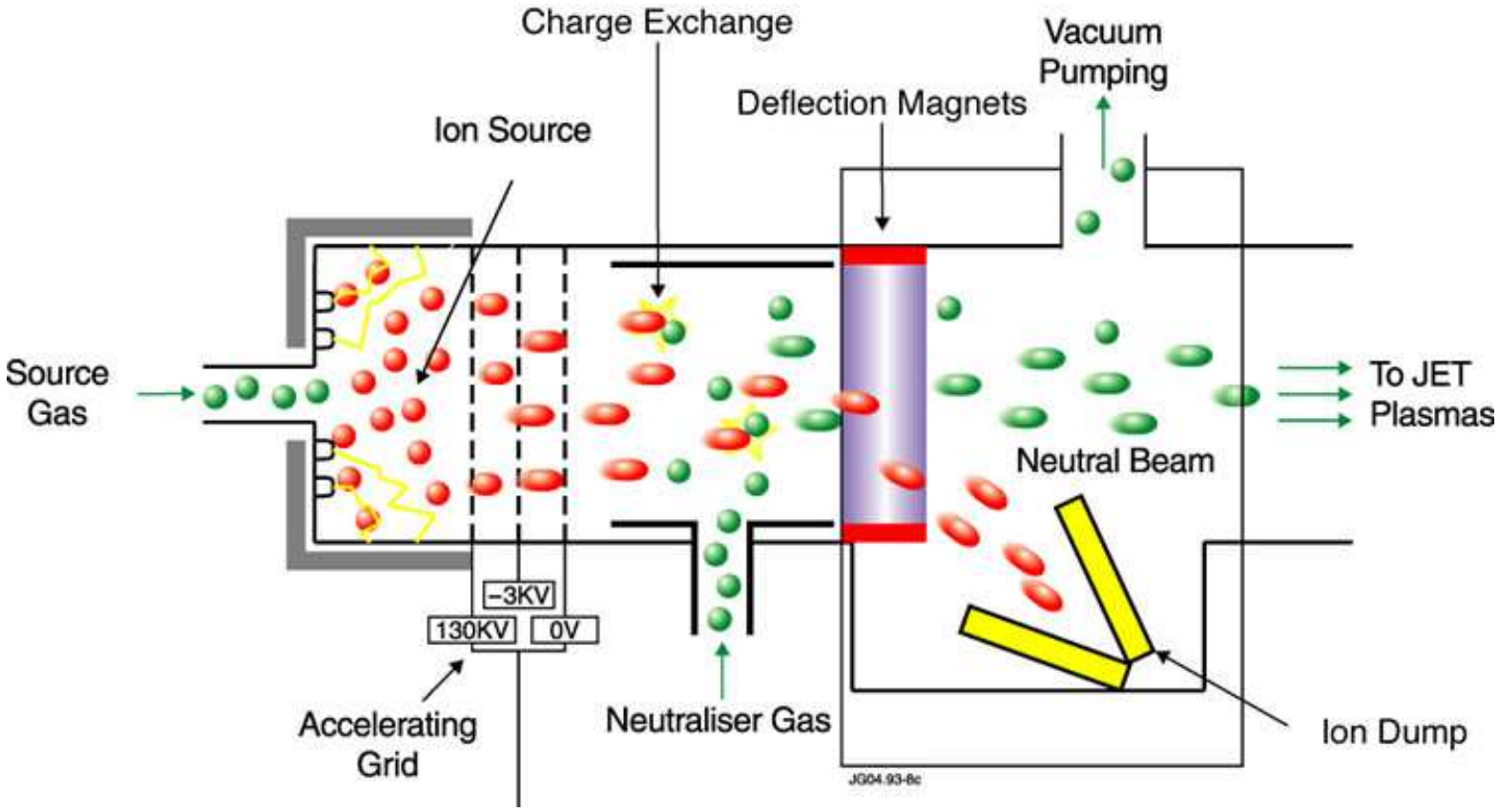
Heating?



Ohmic Heating?

- In the tokamak one needs current
- Induced by tranformer
- Why not use the Ohmic heating effect?
  - Efficiency decreases with increasing temperature
  - Plasma current limited by instabilities
  - Steady state??

Or NBI (Neutral Beam Injection)?

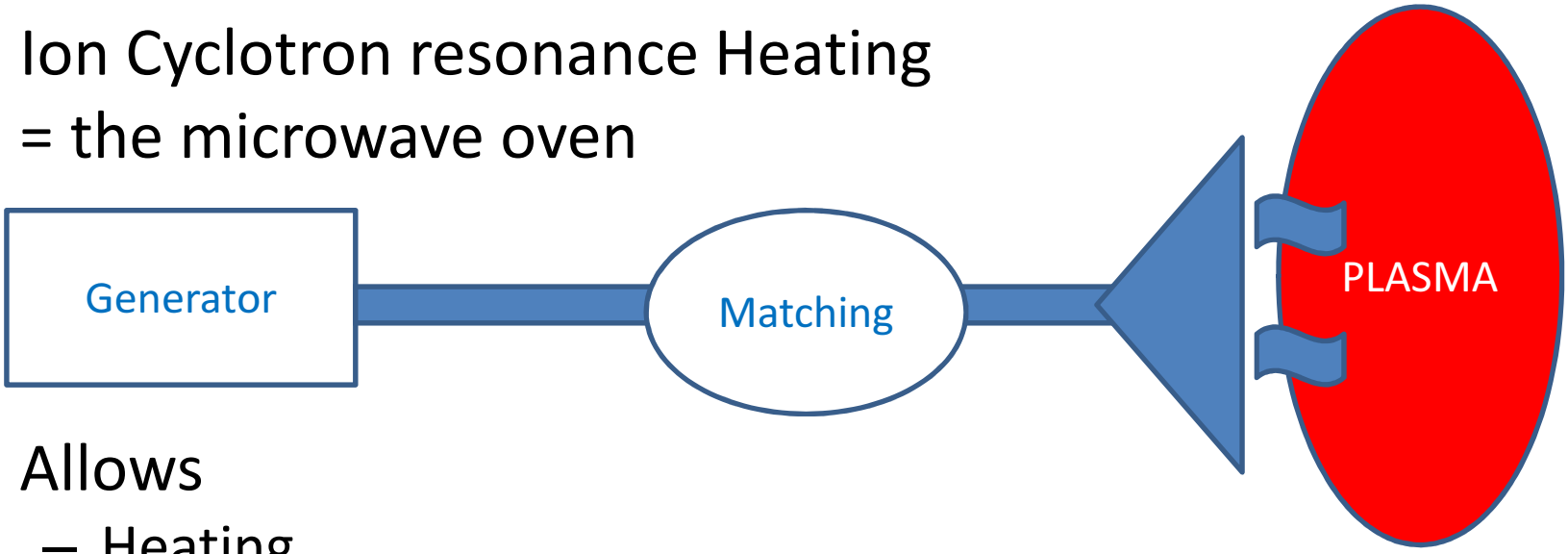


NBI

- Neutralisation efficiency of positive ions dramatically decreases with energy
  - 1-2MW ; 150KeV possible
  - 0.5 MeV needed for heating ; 1-2 MeV for driving current in ITER
- So for high energies : negative ion sources are needed
  - Better neutralisation efficiency at high energies
  - BUT low production efficiency
  - Sources under development …

A versatile solution : ICRH

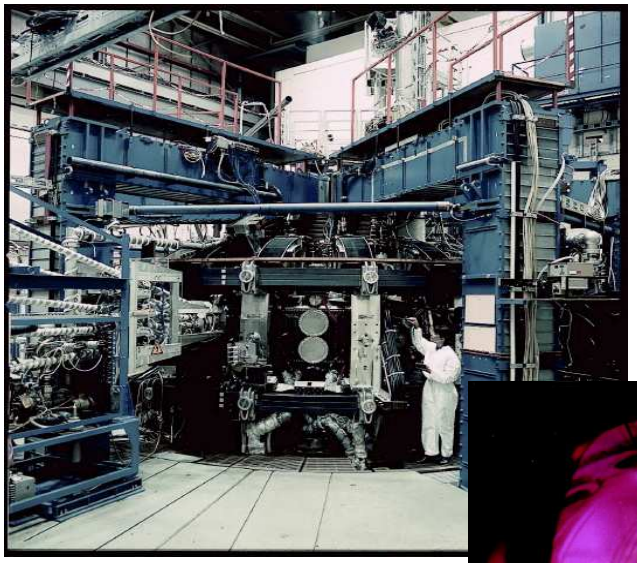
- Ion Cyclotron resonance Heating
- = the microwave oven

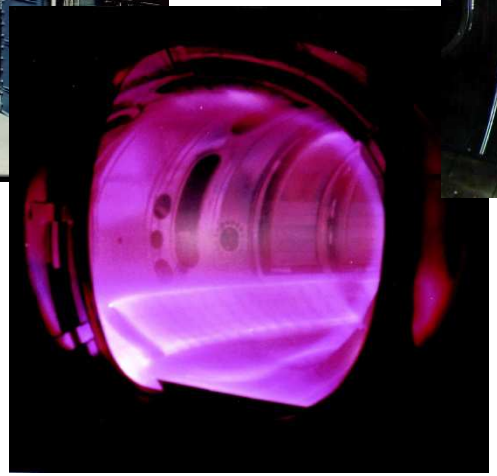


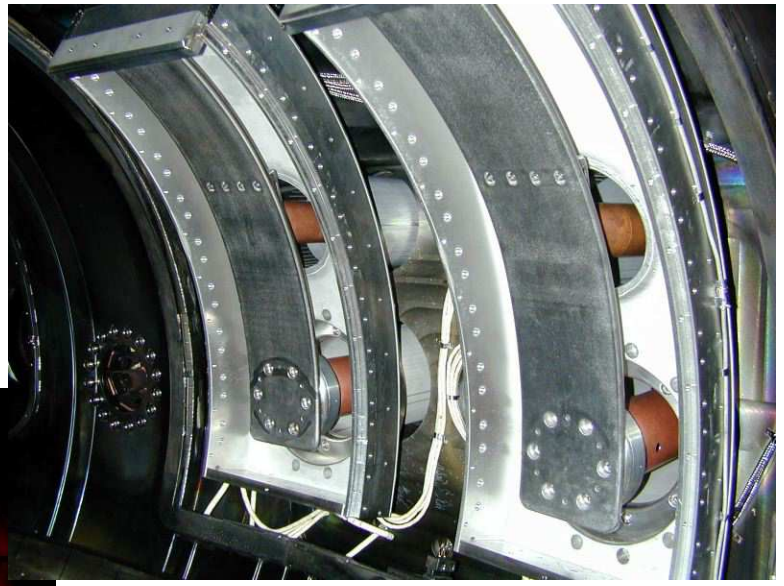
- Allows
  - Heating
  - Current drive
  - Generation fast particles
- Range MHz = available technology for generators
- Coupling / matching : solutions available

ICRH

- TEXTOR (IPP - Forschungszentrum - Jülich)







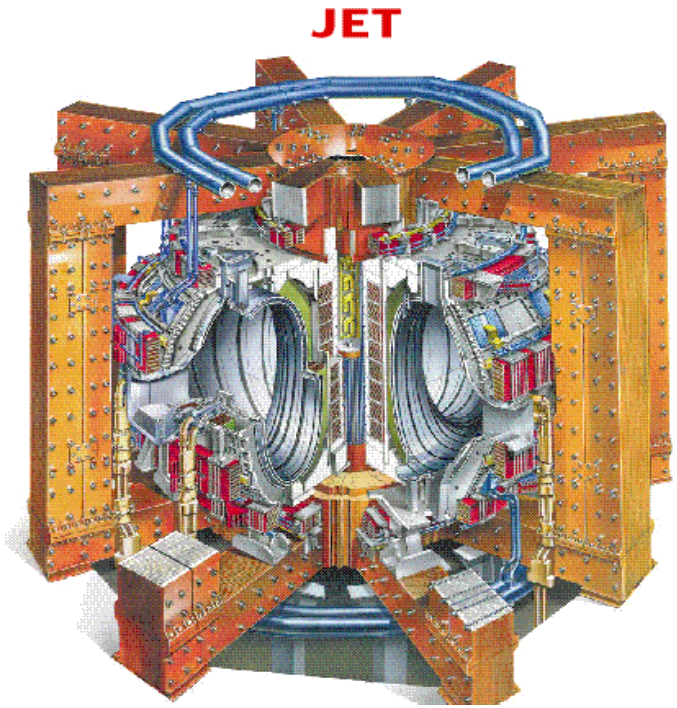
R_o=1.75m

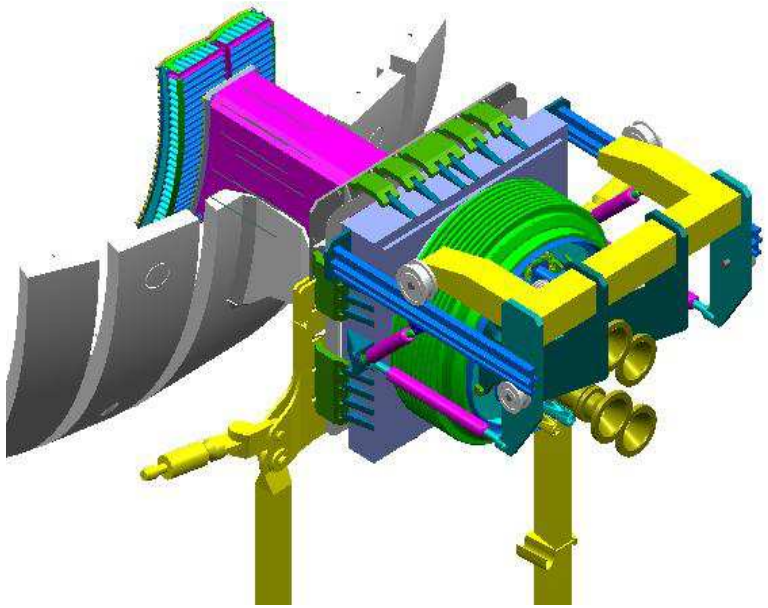
P=2x2MW

25 / 38 MHz

ICRH

- JET - EP



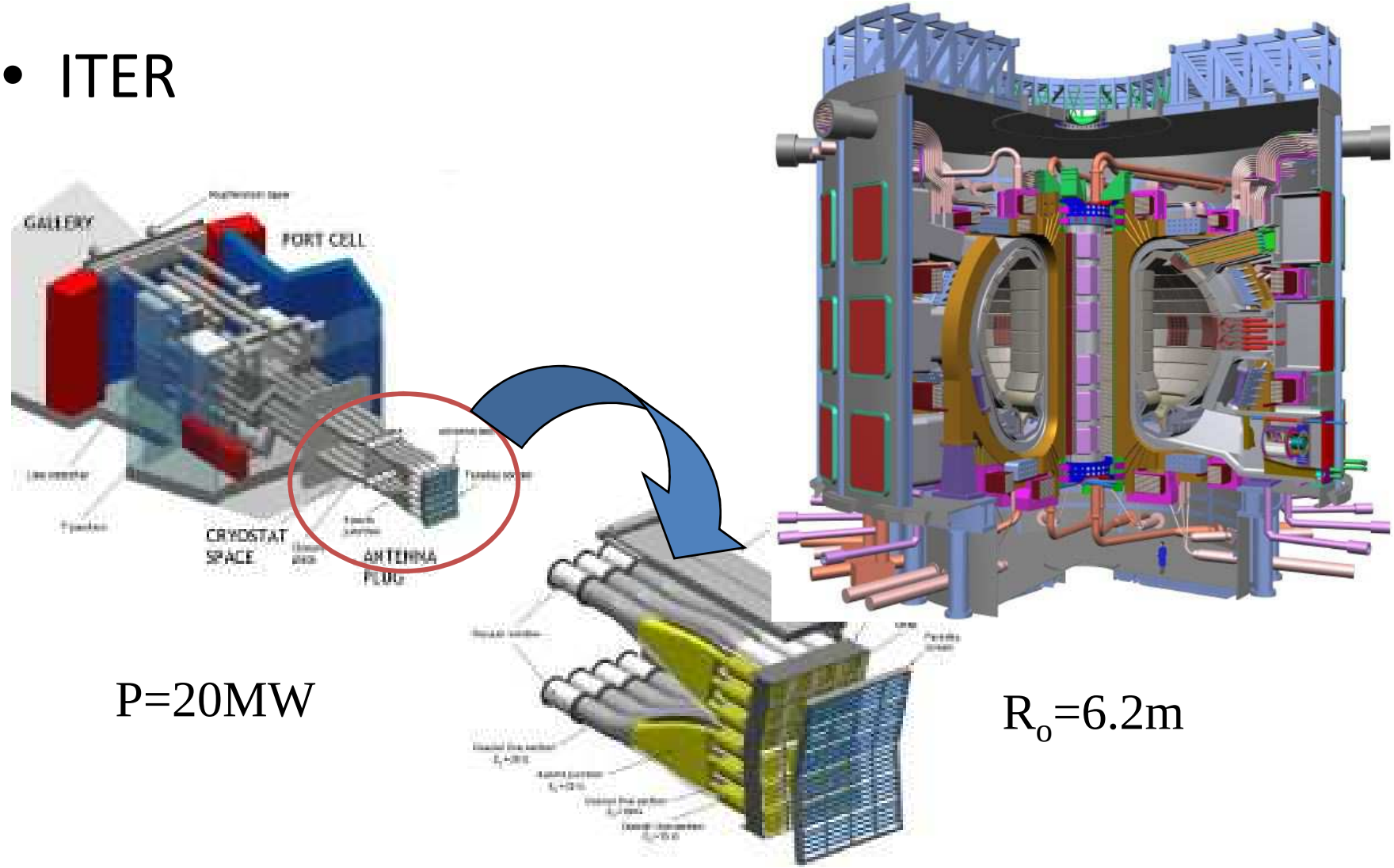


R_o=2.96m

P=8MW

ICRH

- ITER

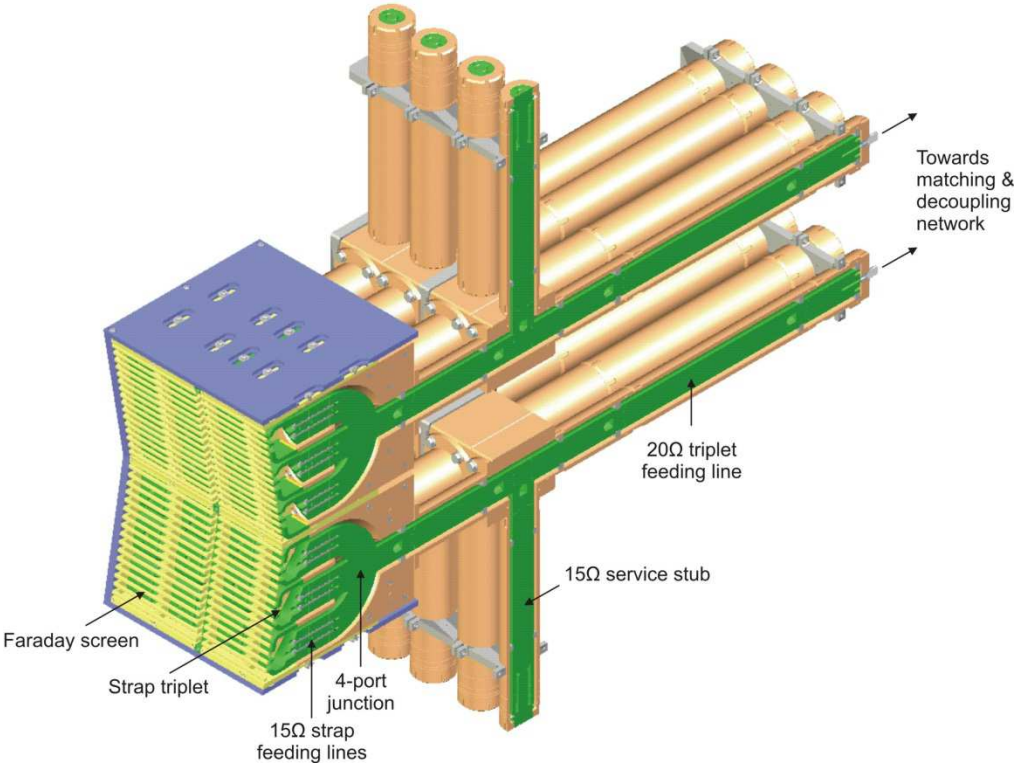


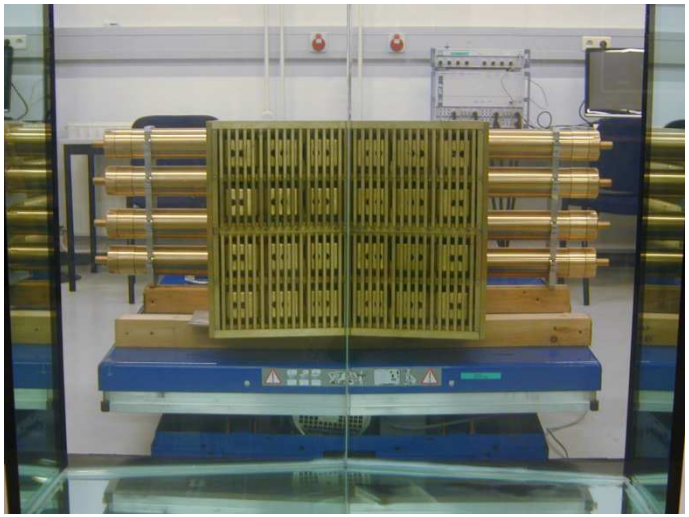
P=20MW

R_o=6.2m

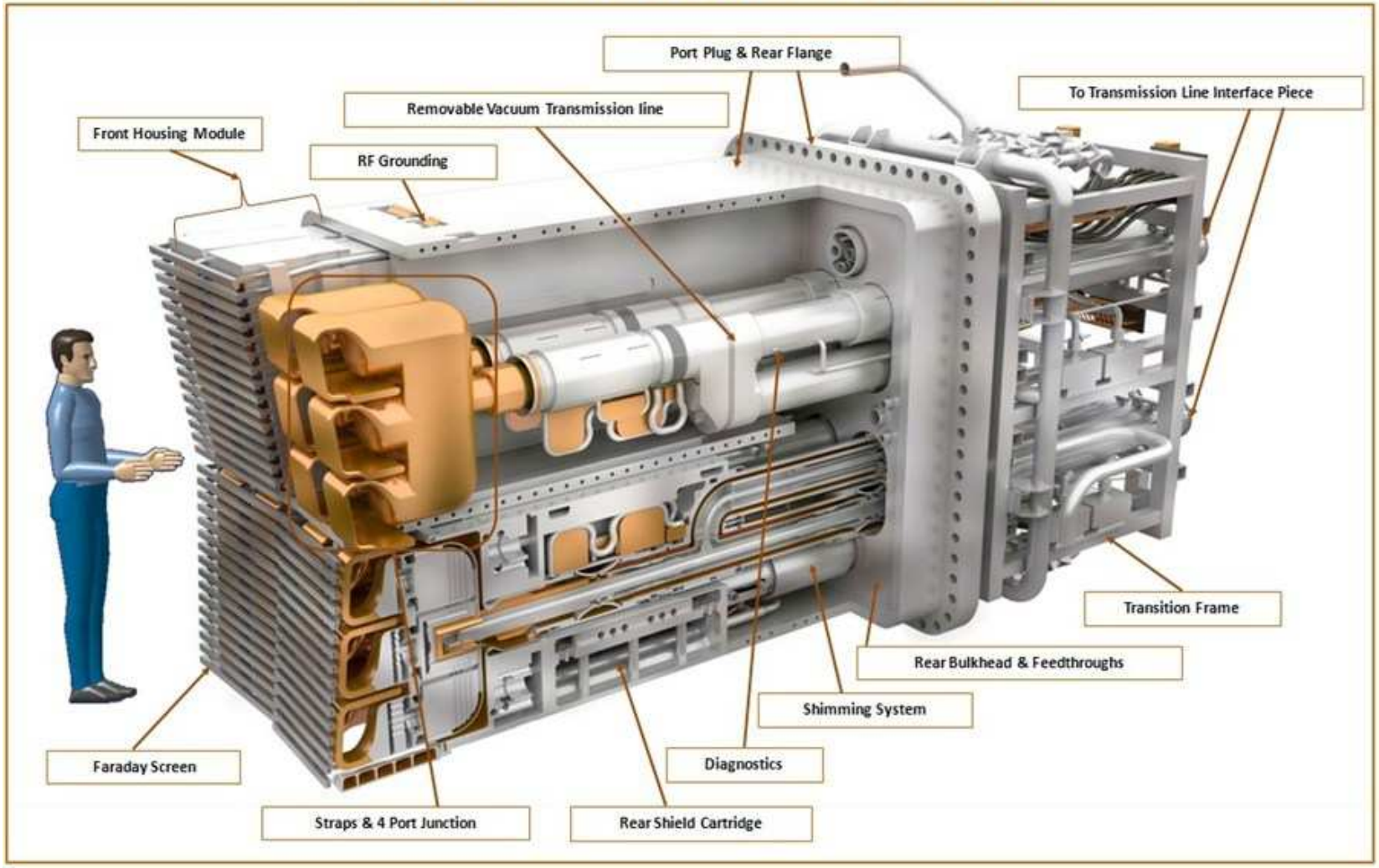
Full antenna RF characterization

- RF characterization of full array
- Impact of Faraday Screen on coupling
- Effect of vertical septa recess
- Effect of grounding



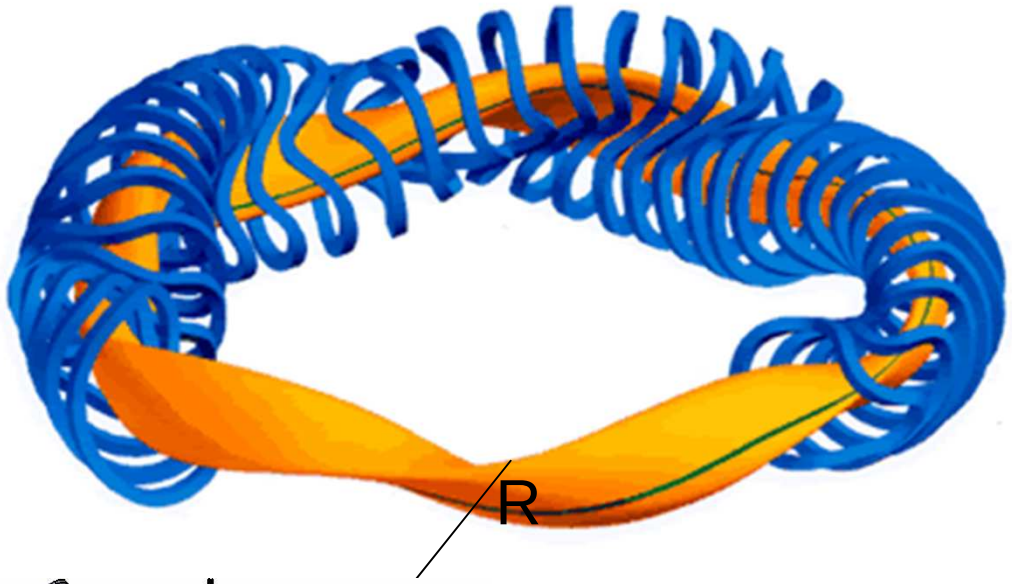


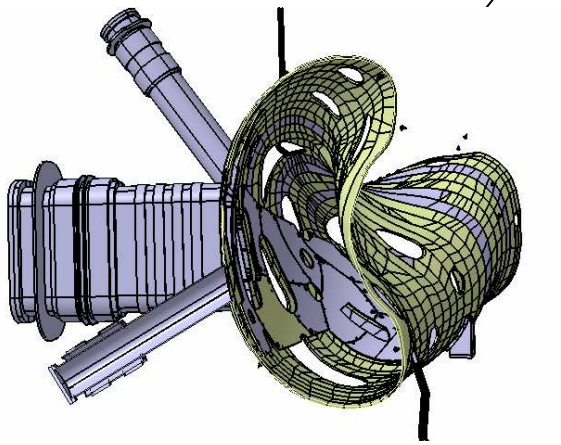
IC H&CD Antenna SYSTEM

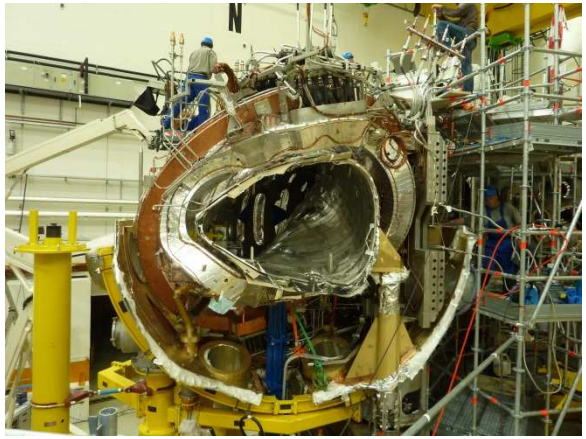


W7-X

- R=5.5 m
- r=0.53m
- B=3T
- Duration
  = 30min







The future : DEMO