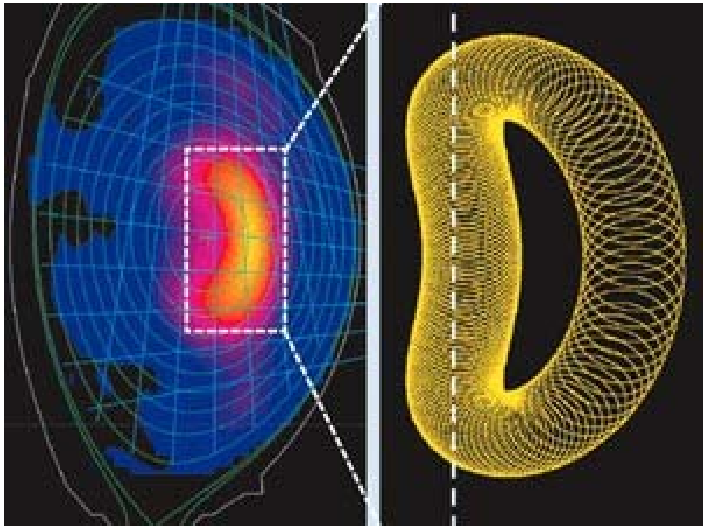
Fusion -- A Challenge for Materials Science.

Energy Materials, Meeting the Challenge -- *10 October 2008*

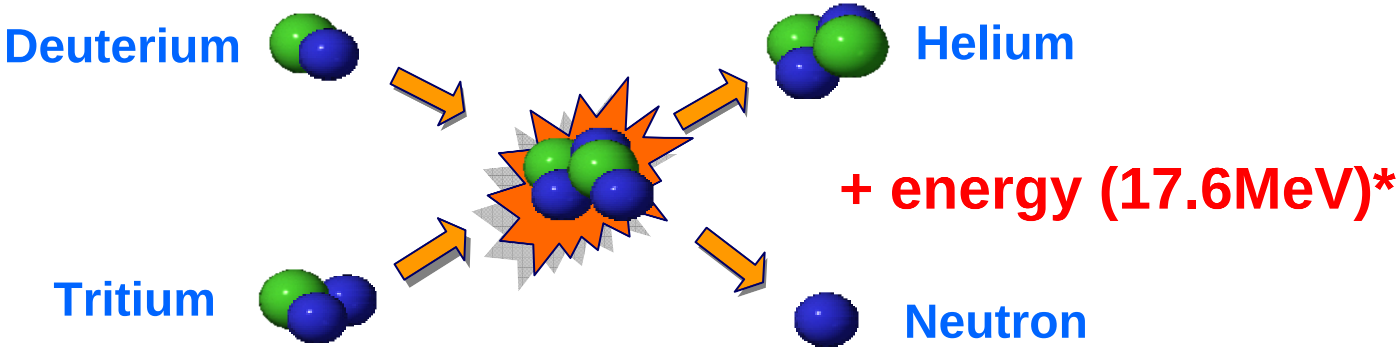
Steve Cowley -- Director UKAEA Culham



UKAEA

What is Fusion?

Most effective fusion process involves deuterium **(heavy hydrogen)** and tritium **(super heavy hydrogen)** heated to above 100 million ∘C. D-T Fusion cross section is ~ barn at 50 keV (elastic cross section is >100 times larger).

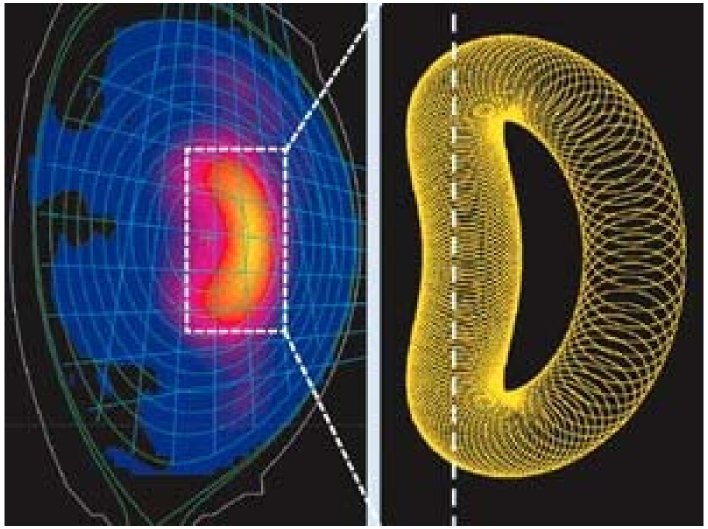


Tritium is bred from lithium using the neutron $Li^6 + n \rightarrow He^4 + T$

UKAEA

After fusion.

Helium gets caught in magnetic field, slows down and heats the plasma

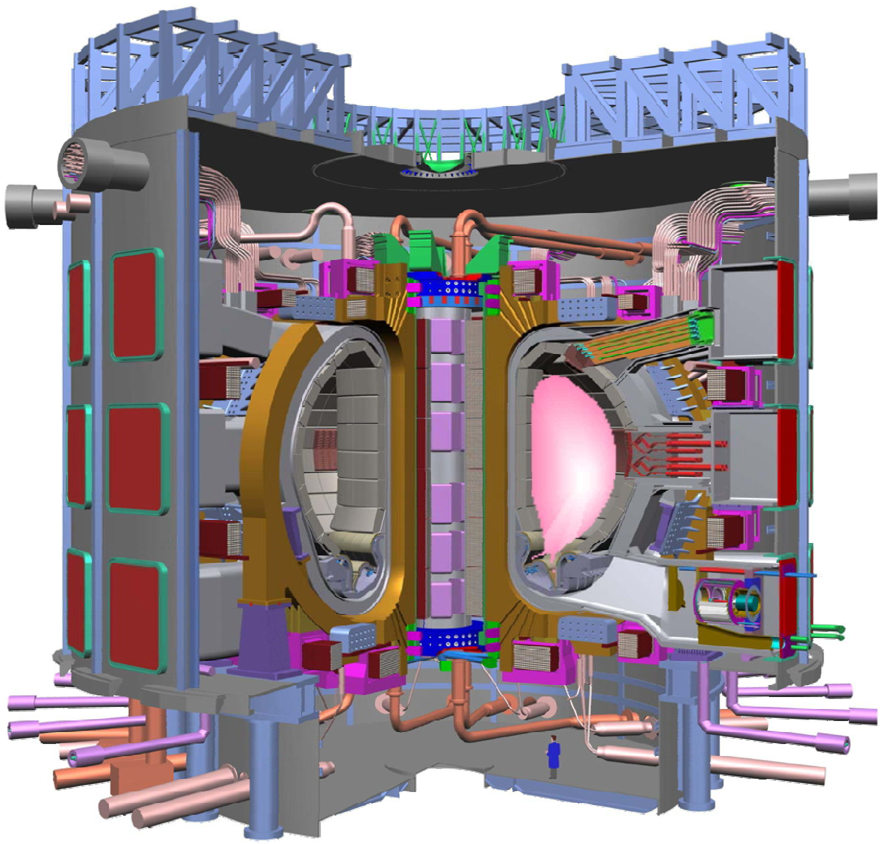


In ITER most of the heating will be by the Fusion produced Helium (alphas)

Neutron crosses the Field and strikes lithium in wall

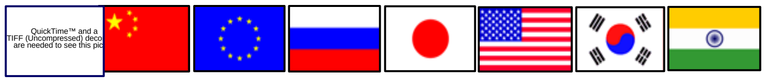
ITER

We are building a bigger international experiment to make the first burning plasma. Starts in 2018 - 2020.

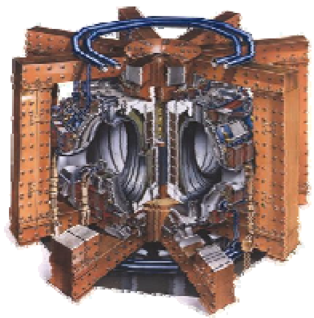


BASIC PARAMETERS.
Plasma Major Radius 6.2m
Plasma Minor Radius 2.0m
Plasma Current 15.0MA
Toroidal Field on Axis 5.3T
Fusion Power 500MW
Burn Flat Top >400s
Power Amplification Q>10

Cost is > 5 Billion Euro.



JET

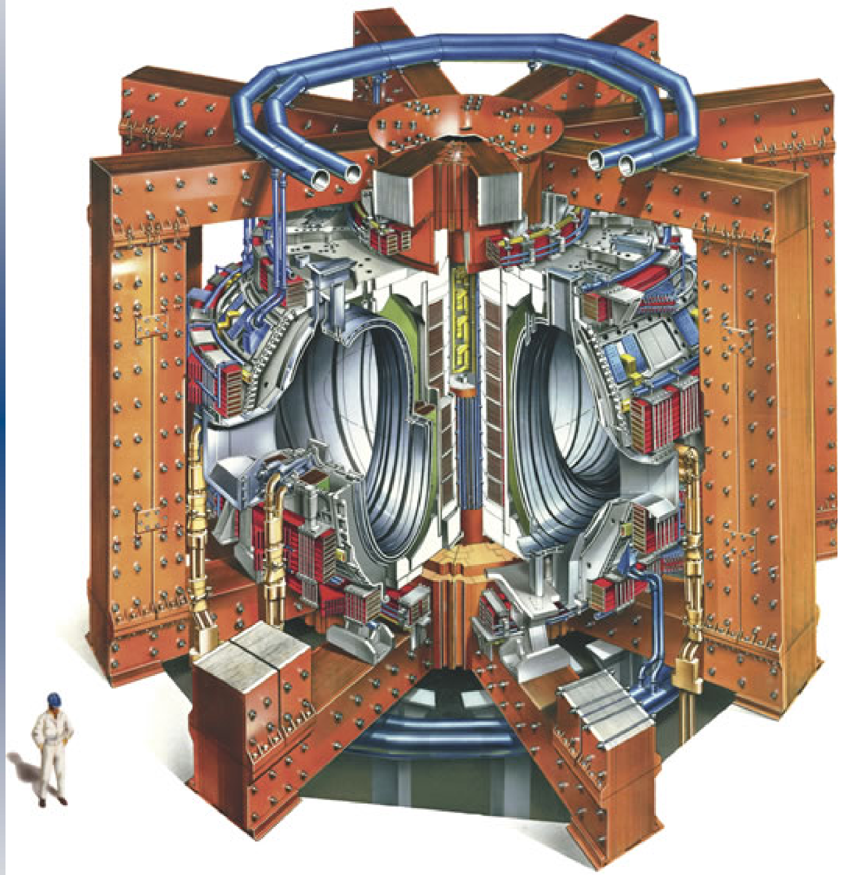


UKAEA

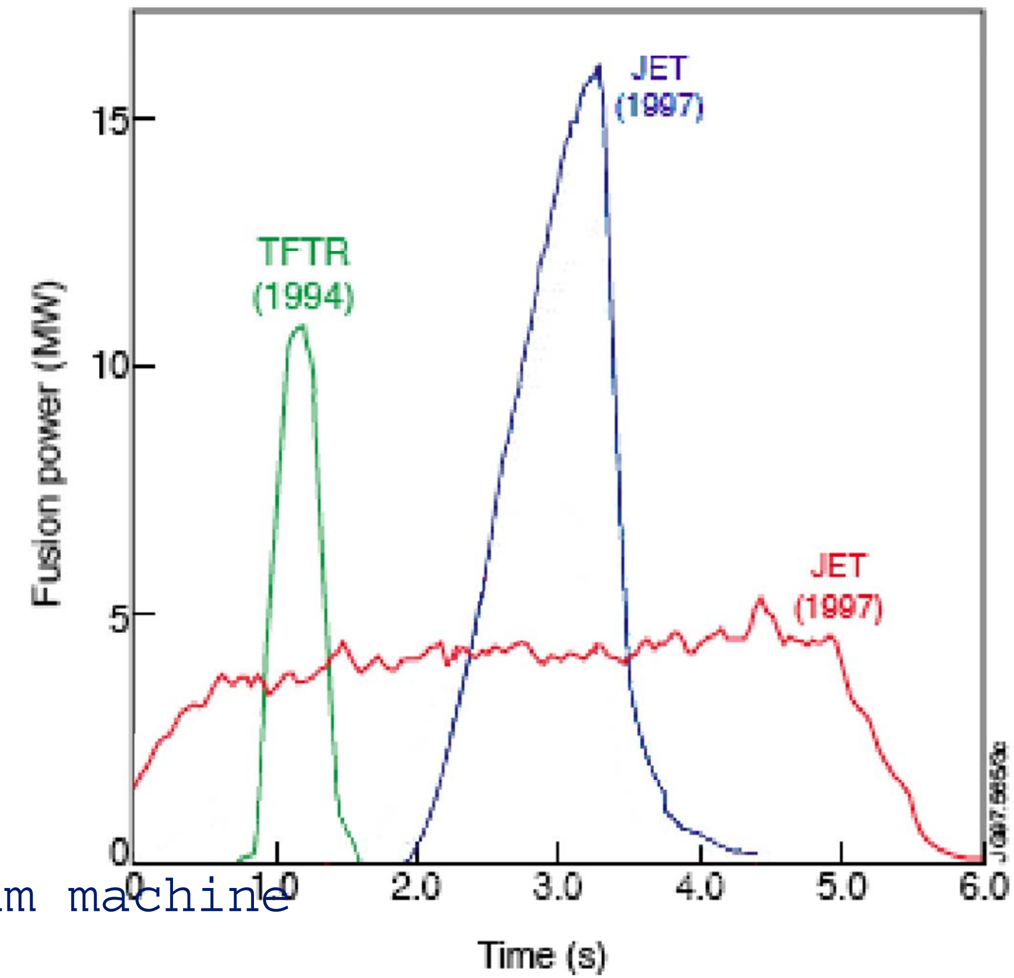
How do we know ITER will work?

UKAEA

JET the Worlds Biggest Fusion Experiment



16MW fusion power 1997



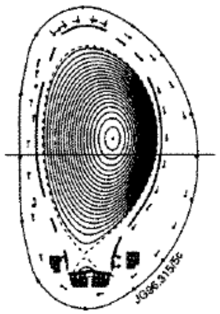
Currently the only Tritium machine

UKAEA

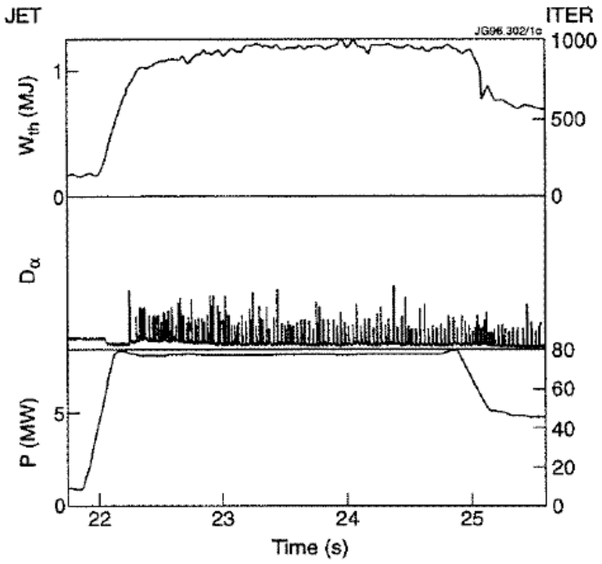
2013 tritium again --new records

JET, ITER's "Wind Tunnel".

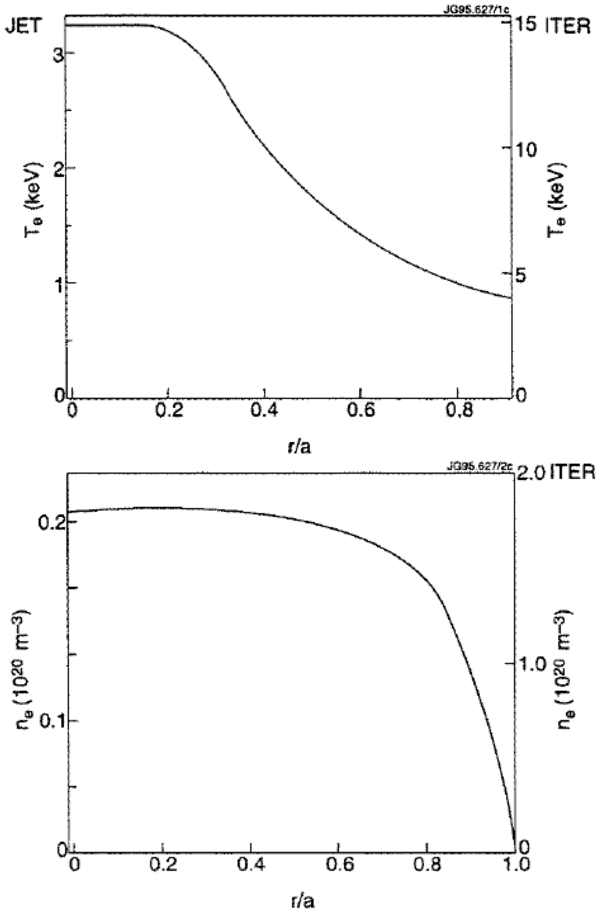
Keep Dimensionless variables fixed while scaling size.



$$n \propto B^{4/3} a^{-1/3}$$
$$T \propto B^{2/3} a^{+1/3}$$
$$I \propto Ba$$
$$W \propto B^2 a^3.$$

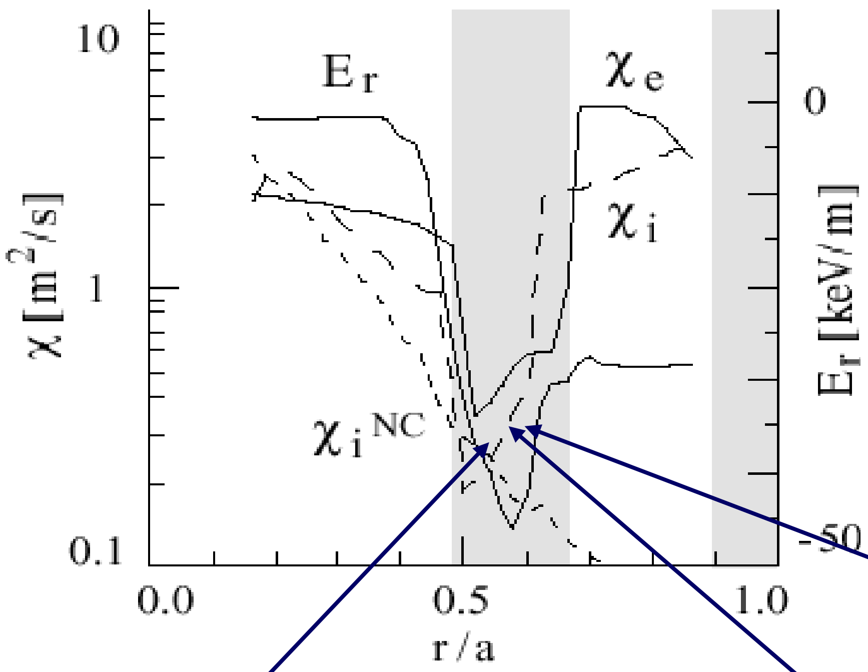


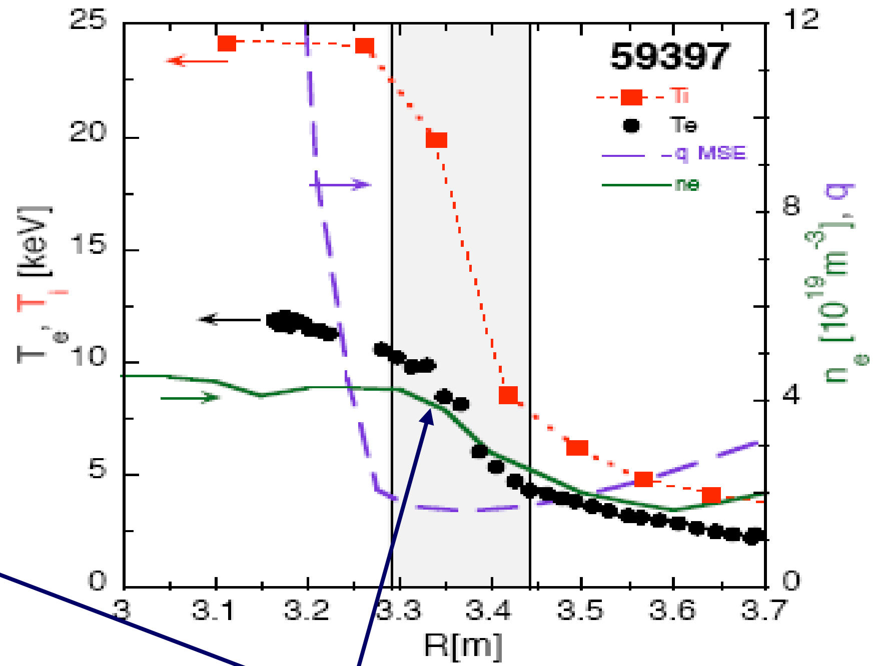
(a)



(b)

Internal Transport Barriers -- Smaller Reactors?





Quiescent “turbulence free” zone

Low transport associated with high **E** × **B** flows in JT-60U

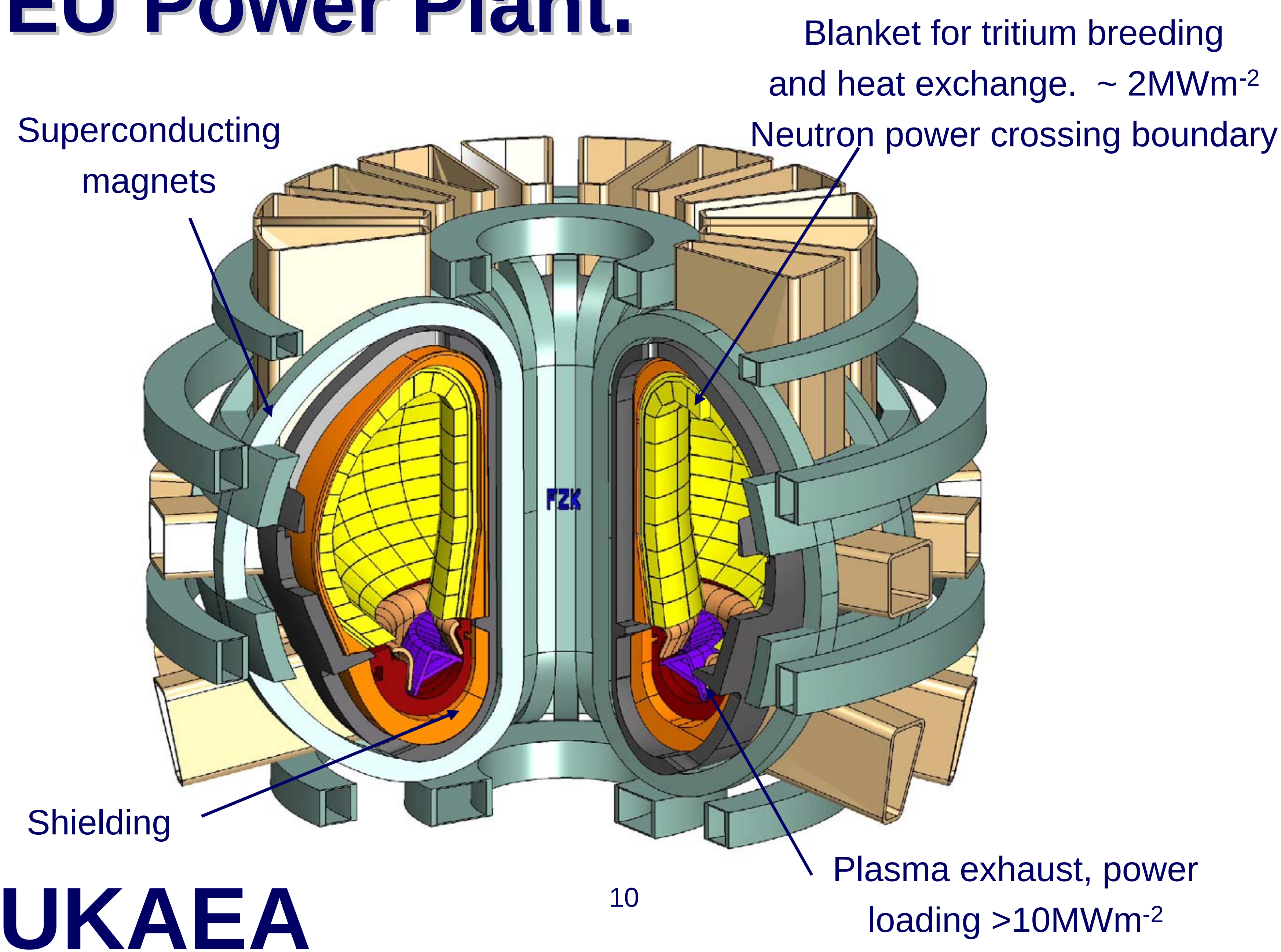
Y Koide & JT-60 U Team Phys Plasmas **4** 1623 (1997)

UKAEA

But we want electricity not neutrons?

UKAEA

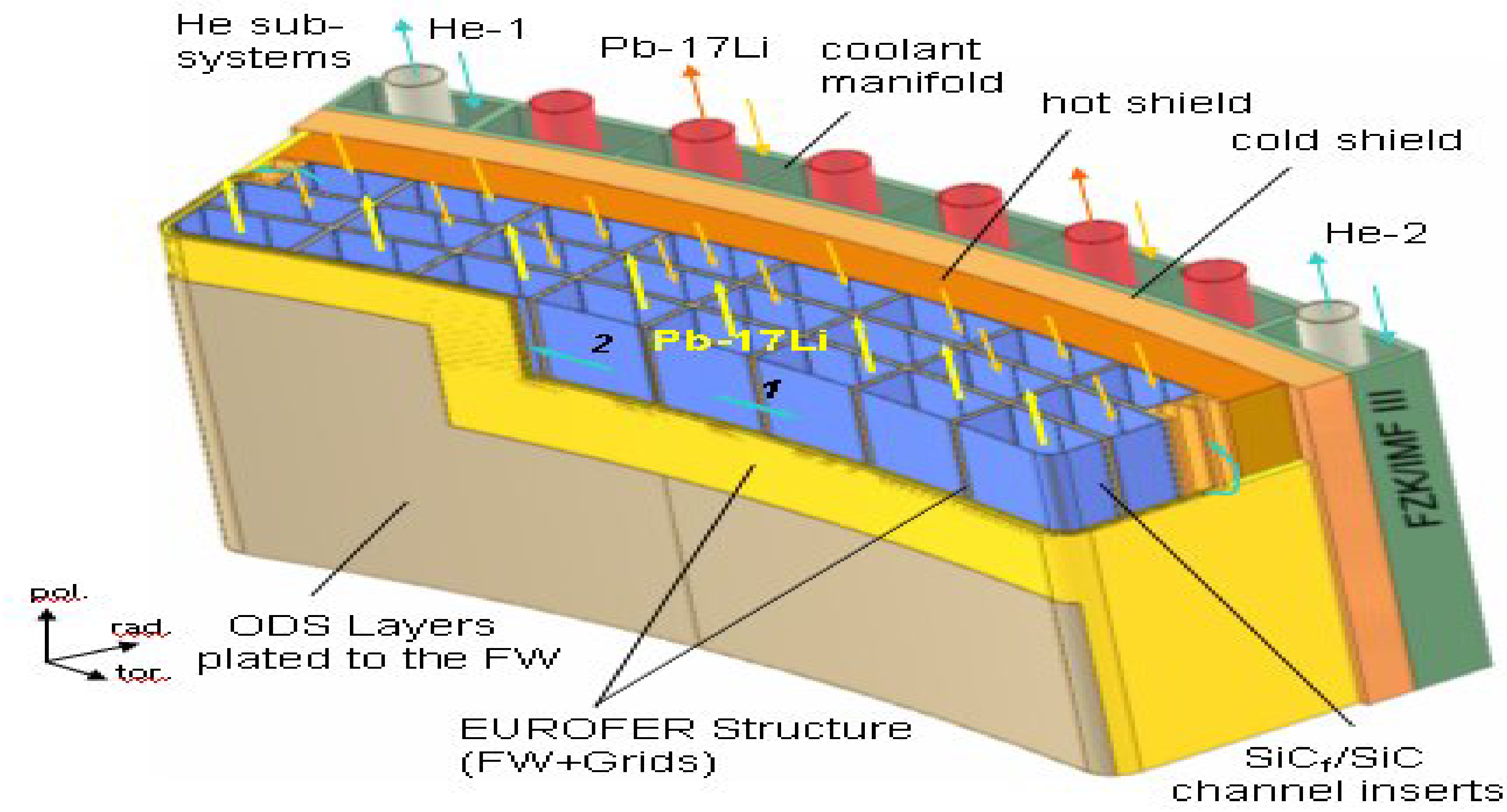
EU Power Plant.



UKAEA

Fusion First Wall and Blanket integrate many technologies

Breeder Blankets + Materials Development are stongly coupled.

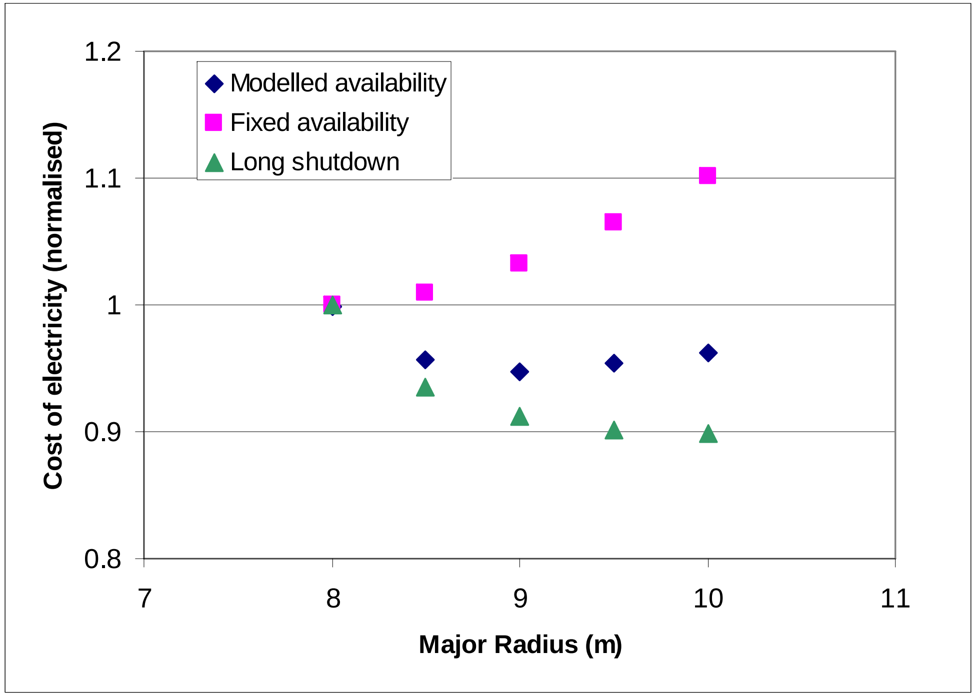


UKAEA

What do we need?

Big or Small

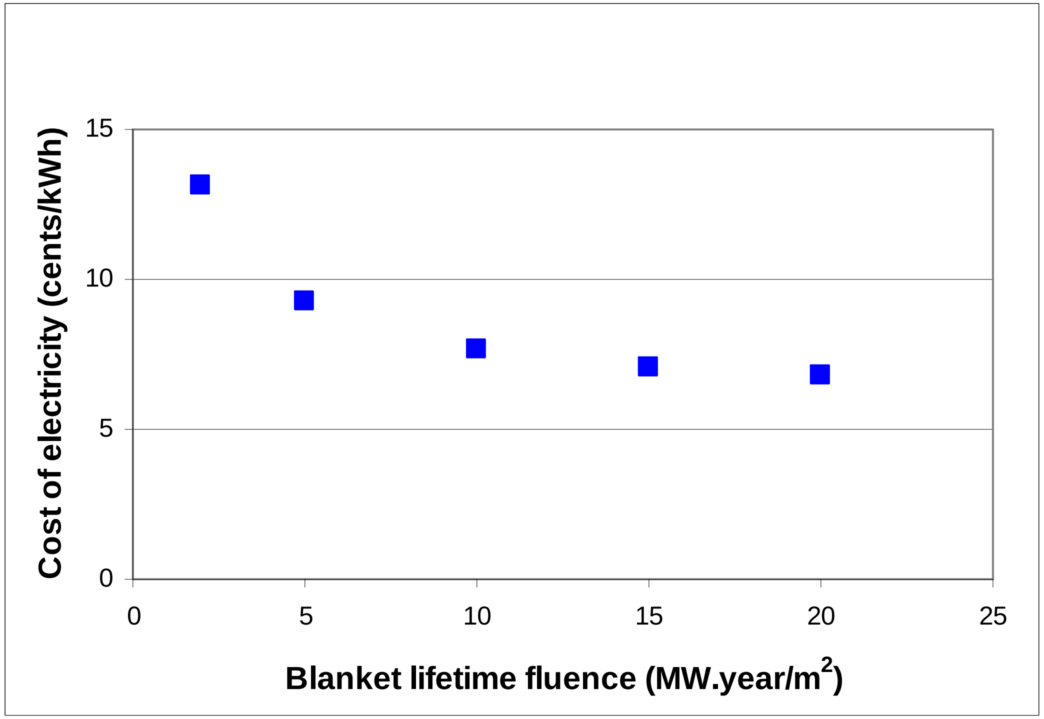
- Neglecting the effect of size on availability means smallest is best (lowest cost) at fixed power.
- Modelling availability can lead to an optimum at larger machine size. (Here very low neutron resilience <20dpa)
- (With long shutdown availability is low and costs are higher)



UKAEA

Overall Variation in Cost of Electricity with Blanket Lifetime Fluence

- **There is little advantage in exceeding 15 MW.year/m^2** but definite advantage in exceeding 5.
- 5 MW.year/m^2 could be a reasonable target for DEMO, 15 for ultimate power plant



10 MW.year/m^2 corresponds to approximately 100 dpa in steel

UKAEA

Link to Materials Development

- Reality is much more complex than implied above.
- E.g. embrittlement can increase rapidly at low dose then more slowly, if at all, at high dose. Small changes in material may lead to large effect in a fusion power plant.
- Phase transitions can occur e.g. at higher temperature.
- Coupling of effects such as temperature and irradiation embrittlement make general statements unreliable.
- The effect of Helium accumulation in materials remains a large uncertainty.
- Power plant concepts should be based around the best knowledge of materials, and evolve as the materials development programme progresses.
- IFMIF (accelerator facility to test fusion materials) must be built now.

UKAEA

Conclusion

Era of Burning plasmas is starting. ITER will be a historic experiment. Fusion engineering is beginning in earnest. Above all we need to get started on the technology now -- in parallel with ITER.

The world needs fusion -- shortening the time to fusion power is essential.

UKAEA