Overview of the development of neutronics instrumentation for the EU ITER TBM at KIT

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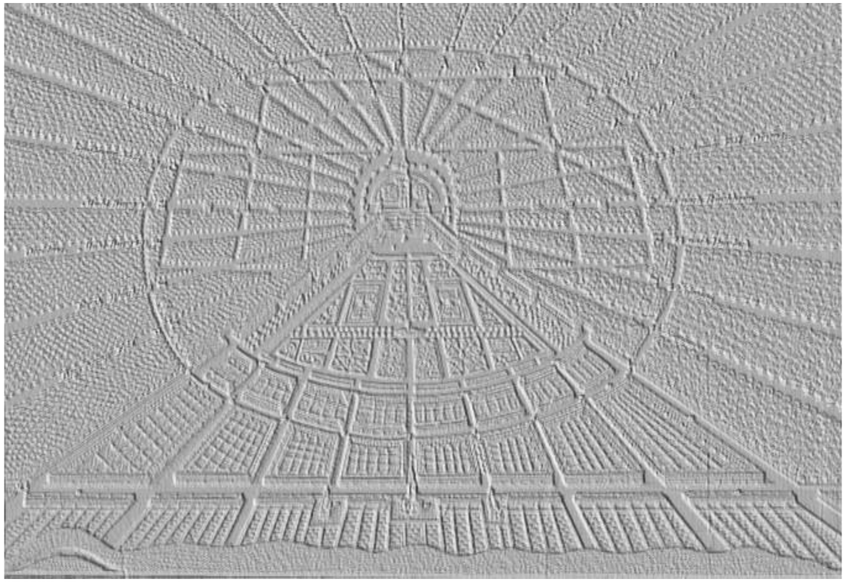


Outline

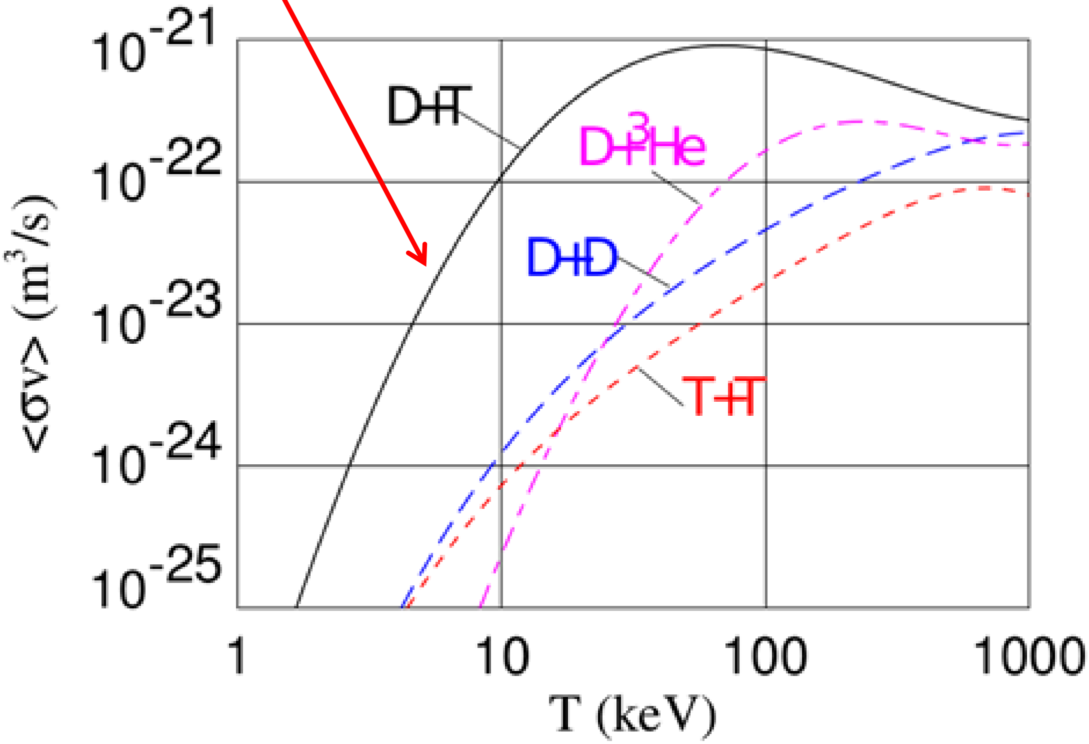
- The basic fuel cycle of (DT) fusion reactors
  (from the neutronics point of view)
- European test blanket modules in ITER
- Neutronics instrumentation for the ITER test blanket modules

Which fusion reactions?

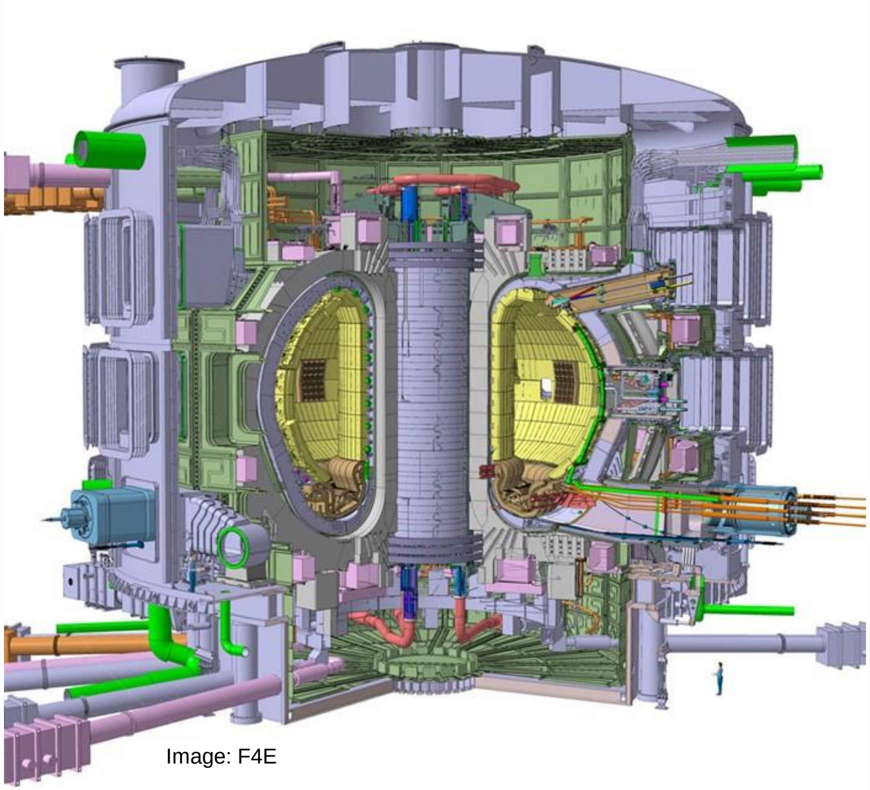
D + D	→	^3He + n	+3.3 MeV
D + D	→	T + p	+4.0 MeV
D + T	**→**	**^4He + n**	**+17.6 MeV**
T + T	→	^4He + 2n	+11.3 MeV
D + ^3He	→	^4He + p	+18.4 MeV

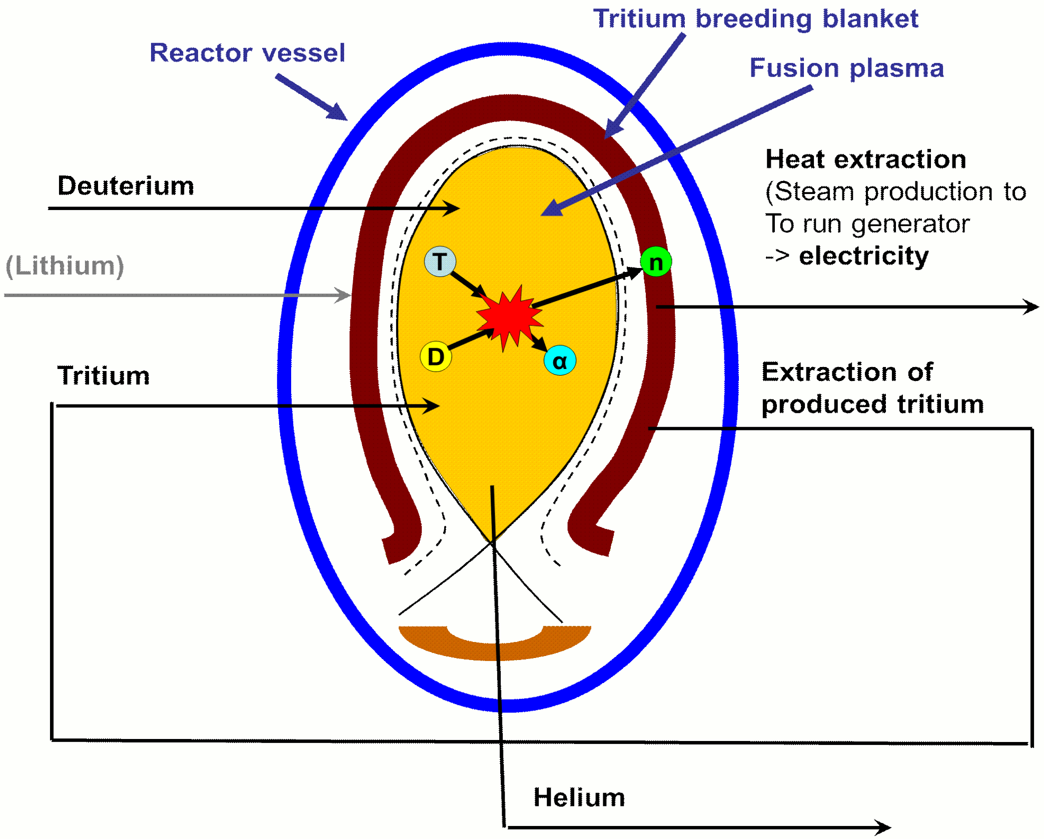
DT reaction: high reaction rate in hot confined plasma

Note that D+^3He is not free of neutron emission (→material activation) due to „parasitic“ DD reactions with some DT contribution.



Basic fuel cycle of a DT fusion power reactor

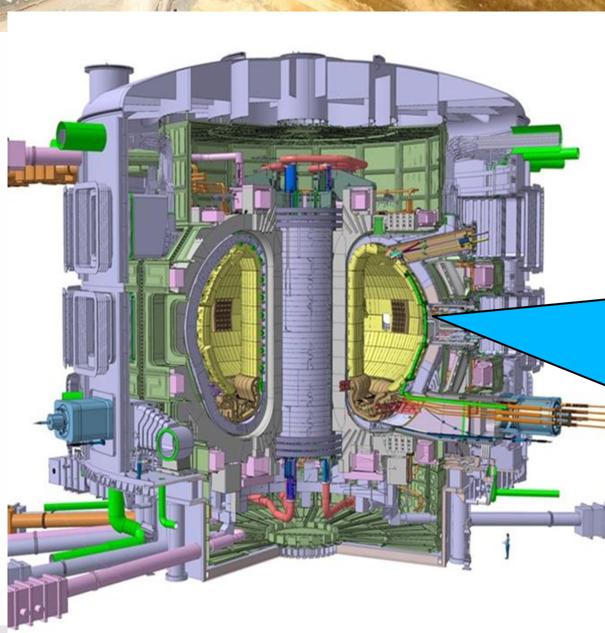




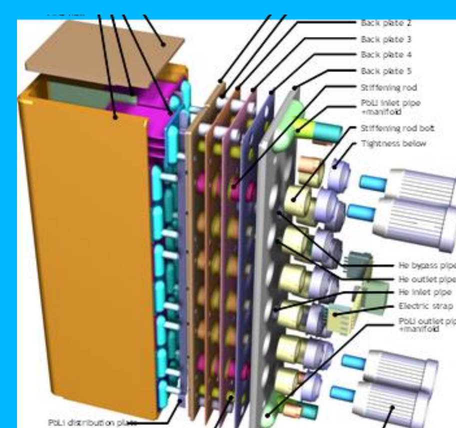
- Tritium for DT reaction must be produced in the blanket: **^{6}Li(n,α)T and ^{7}Li(n,nα)T**
- Tritium breeding ratio **must be larger than 1** plus some margin for losses in the tritium extraction and processing systemplus production of tritium for startup of further fusion power reactors

ITER (The Way): Testing of breeding blanket concepts

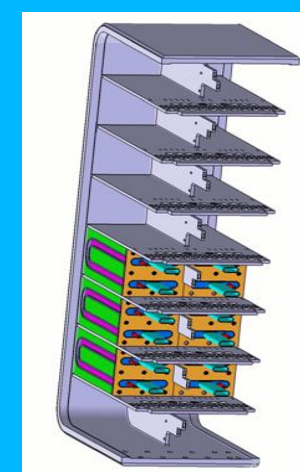
- Output power up to 500 MW
- Q=10 (burning plasma)
- Pulse length 400-600 s
- Studies plasma and fusion reactor technology including the tritium breeding system
- Demonstrates safety of a fusion device



European **T**est **B**lanket **M**odules will be inserted in equatorial port #16



Helium-Cooled Lithium-Lead



Helium-Cooled Pebble Bed

Neutronics instrumentation for the ITER Test Blanket Modules

Local neutron flux measurements:

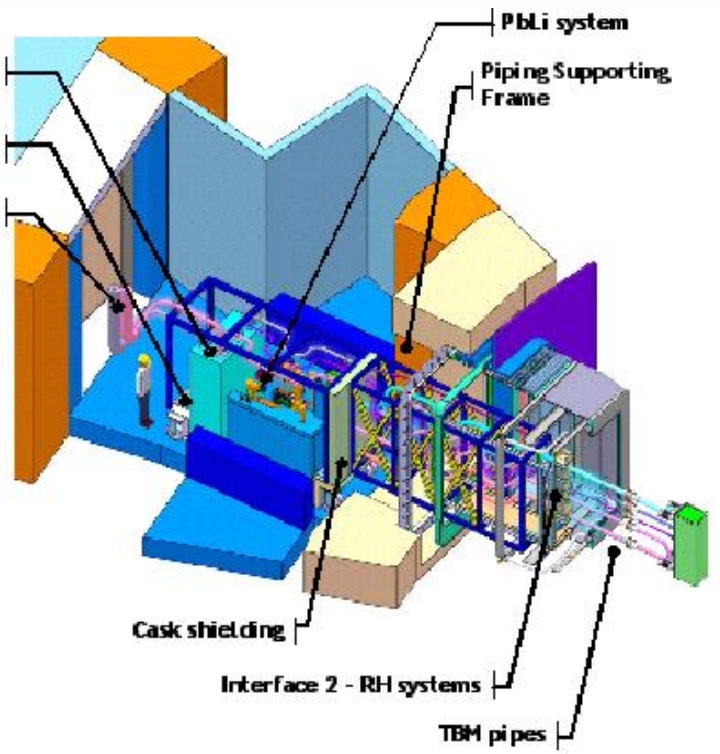
- normalization for other parameters (also „non-neutronics“) in the TBM
- better accuracy than interpolated flux values from measurements outside the TBM

Particular importance for Tritium accountancy!

ITER TBM neutronics experiments will allow to check

- **high-fidelity calculational tools**
- **Modelling of heterogeneous fusion reactor relevant complicated structures under fusion reactor conditions**

Neutronics instrumentation for the ITER TBM
- Conditions in the TBM -



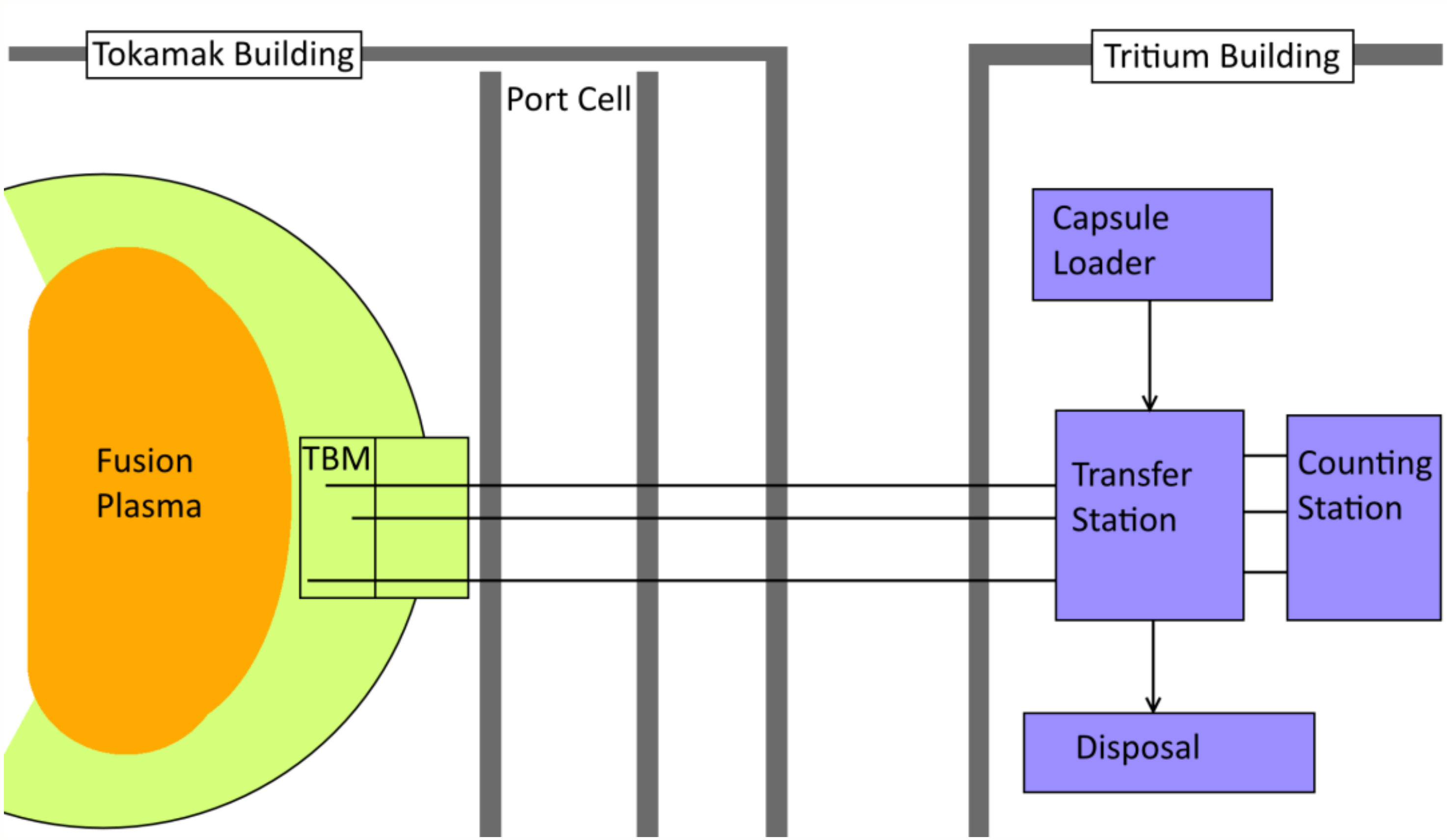
Conditions in the TBM terribly bad for any kind of detectors / diagnostics

- ***10^9~10^{14} n*cm^{-2}s^{-1}***
- **300..550 ºC**
- **Magnetic fields ~4 T**
- **difficult access**
- **little space**

Possible candidates for neutron flux measurements in TBM:

***Neutron activation system**, **silicon carbide detectors:** this talk*
***Self-powered neutron detectors:** next talk by Mr. Prasoon Raj*
Diamond detectors: investigated by ENEA
Miniature fission chambers: not considered yet

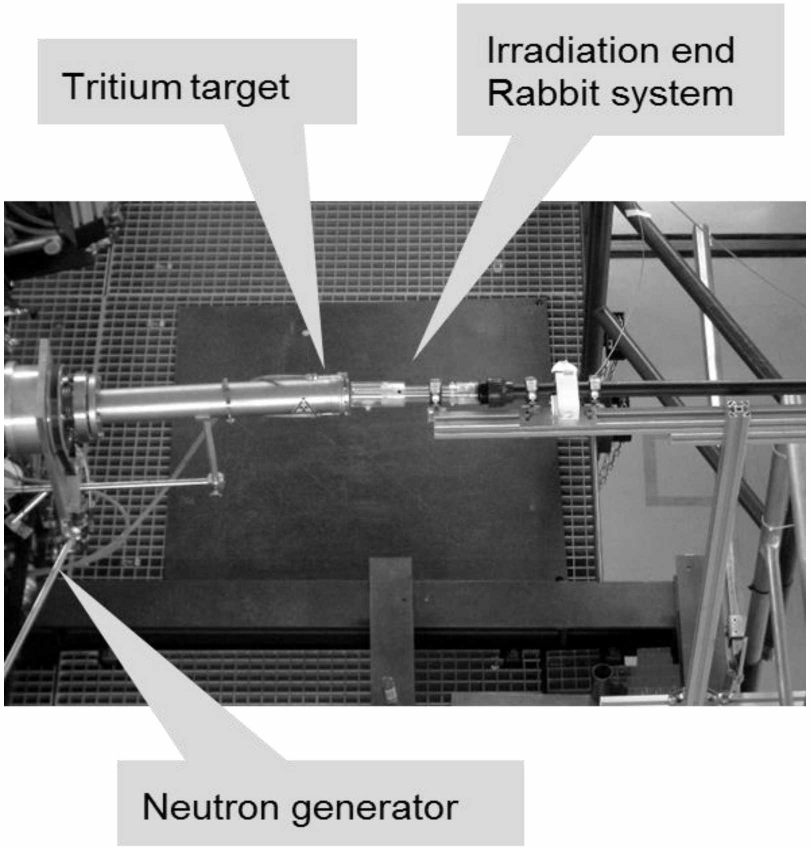
Neutronics instrumentation for the ITER TBM
TBM Neutron Activation System

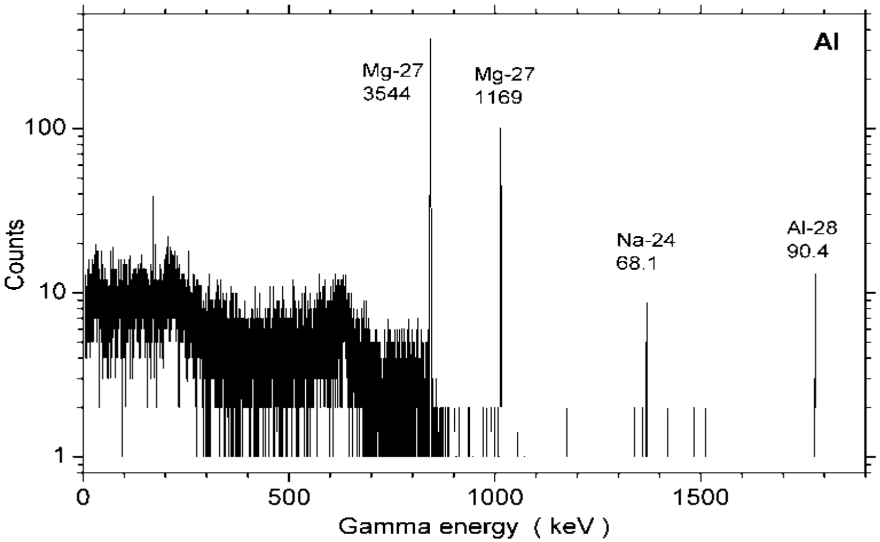


Layout of a TBM neutron activation system

Neutronics instrumentation for the ITER TBM
Neutron Activation System test system

- ➢ Accelerator-based DT neutron generator of Technische Universität Dresden
- ➢ Pneumatic activation probe transport system
- ➢ HPGe gamma spectrometer

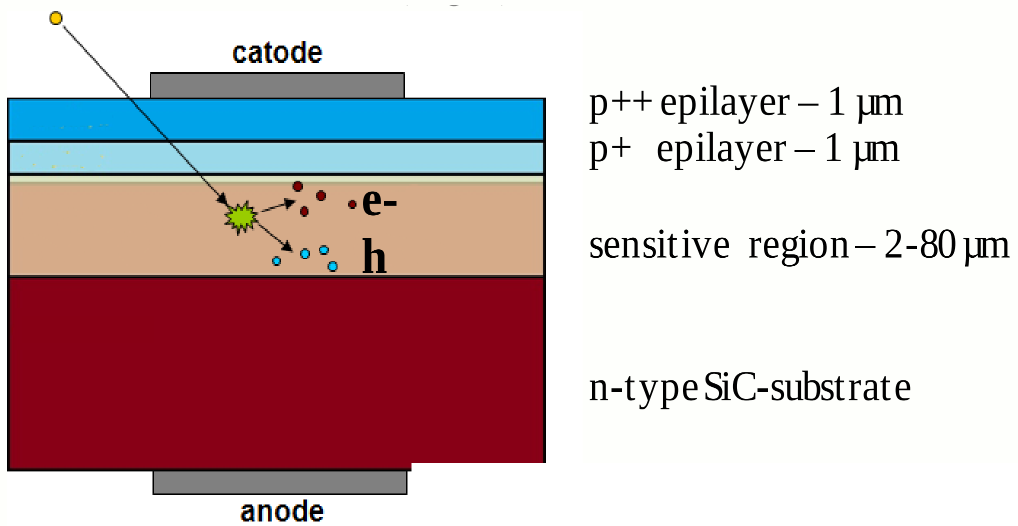




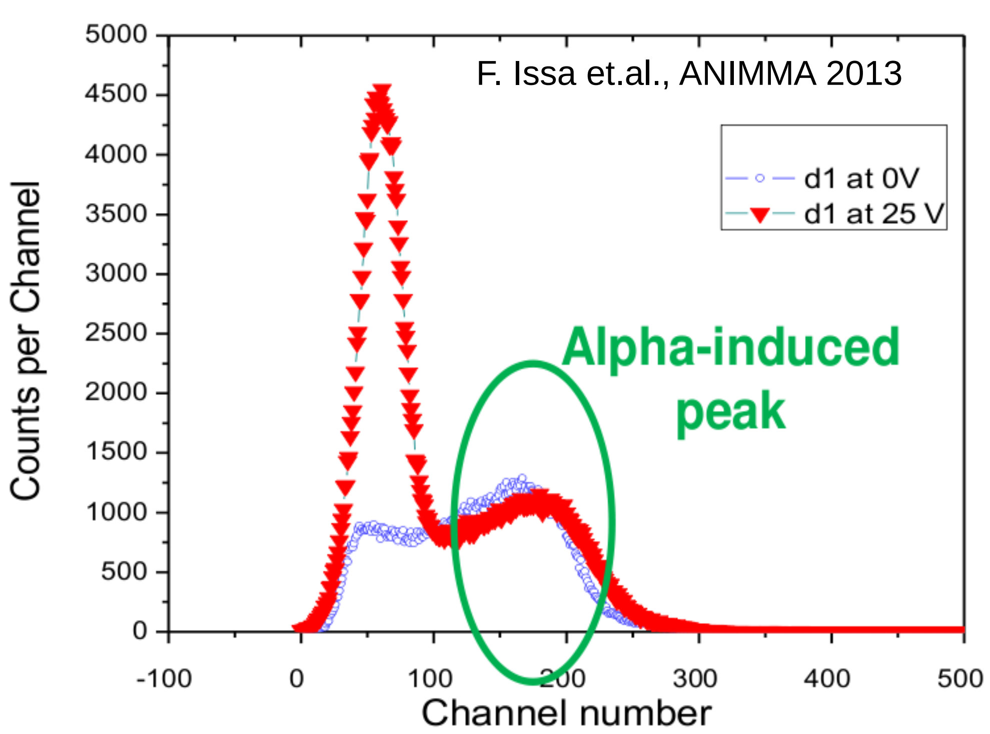
- ➢ Test foils 10 mm diameter, ~0.6 g, material purity >99.9%
- ➢ Irradiation time 60 s, fluence at sample position 3.39 - 4.77×10^{10} n/cm^2
- ➢ Transport time 16..23 s
- ➢ Gamma measurement HPGe, 30%, ca. 5 cm distance, 60 to 600 sec

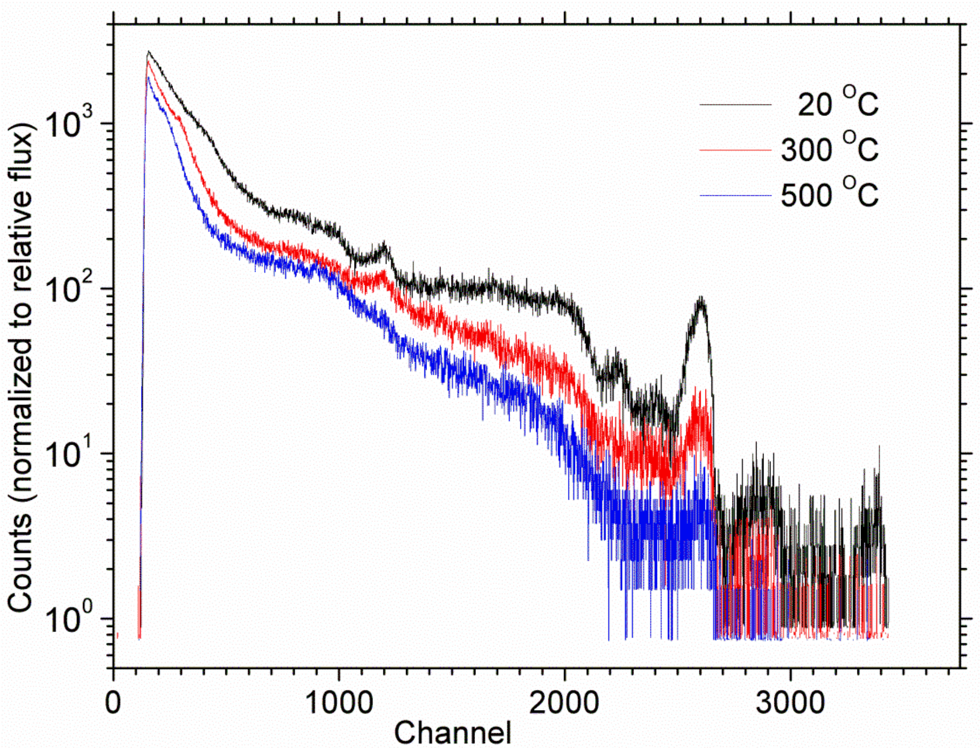
Neutronics instrumentation for the ITER TBM
Silicon carbide detector

- Large band gap semiconductor detectors
- better radiation hardness than Si
- SiC electronics proven to operate at temperatures of several hundred °C
- R&D on SiC detectors has been done since many years
- Signal generation from charged particle emission reactions (thermal neutron + optional lithium/boron layer or implantation, fast neutron + silicon/carbon)



Neutronics instrumentation for the ITER TBM
Silicon carbide detector (I-SMART / KIC InnoEnergy)





With boron implantation in thermal neutron field (BR1, room temperature)

Without boron implantation at temperatures relevant for the ITER TBM in 14 MeV neutron field (TUD-NG)

Spectroscopic behaviour is retained to some extend.

Summary

- A tritium breeding rate >1 plus some margin is essential for self-sustained operation of power fusion reactors
- Numerical tools for the design of fusion power reactors **require experimental testing and validation**
- **ITER provides an experimental environment which would allow a more reliable extrapolation to a DEMO reactor**
- Neutron flux in the TBM is a basic parameter to which many other measurements in TBM experiments will be related (neutronics and non-neutronics)
  (→ Tritium accountancy)
- Development of measurement methodology and nuclear instrumentation which can sustain the harsh environment in a TBM underway

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