Fusion neutronics experiments utilizing the intense DT neutron generator of Technical University of Dresden

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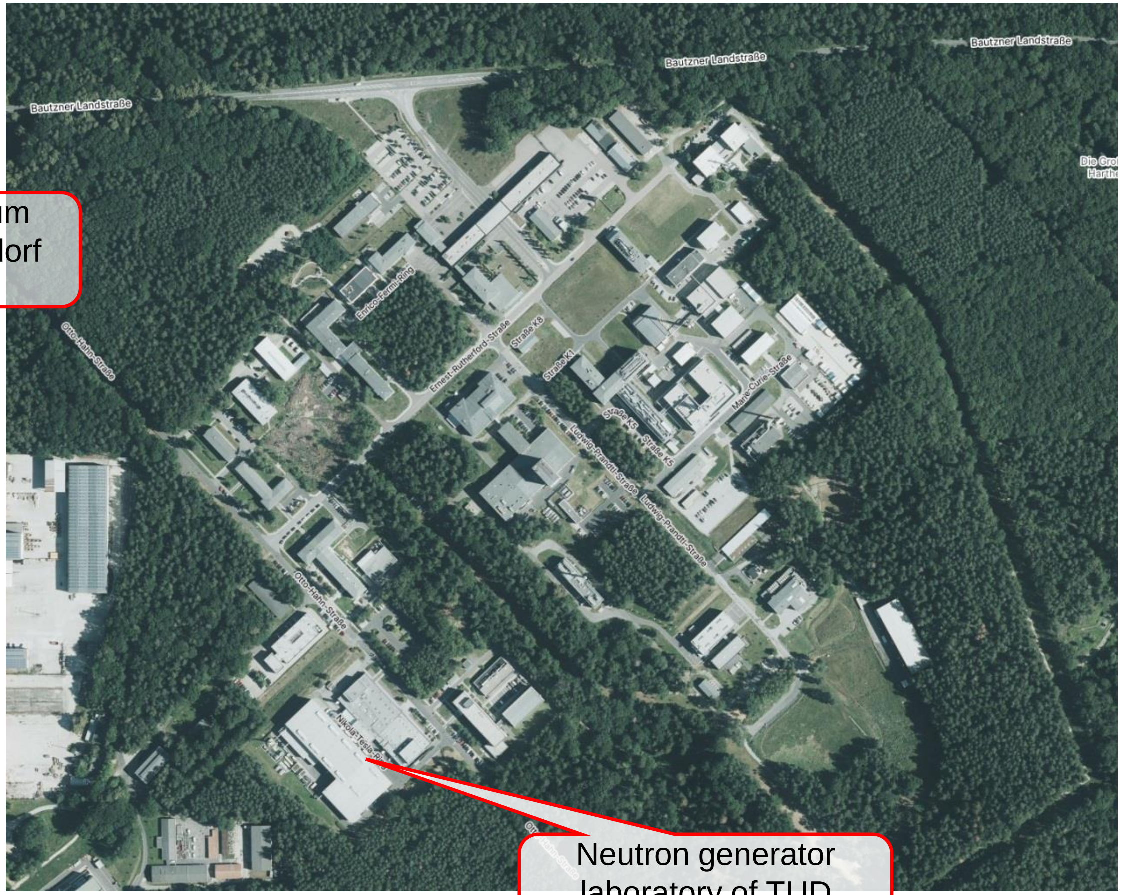
Overview

- Accelerator-based neutron generator of TUD
- Properties of the neutron source
- Some experimental highlights related to fusion neutronics
- Outlook (experimental work, NG upgrades)

Technische Universität Dresden
Neutron generator laboratory



TECHNISCHE UNIVERSITÄT DRESDEN

Technische Universität Dresden
Neutron generator laboratory

Karlsruher Institut für Technologie

TUD has been operating neutron generators for nuclear physics and fusion research since decades

Construction of the present laboratory started at the end of 90ies

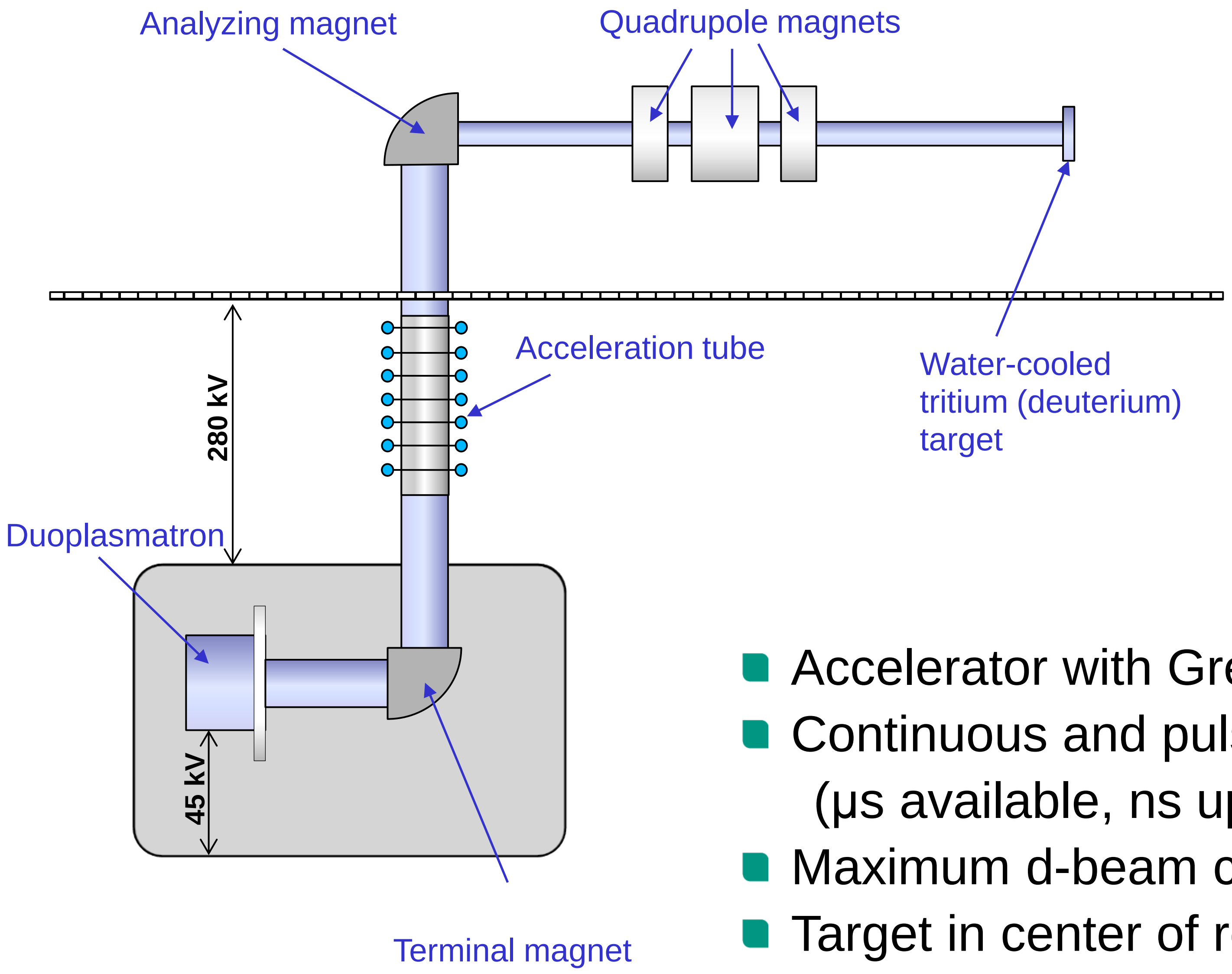
Involved in European fusion research since first operation in 2004 via Research Center Karlsruhe (now Karlsruhe Institute of Technology)

Funding and support from

- *European Fusion Development Agreemenet (EFDA)*
- *Fusion For Energy*
- *Eurofusion*

Collaborations with HZDR, KIT, PTB, ENEA (Italien), NPI (Czech Republic), CEA (France), AGH (Poland), JSI (Slowenia), CCFE (UK), JAEA (Japan), …

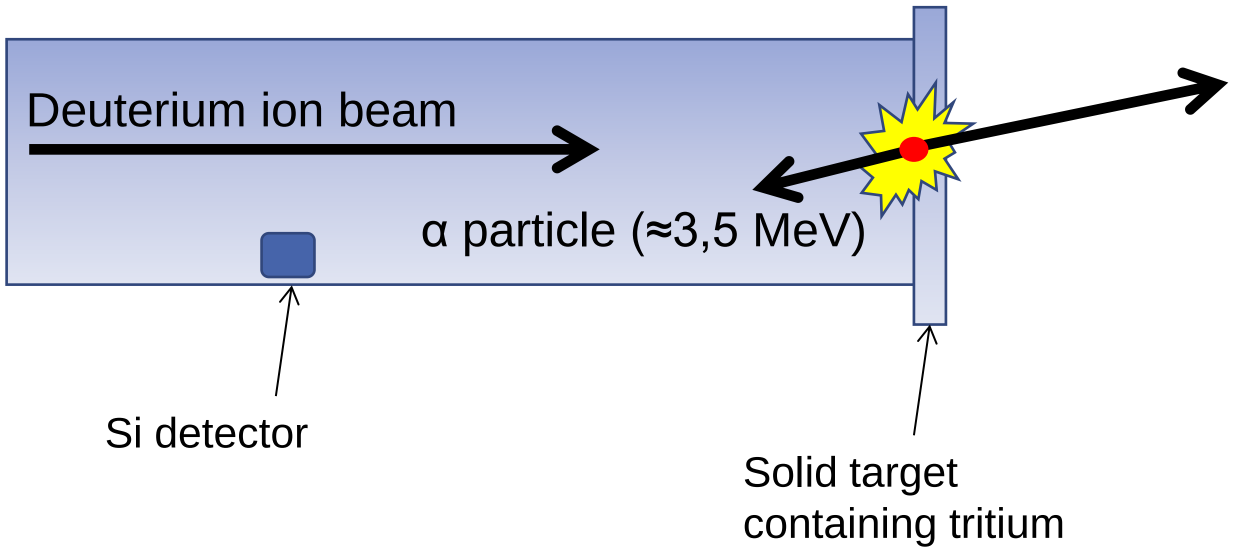
Neutron generator layout

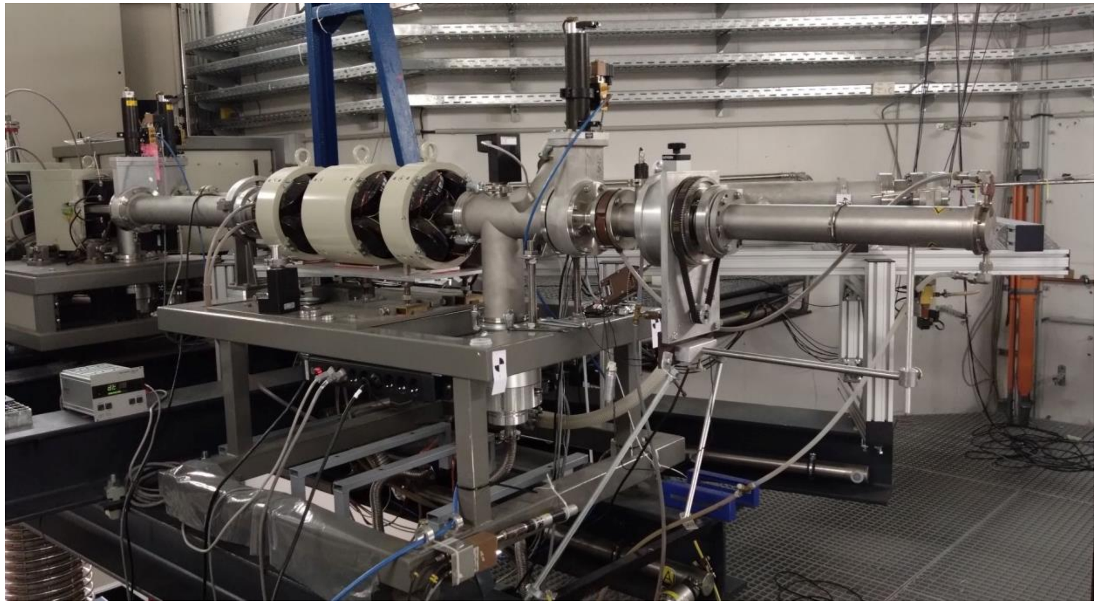


- Accelerator with Greinacher multiplier (Cockroft-Walton)
- Continuous and pulsed mode
  (μs available, ns upgradeable)
- Maximum d-beam current 8...10 mA, energy up to 345 keV
- Target in center of room, distance to walls more than 4 m

Beamline and target

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



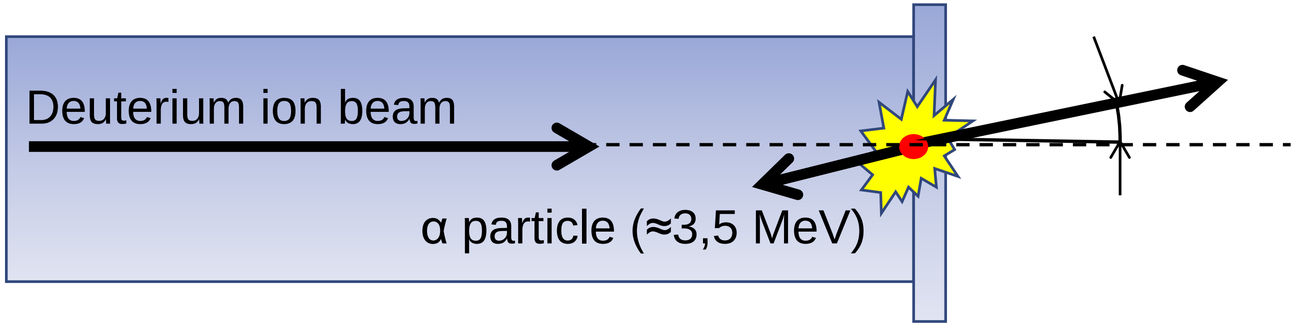


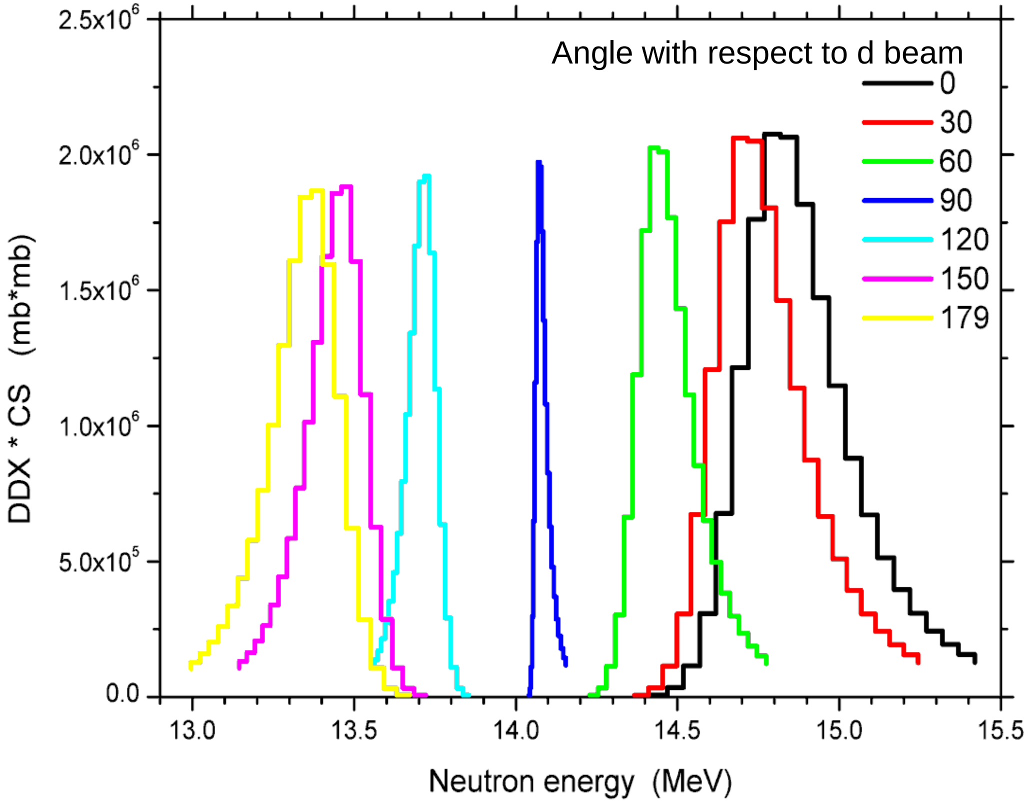
Primary monitor: Si detector in beam tube
Secondary monitor: ^{238}U fission chamber
Optional deuterium target (2.5 MeV).

- Neutron energy ≈14.1 and 2.5 MeV
- Licensed up to $10^{12}\ s^{-1}$ (DT neutrons)
- Typical operation 10^{9} -$10^{11}\ s^{-1}$
- Nearly isotropic

Beamline and target

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





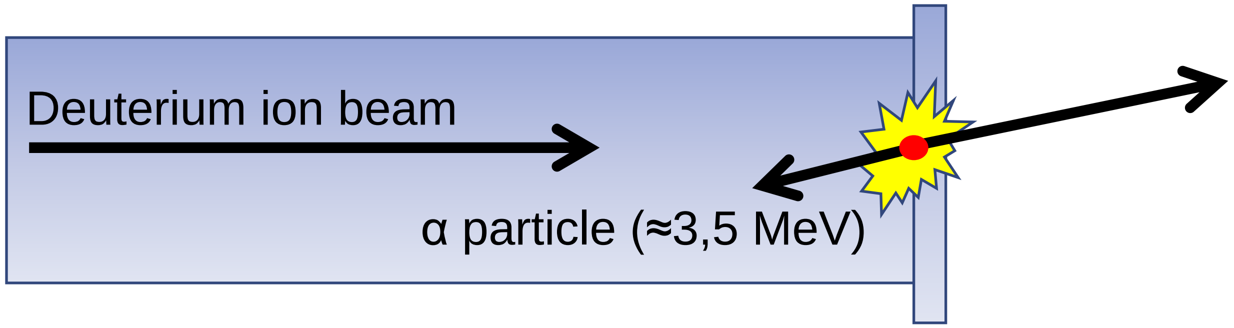
Calculated spectrum of the DT neutron Peak depending on angle to D-beam

Assuming thick target and 320 keV deuteron energy

→ reaction cross section measurement around 14 MeV

Beamline and target

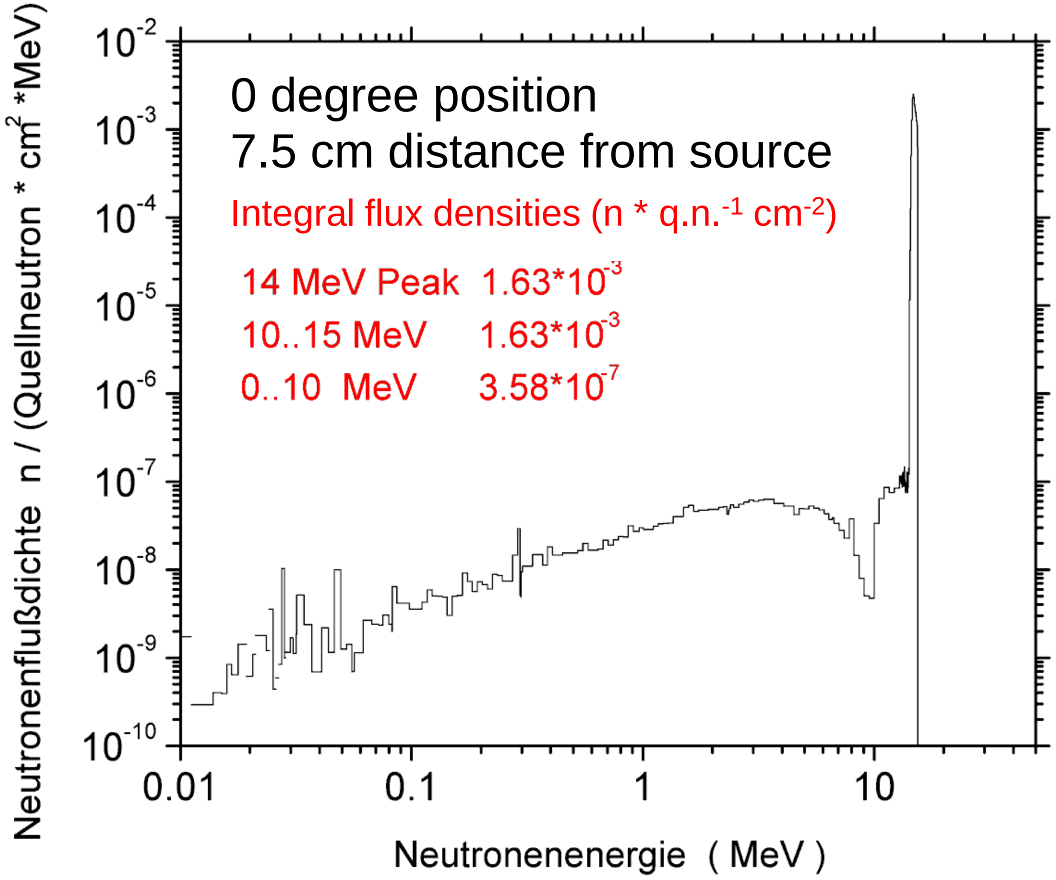
$D + T \rightarrow {}^4He + n \ +17.6 \ MeV$



Calculated neutron spectrum

Neutron energy distribution from DROSG[1]

Transport through target assembly with MCNP[2] .



1) M.Drosg, DROSG-2000: Neutron Source Reactions, IAEA-NDS-87, IAEA Nuclear Data Section, May 2005
2) MCNP—A General Monte Carlo N-Particle Transport code, Version 5, Report LA-UR-03-1987, Los Alamos, 2003

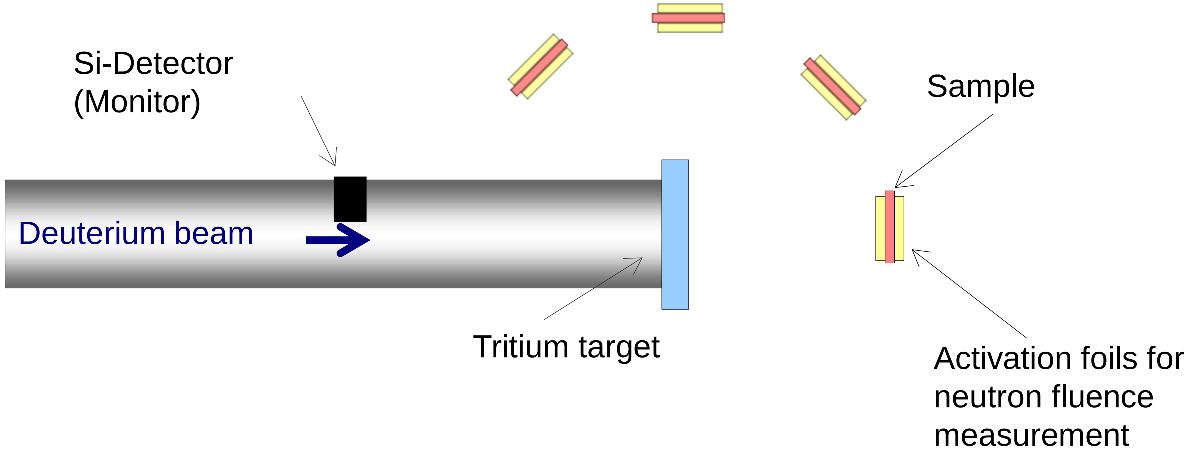
Experimental infrastructure

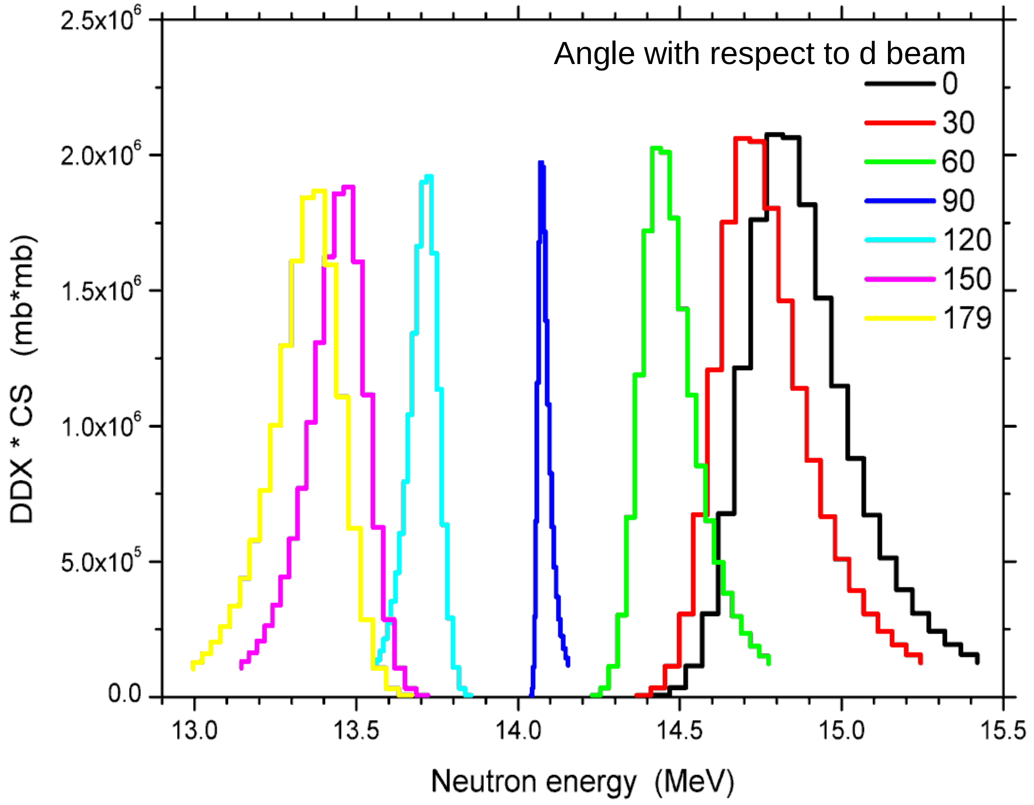
- Two stationary 30% high-purity germanium detectors
- Ne-213 scintillator detector with pulse-shape processing for n/g discrimination, ^{3}He detector for thermal neutrons
- Two mobile 40% HPGe detectors
- Table-top ESR spectrometer for dosimetry and radiochemical investigations
- Gamma camera and intensified optical camera for gamma-ray imaging
- Pneumatic transport system
- Various radionuclide sources: AmBe, Cf-252, low uncertainty standard sources traceable to national standards

Material parameters and properties which can be addressed with DT neutron generators

- Cross section measurements
  - radiation transport
  - activation
  - gas production
- Irradiation of mockups (for checking of numerical simulations)
  - shielding capabilities
  - tritium production rates and neutron fluxes/fluences
- Development, qualification and calibration of instrumentation
- Electronics testing
  - radiation hardness
  - single event upsets

Cross section measurements



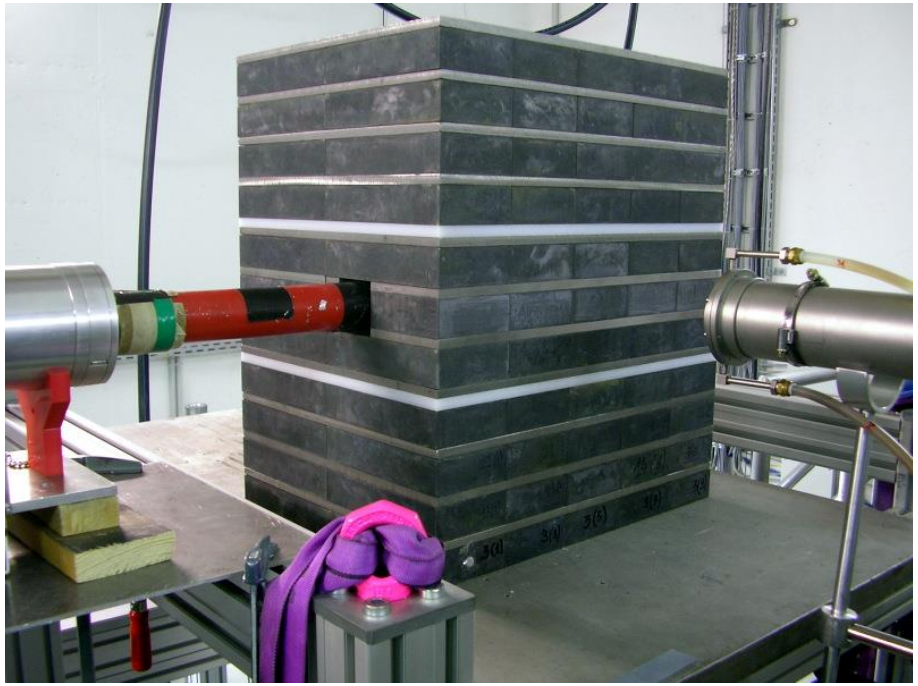


Irradiations in the energy range 13.3 to 15 MeV possible by changing the angle with respect to the deuterium beam

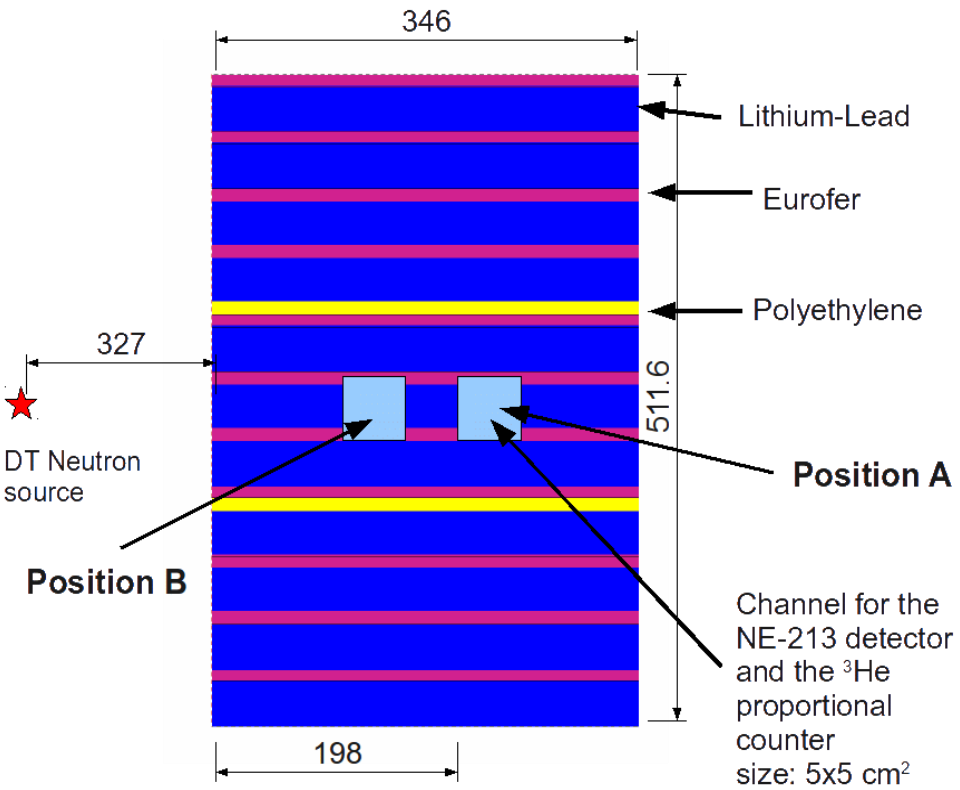
Measurement of induced activity with HPGe detectors and AMS (available at HZDR)

Breeding blanket mockup experiments
HCLL TBM mockup

A collaboration between ENEA, TUD, FZK, AGH, JSI (EFDA-F4E) and with JAEA (IEA-NTFR Implementing Agreement)

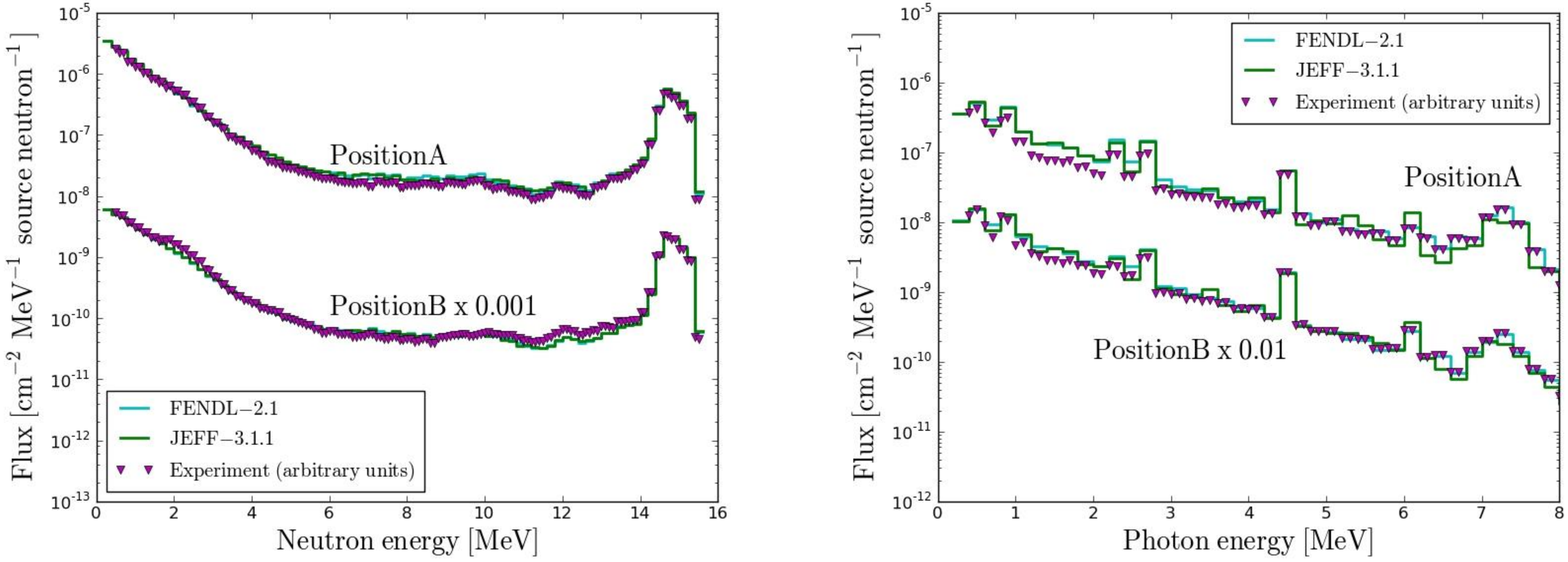


Left: NE-213 detector (1.5"x1.5 ")
Right: Ti-T target of neutron generator
Middle: Mock-up



Two measurement position have been used. Only one channel was present at a time.

Breeding blanket mockup experiments
HCLL TBM mockup

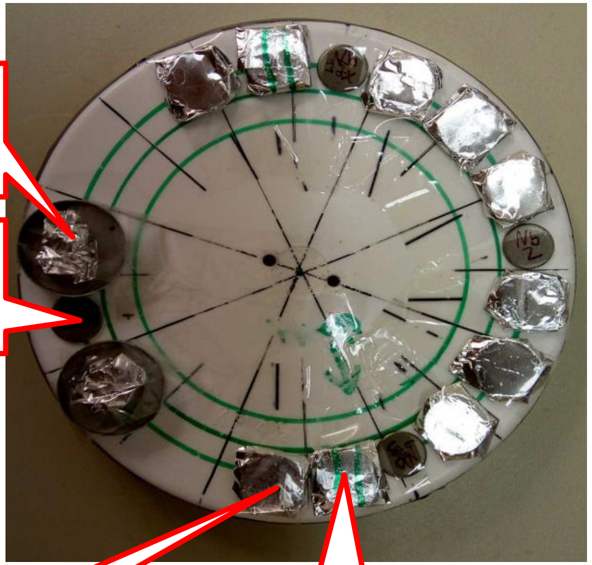


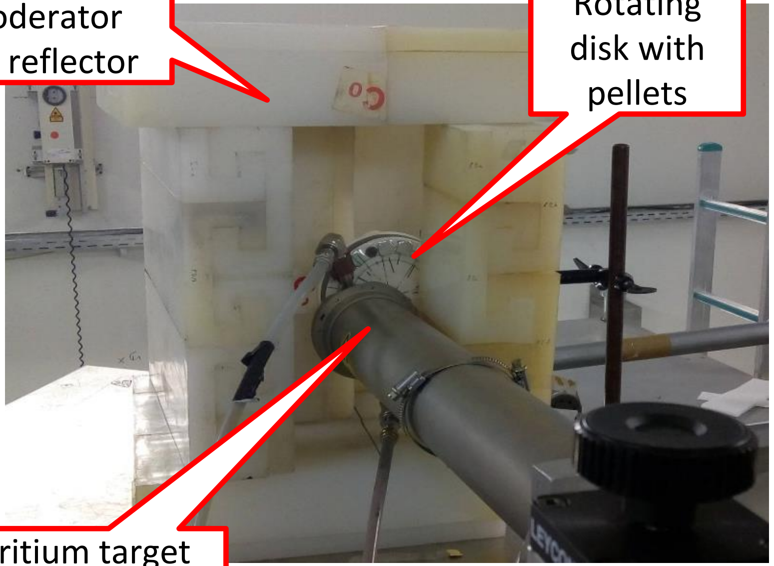
Pulse height spectra recorded with the NE-213 detector
Unfolding with suitable code and response matrix
Comparison with calculations (here: MCNP5 and JEFF-3.1.1 + FENDL-2.1)

Breeding blanket experiments
Measurement method development and calibration

Lithium carbonate pellets for tritium production rate measurements in the WCLL mockup experiment (at FNG/Frascati)

Checking stability of measurement method and calibration

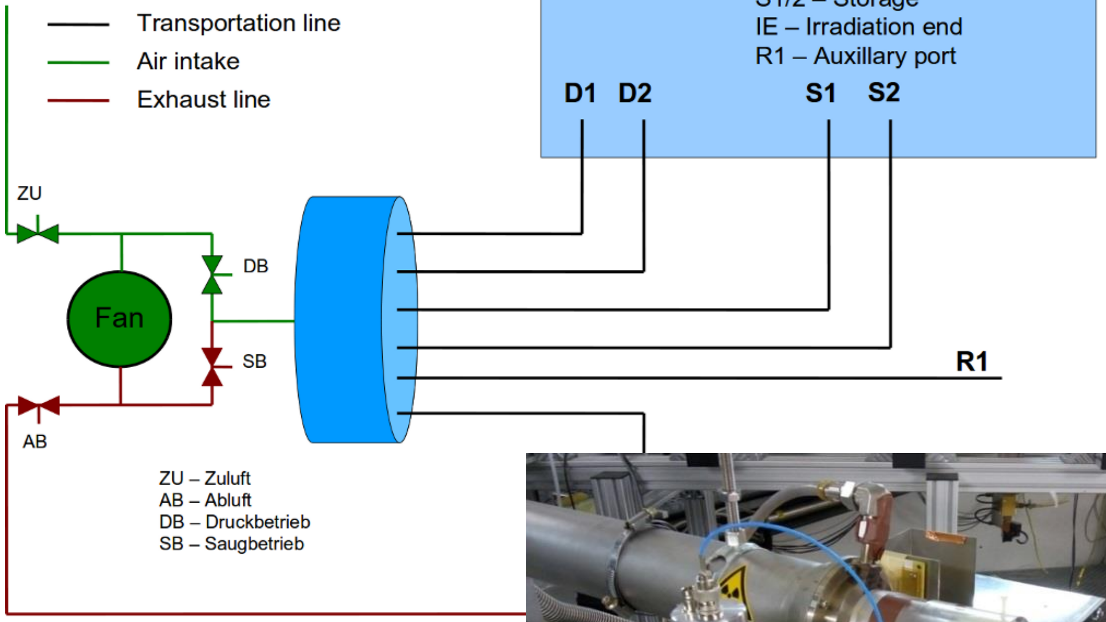




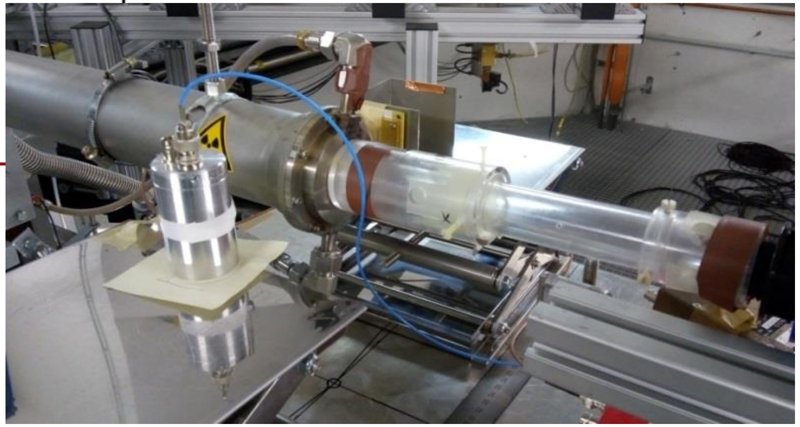
Detector development for ITER TBM and beyond

Neutron activation system

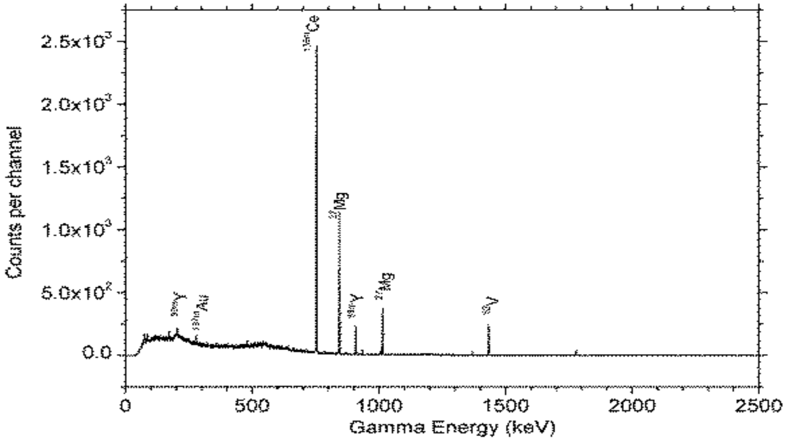
Schematic view of the sample transport system



Test rabbit: Nb, Al plugs, Au/Cr/CeO_2 powder filling, PE carrier, F4E FPA-395-02-03

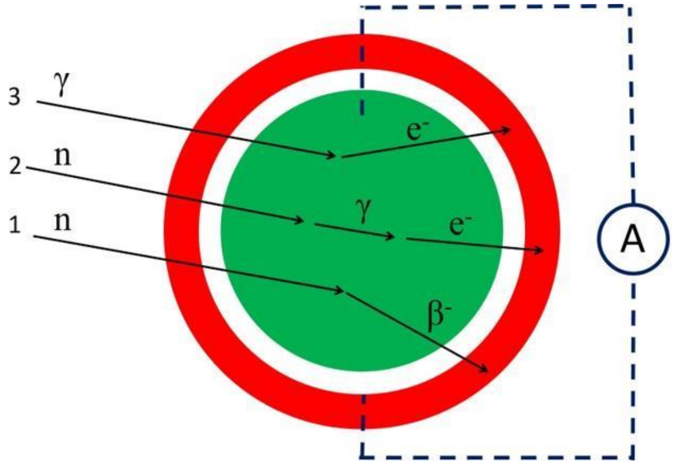


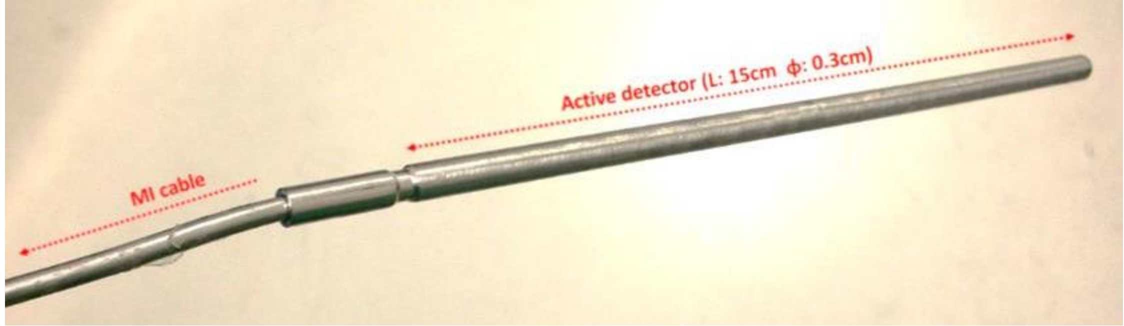
Irradiation end and T target of neutron generator.



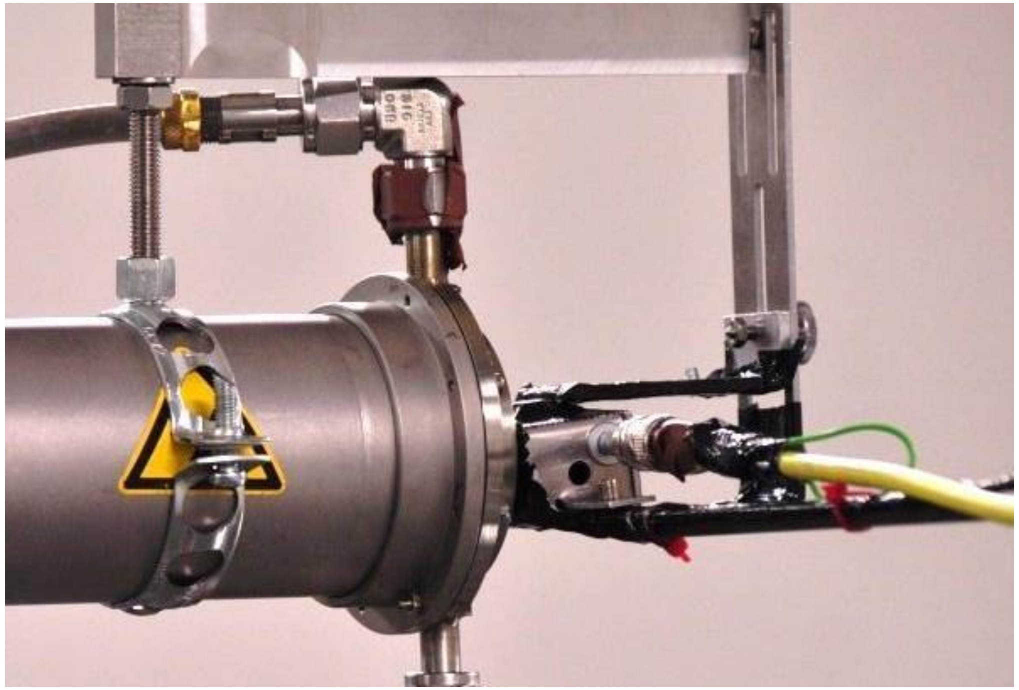
13 s to 82 s after extraction
(69 s measurement time)

Detector development for ITER TBM and beyond
Self-powered detector





Electric current caused by beta decay or Compton electrons plus several sources of noise

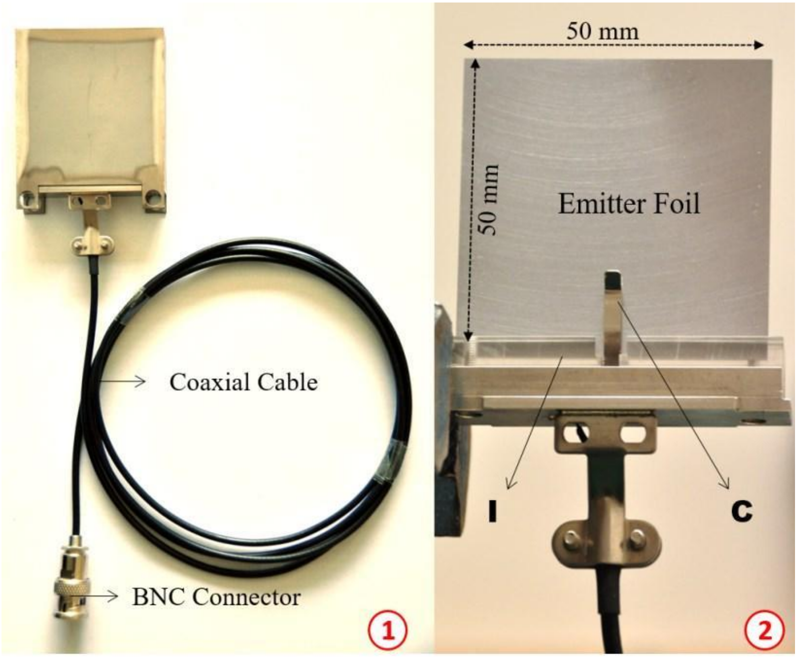


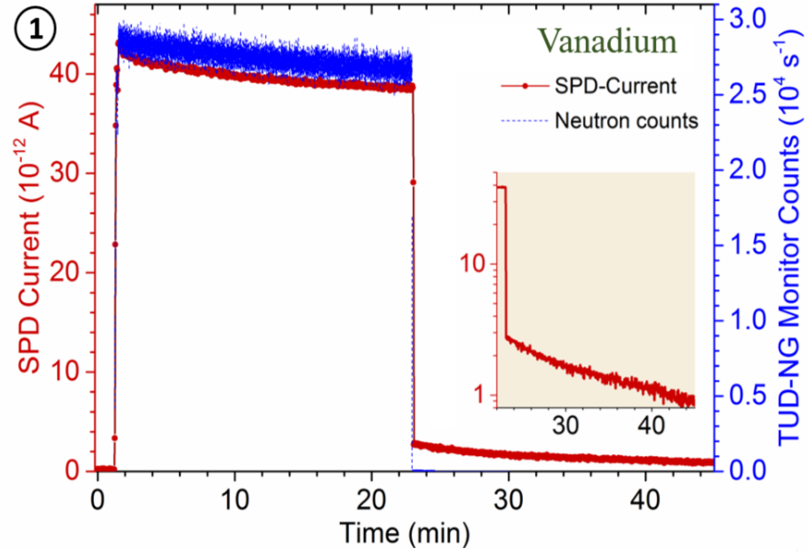
Test setup at TUD-NG, short distance to neutron source required

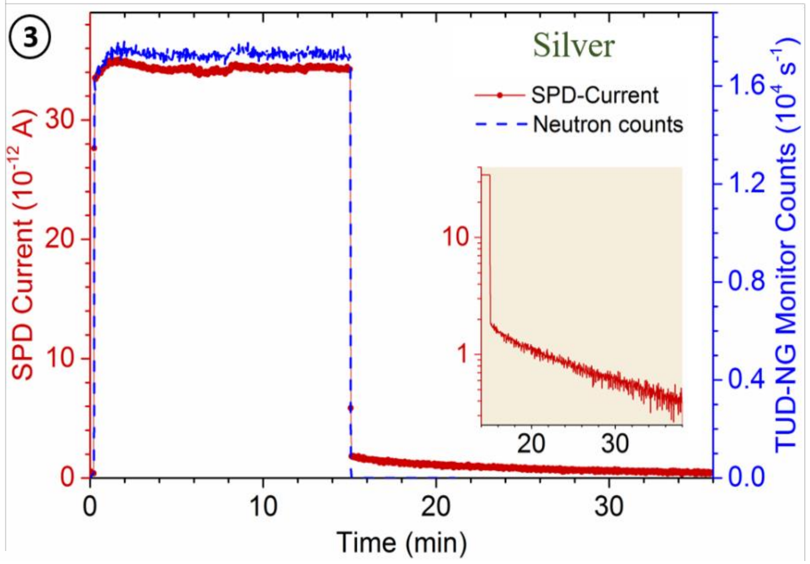
Detector development for ITER TBM and beyond

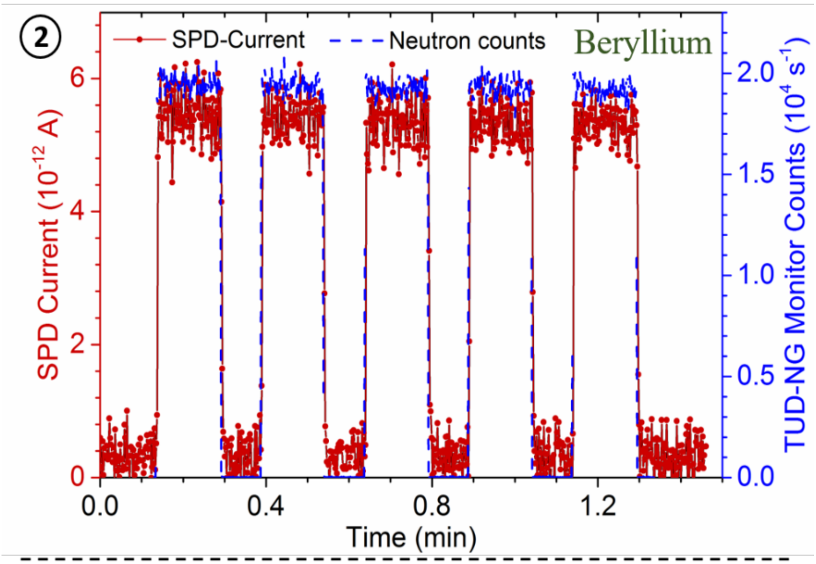
Self-powered detector

- Flat sandwich design → better use of DT neutron source
- Response to fast neutrons smaller compared to thermal neutrons, expected due to cross section differences
- Contributions from photons apparently similar
- Signal proportional to neutron yield









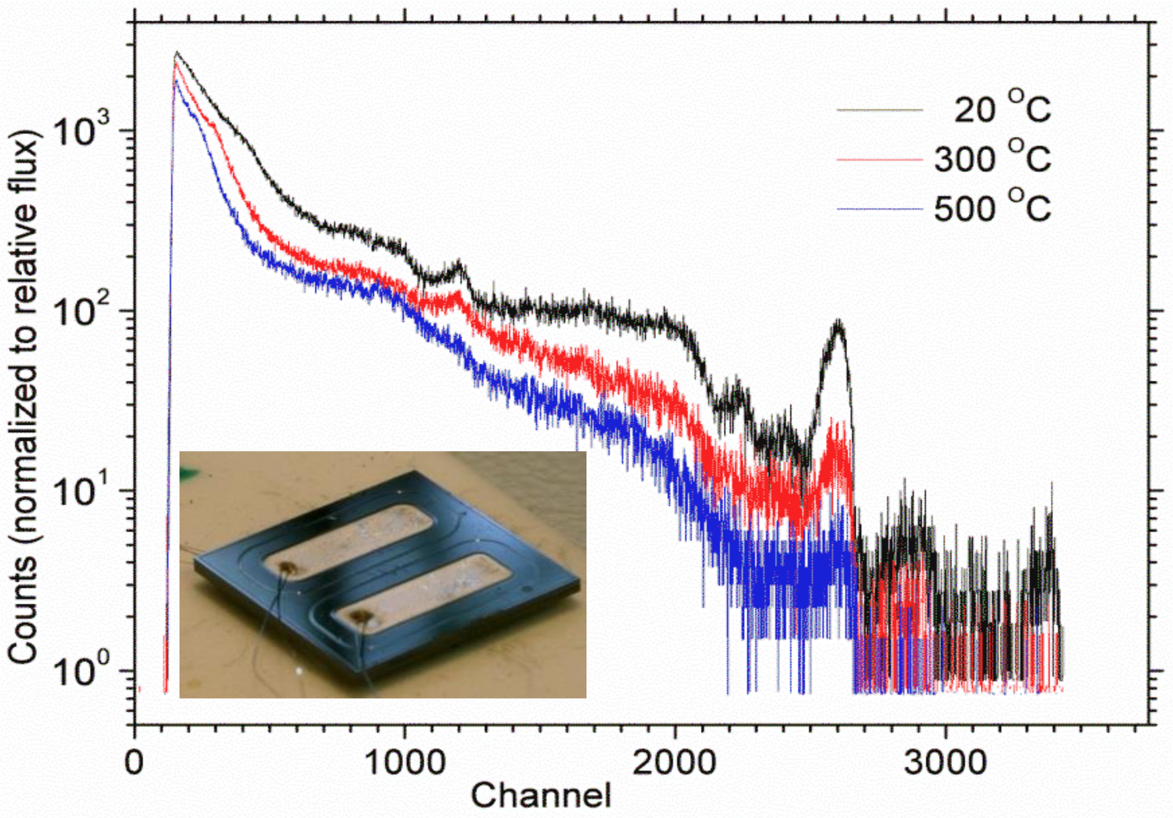
Detector development for ITER TBM and beyond

Silicon carbide detector

I_SMART: Detectors for fast neutrons (plain SiC) and thermal neutrons (boron conversion layer) developed

Funded by KIC InnoEnergy with the aim to develope a detector system

Signal processing electronics based on SiC investigated



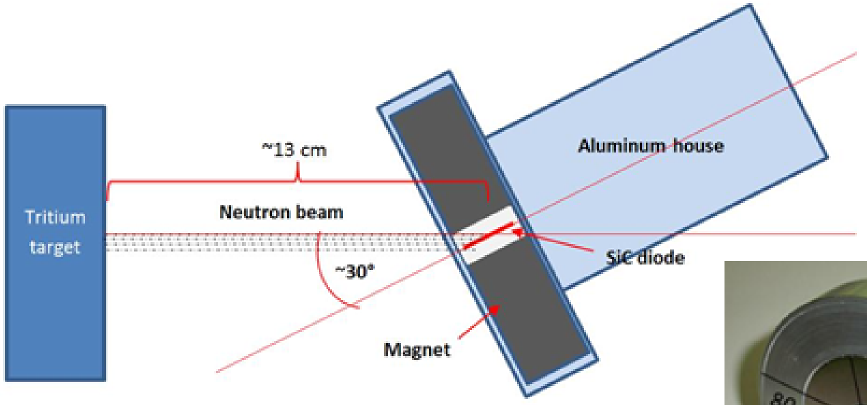
SiC detector without neutron converter at temperatures up to 500 °C.

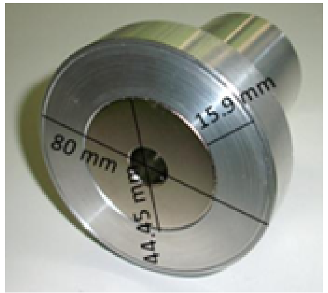
Collaboration between CEA, KIT, SCK*CEN, AMU, Univ. of Oslo, KTH, AGH

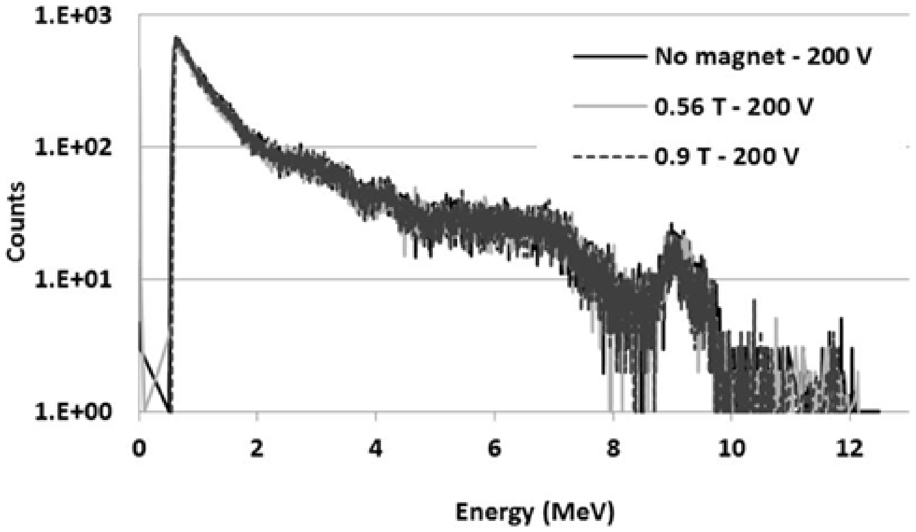
Detector development for ITER TBM and beyond
Silicon carbide detector

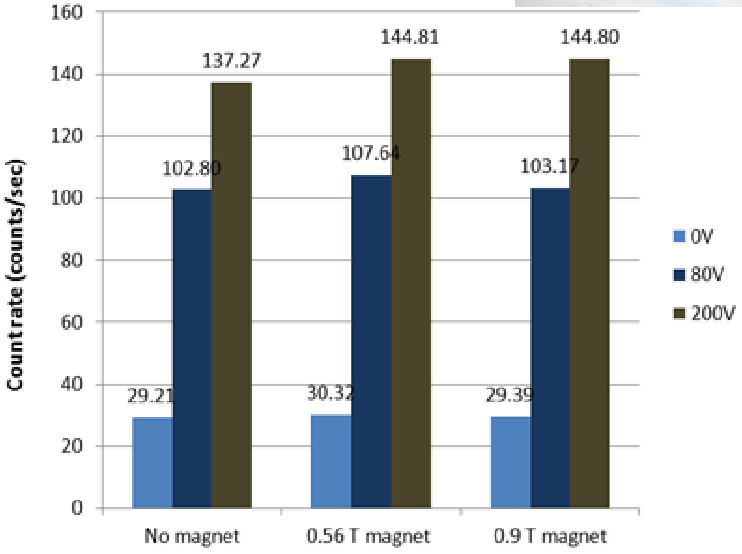
- DT neutrons from TUD-NG
- Room temperature
- Permanent magnets

No significant changes in pulse height spectrum









Current activities related to nuclear fusion

- Further experiments with self-powered detectors at elevated temperatures
- Cross section measurements (for example $^{39}K(n,p)^{39}Ar$), in particular for long-living products (involving the AMS facility at HZDR)
- Investigation into feasibilty of radiochemical measurements with ESR
- Improvements on the tritium target assembly
    - higher fluence at 14 MeV
    - Reduction of influence of cooling water on neutron spectrum and flux
- Upgrade of neutron generator control system

Thank you for your attention