Issues for Neutron Calculations for ITER Fusion Reactor

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NSFS meeting Ålesund, Norway
May 26-30, 2008

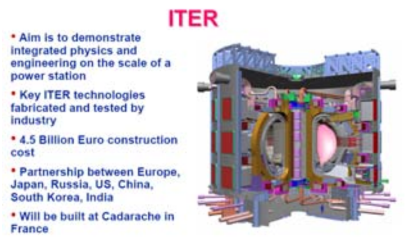
Introduction

Outline

1. Fusion development
2. Issues for neutronics calculations
3. Risø DTU reasons for participating in ITER
4. Example of calculation on ITER-CTS diagnostics system

Fusion development

ITER, International Thermonuclear Experimental Reactor

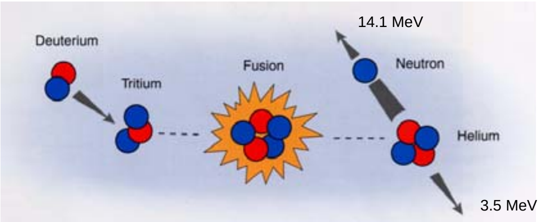


ITER to be build in France

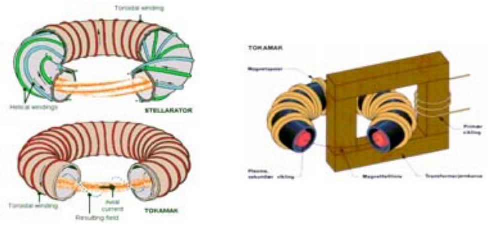
Fusion process

The process involved is the following:

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



Development of fusion designs



JET

JOINT EUROPEAN TORUS (JET)

Currently the world's largest fusion research facility

Operated by UKAEA as a facility for European scientists

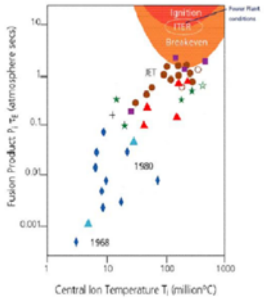
Major progress

Major progress in recent years

- Huge strides in physics, engineering, technology
- **JET**: 16 MW of fusion power ~ equal to heating power. 21 MJ of fusion energy in one pulse
- Ready to build a Giga Watt-scale tokamak: **ITER** – which (see next slide) is expected to achieve desired performance

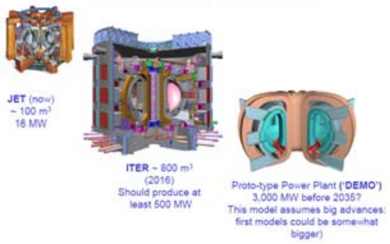
[P_i =pressure in plasma;

τ_E = (energy in plasma)/(power supplied to keep it hot)]



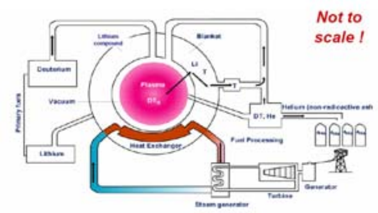
Next steps for fusion

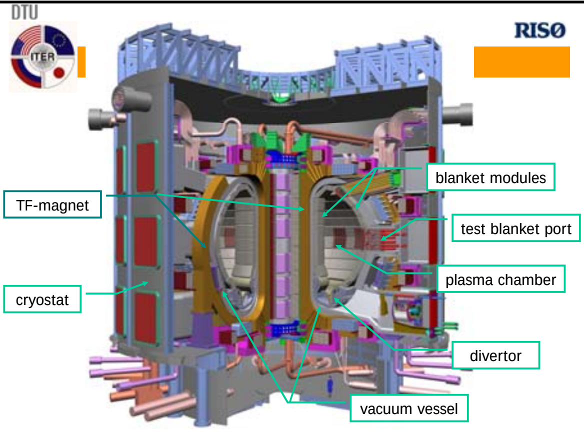
Next steps for Fusion



Design principle for a fusion plant

A Fusion power plant would be like a conventional one, but with different fuel and furnace

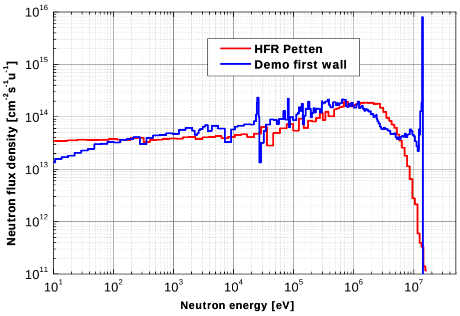




Issues for fusion vc. fission neutronics calc.

- Neutron source in fission is determined by a criticality iteration
- Neutron source in fusion is prescribed by the plasma conditions – no iteration is needed
- Different neutron energy spectra
  - Fission peak 1-2 MeV
  - Fusion peak 14 Mev

Neutron flux spectra: fusion vs. fission



Fusion process and tritium breeding

$$D + T \rightarrow {}^{4}He + n + 17.6\ MeV$$

$${}^{6}Li + n \rightarrow T + {}^{4}He + 4.86\ MeV$$
$${}^{7}Li + n \rightarrow T + {}^{4}He + n - 2.5\ MeV$$

$${}^{9}Be + n \rightarrow 2n + 2\ {}^{4}He$$

Neutronics calculations

Fusion Reactor Design Issues

- Blanket
  - Tritium breeding, power generation, (shielding)
  - ⇒ *assure tritium self-sufficiency, provide nuclear heating data for thermal-hydraulic layout*
- Shield
  - Attenuate radiation to tolerable level
  - ⇒ *assure sufficient protection of super-conducting magnet*
  - ⇒ *avoid structural damage, helium gas production in steel structure*
- Safety & Environment, Maintenance
  - Material activation
  - ⇒ *minimise activation inventory with regard to short-term and long-term hazard potential*
  - ⇒ *maintenance service during reactor shutdown (dose level)*

Neutronics calculations

QA/QC

- Fusion Reactor Design relies on data provided by nuclear design calculations
- Qualified computational simulations are required
  - ⇒ Appropriate computational methods, tools (codes) and data (nuclear cross-sections)
  - ⇒ Validation
- Qualification through integral benchmark experiments.

Risø DTU reasons for participating in ITER

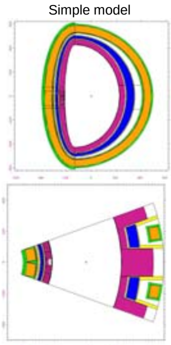
- Experience in calculation of neutron and gamma fluxes and neutron activation in fission reactors by means of the Monte Carlo code MCNP
- Validation calculations performed for Forsmark Nuclear Power Plant
- Local Association Euratom/Risø DTU Plasma group, need for in-house neutronics calculation capabilities for designing the Collective Thomson Scattering (CTS) diagnostics system

Monte Carlo calculations

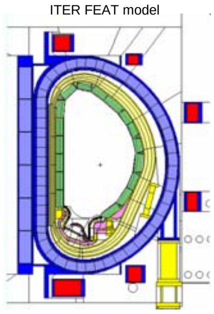
- A simplified ITER 40 degree geometry input model for MCNP-5 has been developed (about 300 cells)
- Detailed geometric description of the CTS diagnostics system
- Well suited for parametric studies – short CPU time
- The input model has been benchmarked against the (20 degrees) ITER FEAT reference model (about 3000 cells)

Geometry of simple model vs. ITER FEAT model

Simple model

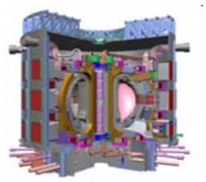


ITER FEAT model

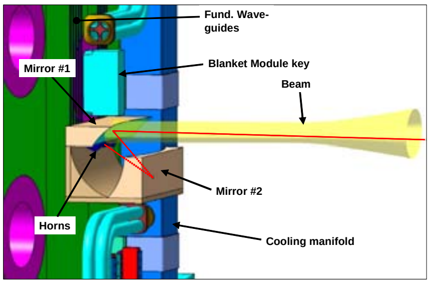


Risø's CTS system

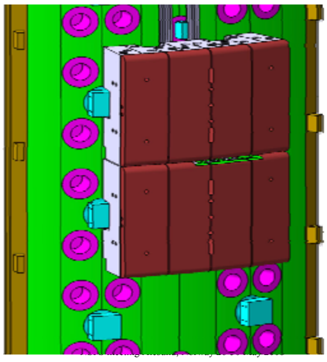
- CTS: Collective Thomson Scattering
  - diagnostic of fast ions
  - alterations to inboard blanket
- Neutronics:
  - Temperature increase in the TF coil magnets
  - Material damages due to fast neutrons



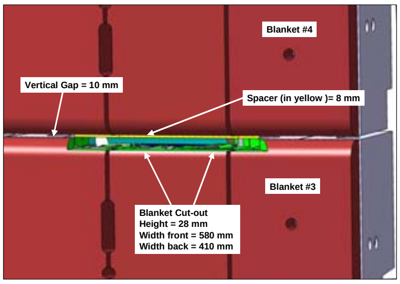
Mirror 1 and Mirror 2



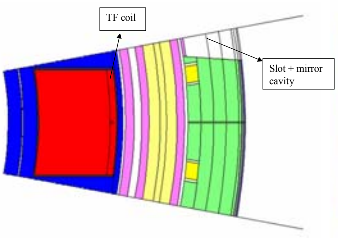
Blanket module



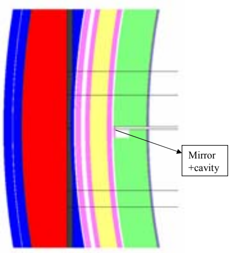
Blanket Cut-out



CTS calculation with mirror cavity and slot



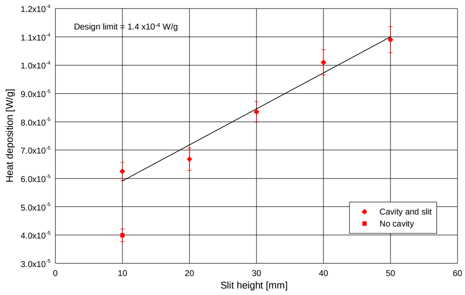
Horizontal cross section



Vertical cross section

Nuclear heating of TF winding pack

Nuclear heating of TF winding pack



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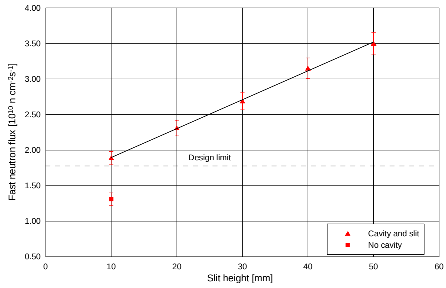
Fast neutron flux in TF coil insulator (epoxy)

Fast neutron flux (E>0.1 MeV) in TF coil insulator



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