Silicon carbide detector testing with DT neutrons and at high temperatures

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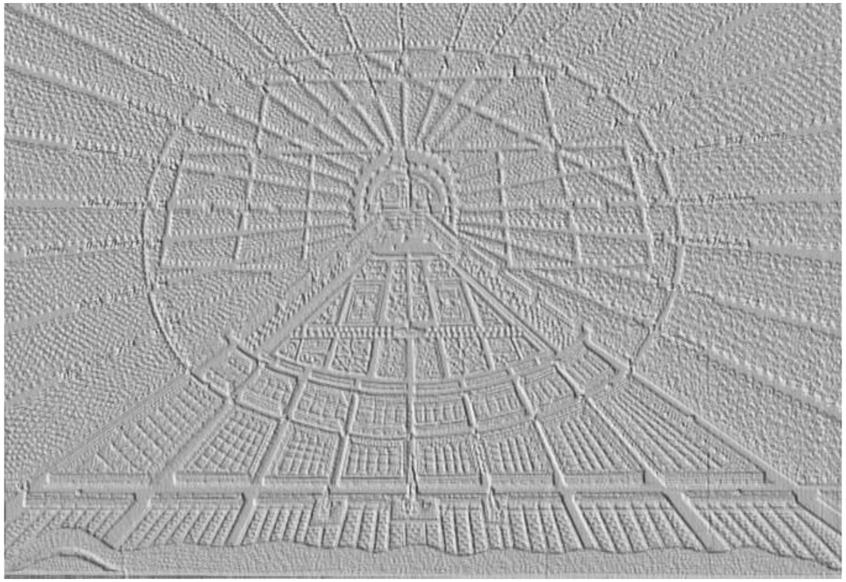
INSTITUTE FOR NEUTRON PHYSICS AND REACTOR TECHNOLOGY



Institute for Neutron Physics and Reactor Technology (INR/KIT)

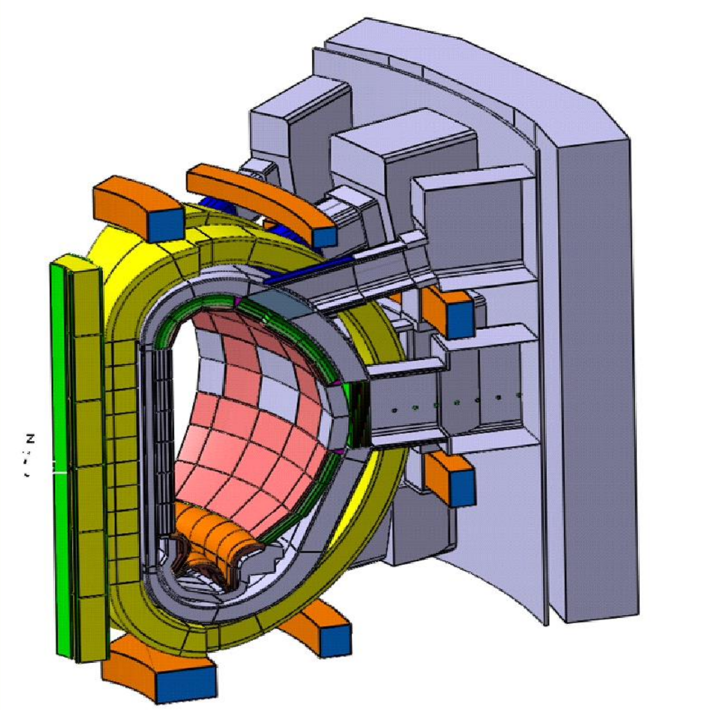
Work Group **Neutronics and Nuclear Data**

Nuclear analyses	ITER, DEMO, IFMIF, ESS, NFS
Development of numerical tools and software	MCCAD, R2S, R2SMesh …
Nuclear data	Evaluations, contributions to EAF / EFF / JEFF / FENDL …
Neutronics experiments	Benchmarks and mock-ups Activation, shut-down dose rates **Development of nuclear instrumentation for TBM**

Nuclear designs and performance assessments of breeding blankets

Breeding blanket: Important nuclear responses to neutrons

Tritium production rate	→	Fuel (self-sufficiency)
Shielding	→	Life time of components (field coils etc.)
Heat generation	→	Energy conversion, cooling requirements
Gas production	→	Material damage
Material activation	→	Radiation safety (licensing, operation regime maintenance, decommissioning)

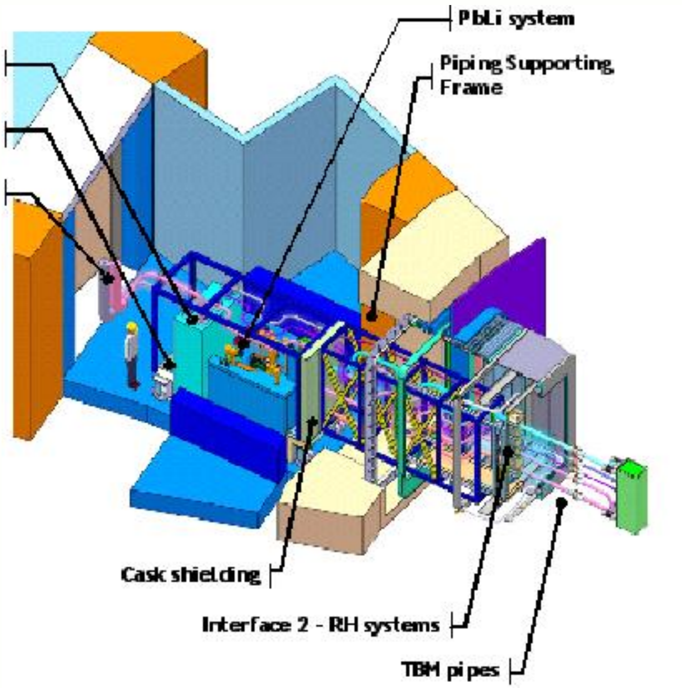


To large extent determined by the neutron flux and material distribution

Experimental proof of suitability and applicability of available transport codes, nuclear data and method for predicting such responses:

Calculation +/- Uncertainty
to be compared with
Experiment +/- Uncertainty

Environmental conditions for TBM instrumentation



Conditions in the TBM bad for detectors / diagnostics

- *Neutron flux 10^9~10^{14} $cm^{-2}s^{-1}$*
- 300..550 ºC (could be higher in breeding layers of HCPB TBM)
- Magnetic fields ~4 T
- difficult access
- little space

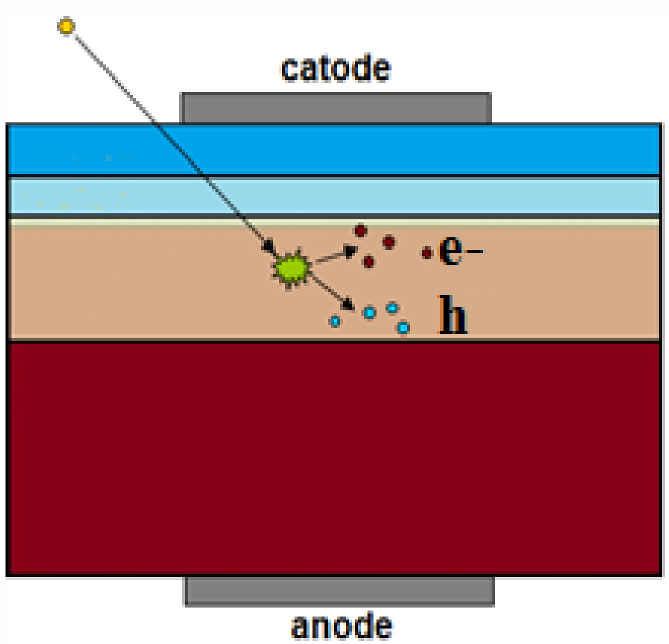
Possible candidates:

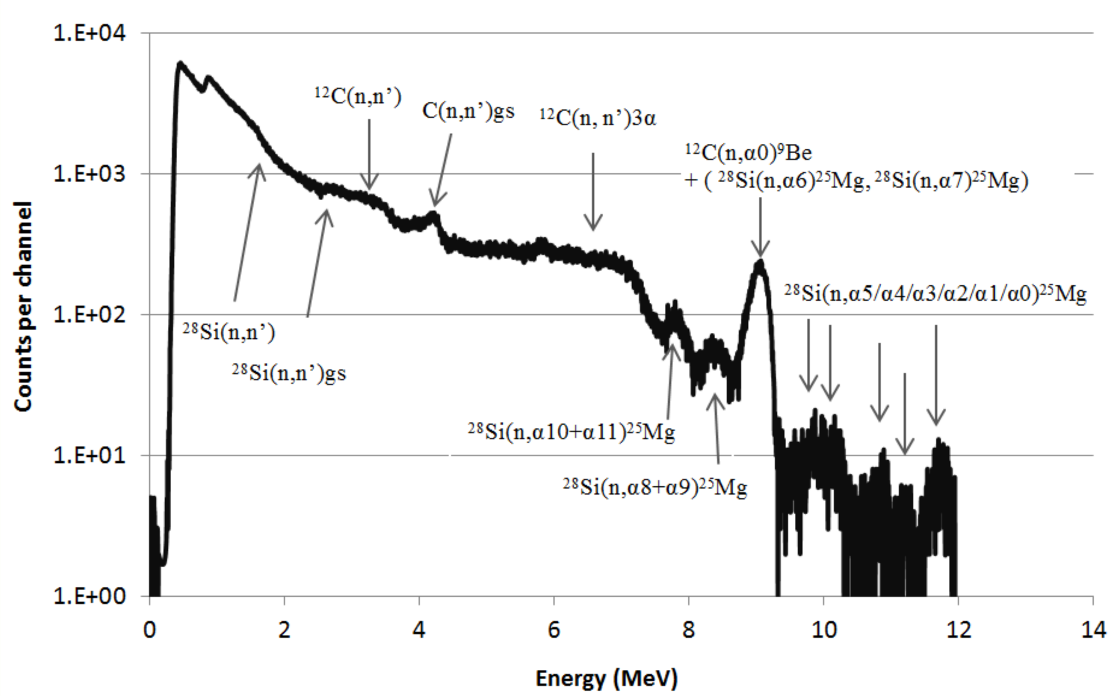
Neutron activation system, miniatur fission chambers, diamond detectors, **silicon carbide detectors**, self-powered neutron detectors

R&D work mostly funded by F4E grants so far

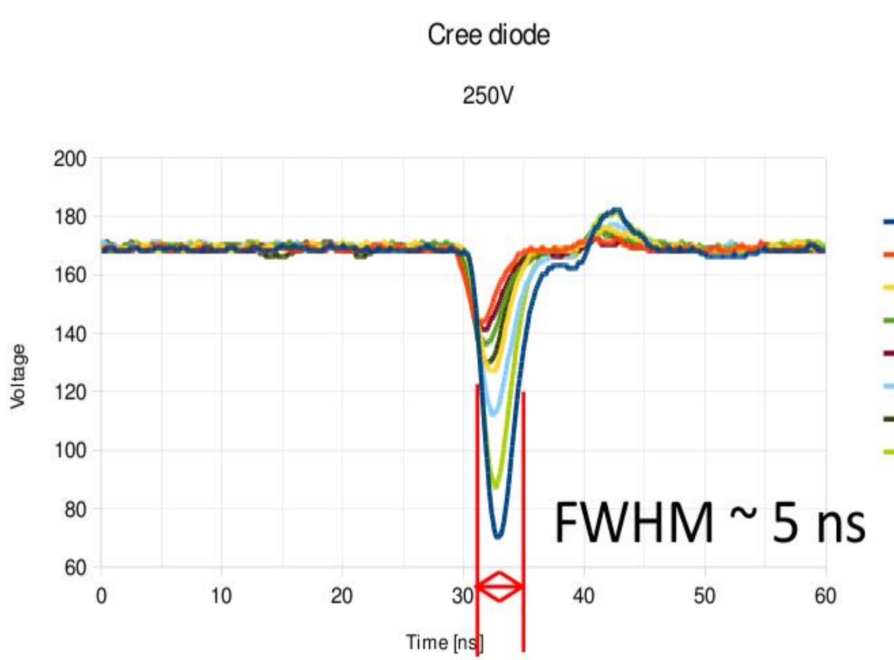
Silicon carbide (fast) neutron detector

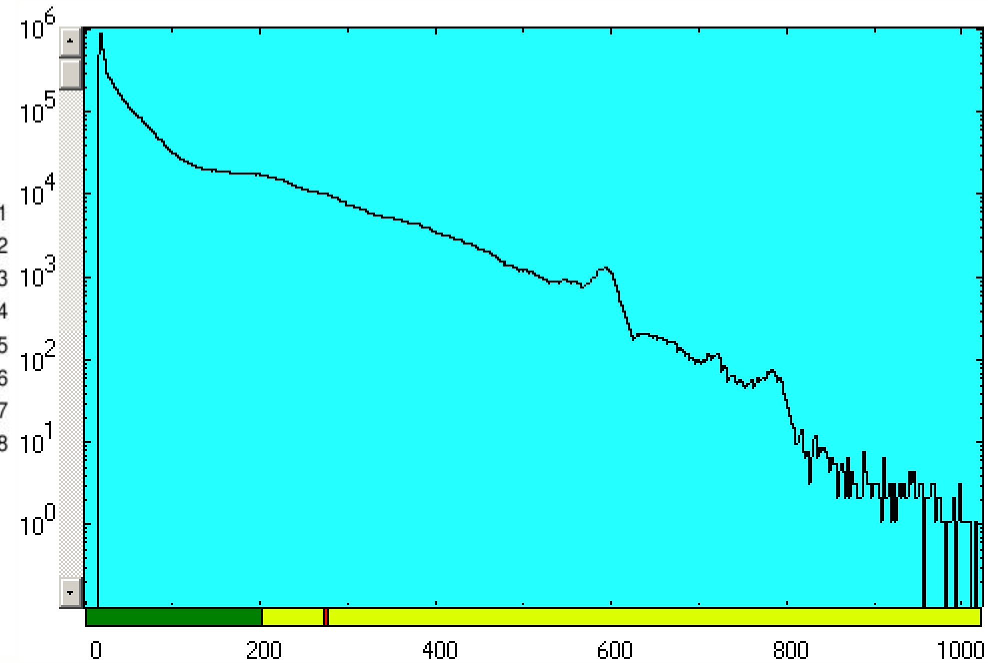
- Large band gap semiconductor detectors
- better radiation hardness than Si
- SiC electronics proven to operate at temperatures of several hundred °C
- R&D on SiC detectors has been done since many years





Silicon carbide (fast) detector



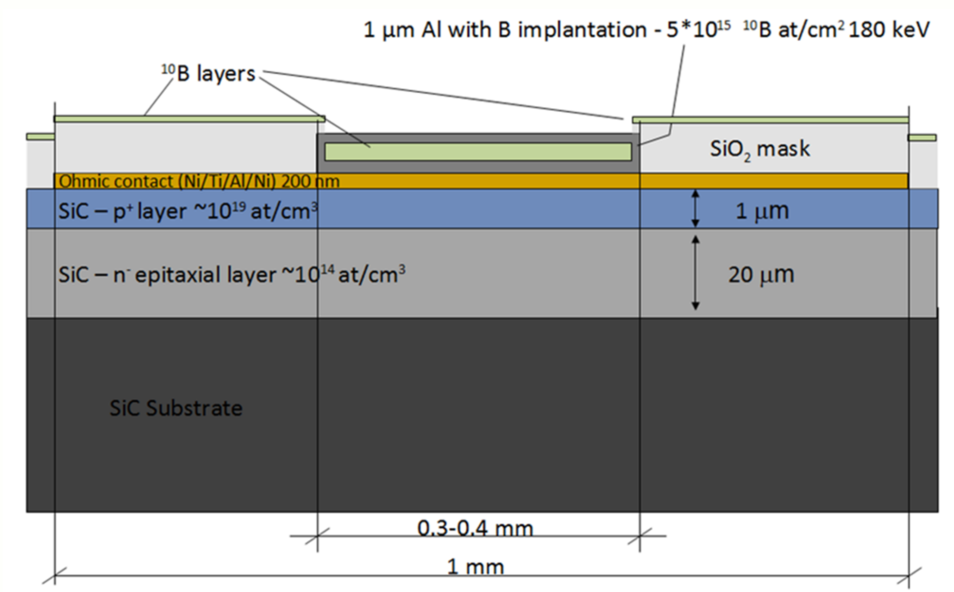


Typical signal from a commercial Schottky diode irradiated with 14 MeV neutrons and corresponding pulse height spectrum

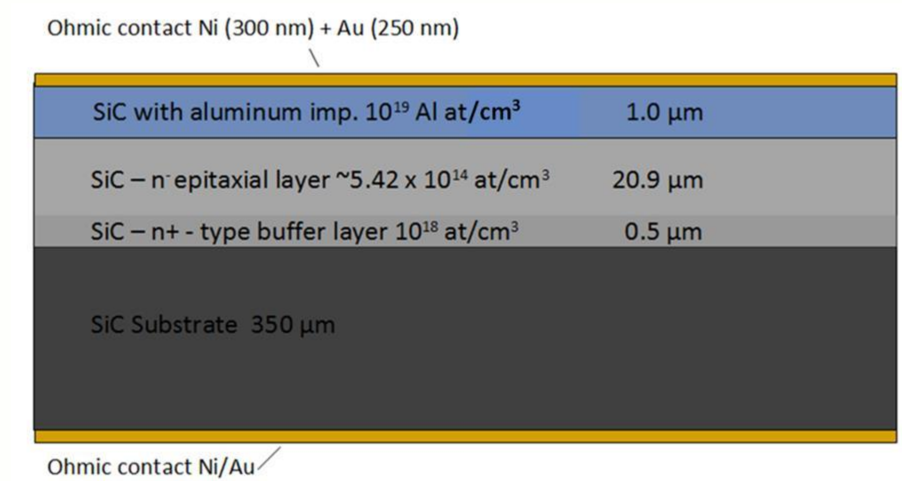
Silicon carbide detector

I_SMART (KIC-InnoEnergy)

Collaboration between
CEA, KIT, SCK*CEN, AMU, Univ. of Oslo, KTH, AGH
funded by KIC InnoEnergy with the aim to develope a SiC detector system

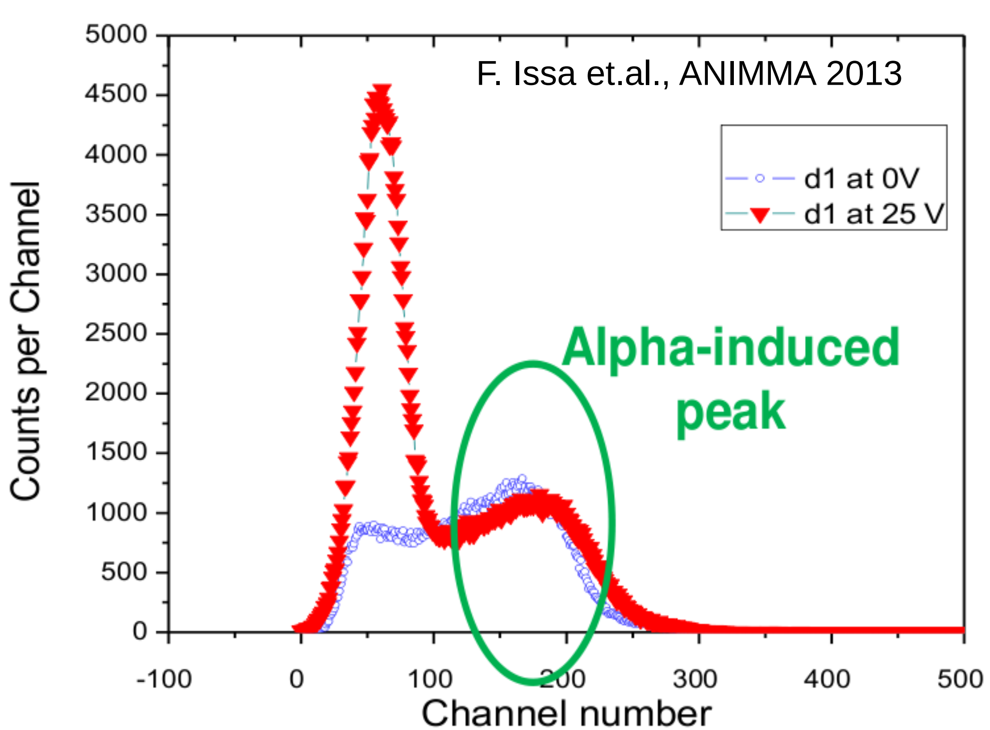


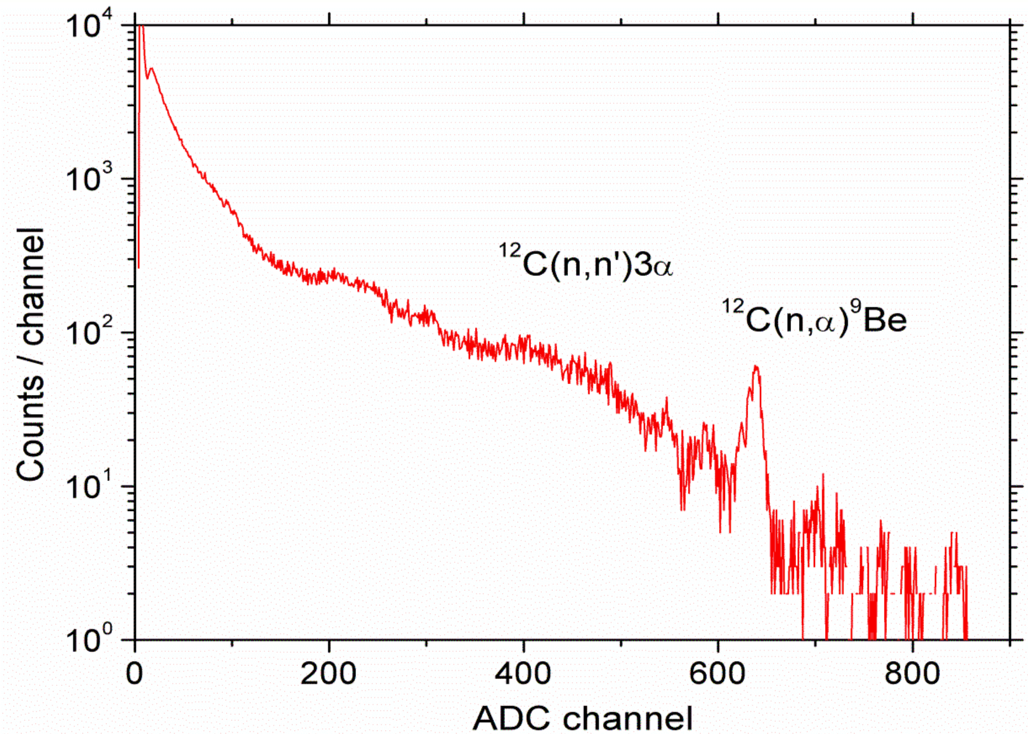
SiC diode with boron conversion layer for thermal neutrons.



Plain SiC diode

Response of the ISMART diodes to thermal and fast neutrons





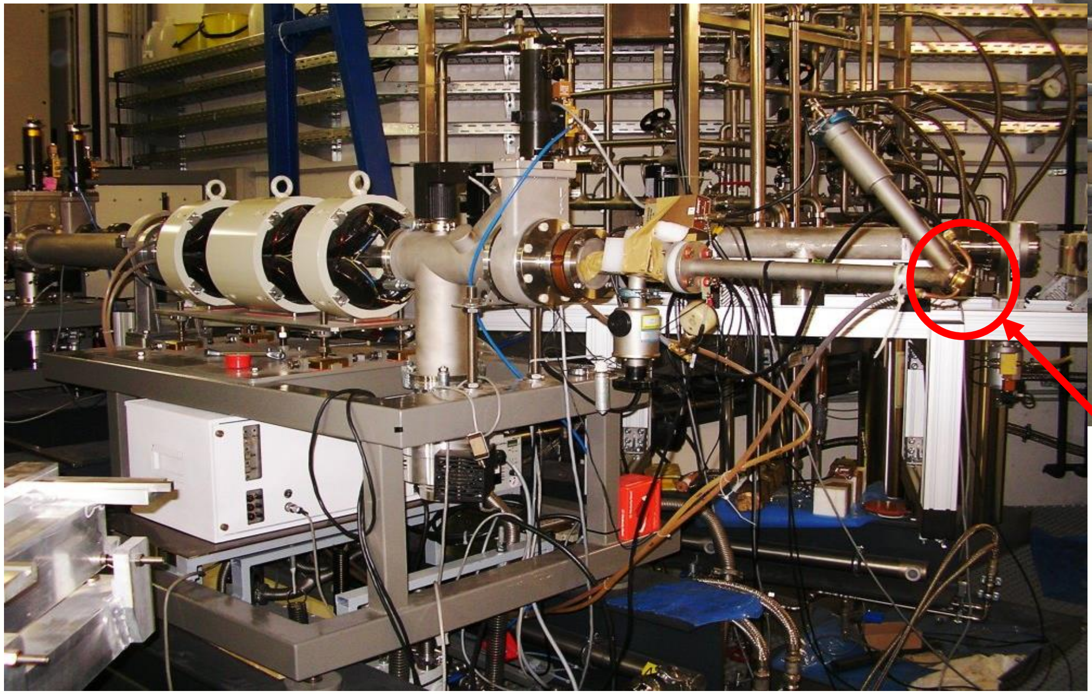
With boron implantation
in thermal neutron field of
BR1(SCK*CEN Mol)
at room temperature

In DT neutron field
(TUD-NG, HZDR
Rossendorf)
at room temperature

Neutron laboratory of Technical University of Dresden
DT neutron irradiations

TUD-NG: 300 kV, 10 mA deuterium beam on solid tritium/deuterium targets

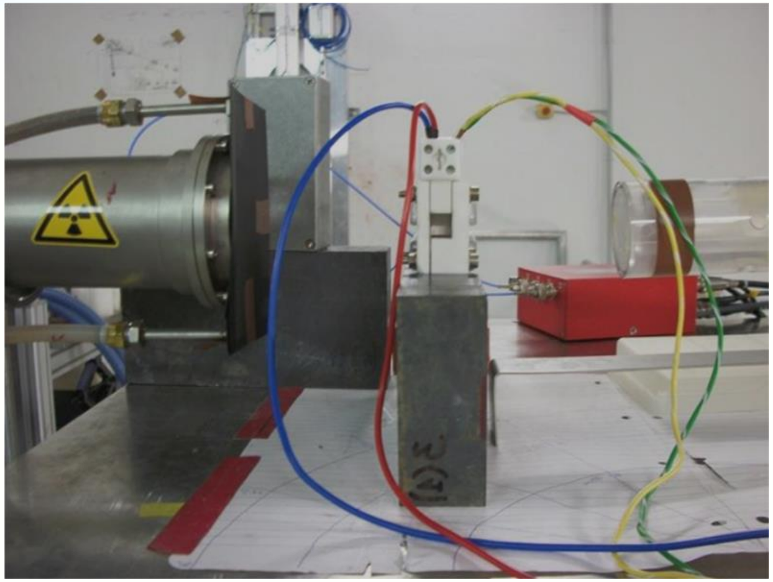
- up to 10^{12} n / s
- continuous or pulsed operation
  (accelerator prepared for ns pulsing)
- fixed and rotating T-Target

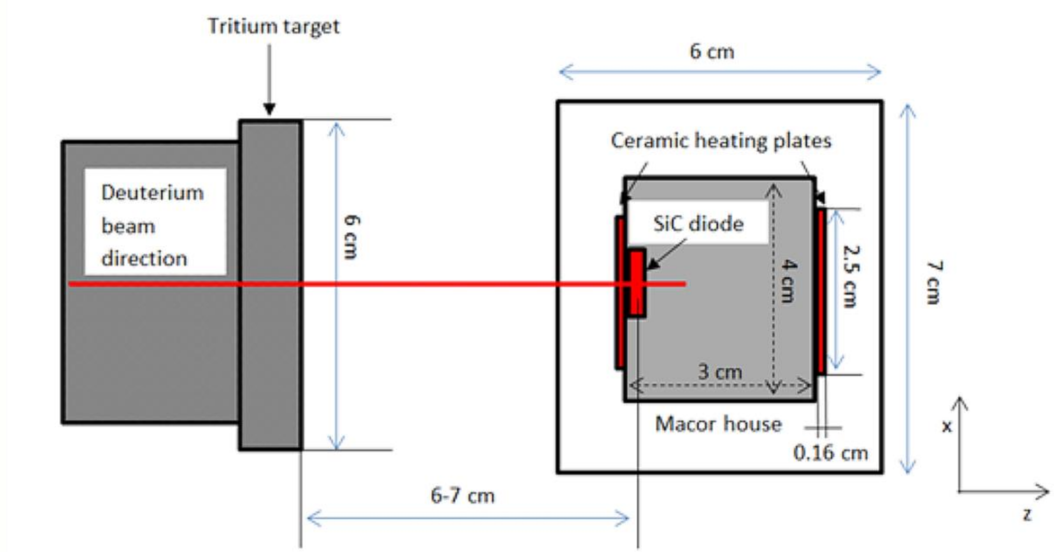


Targets:

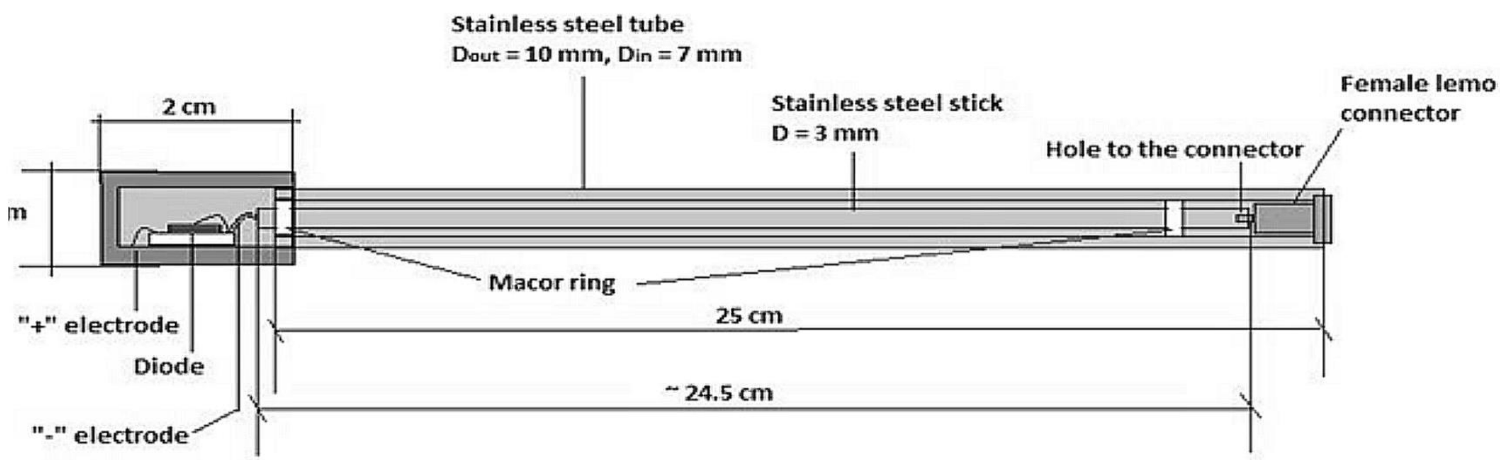
Tritium: 3, 30, 250 Ci
Deuterium

Setup for high temperature tests at TUD-NG



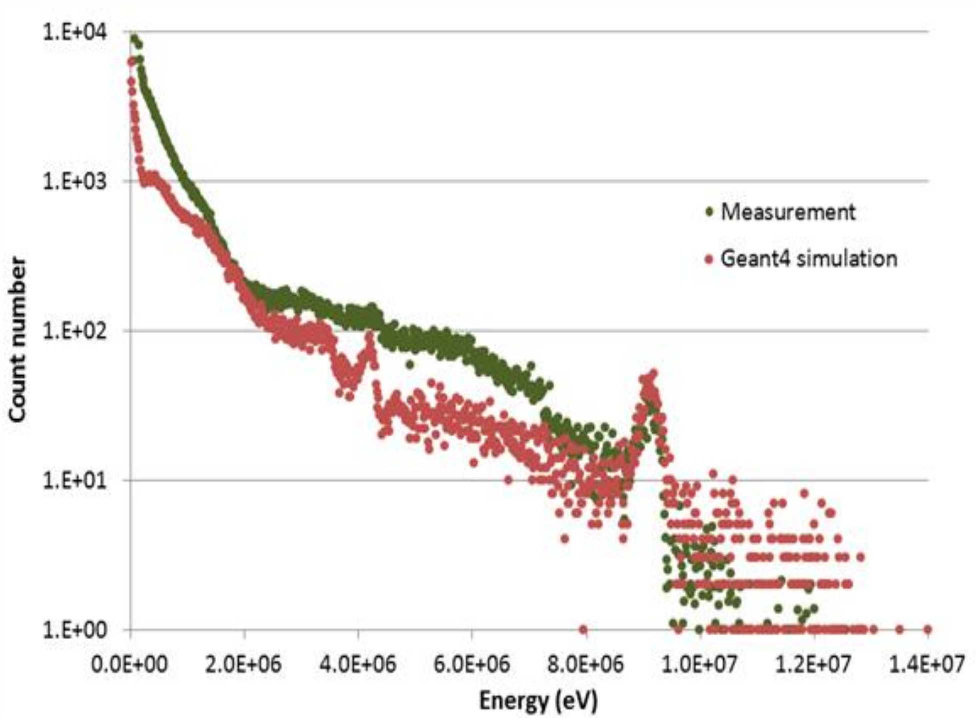


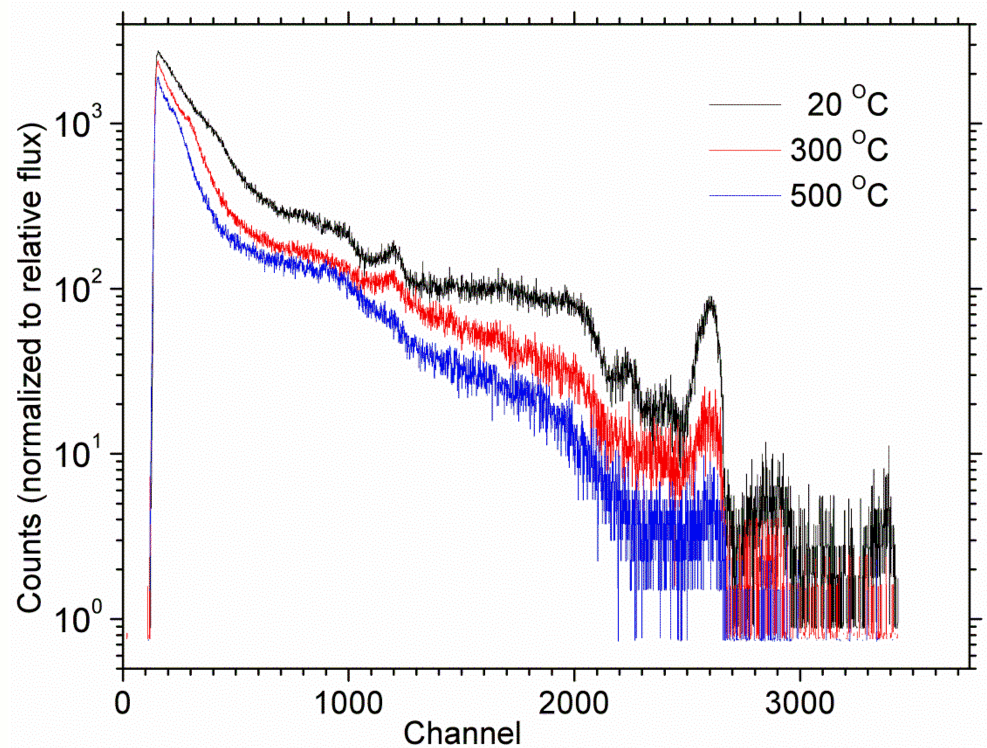
Experimental setup for high temperature tests under DT neutron irradiation



Diode encapsulation with stainless steel coaxial „cable“

Response of the ISMART diodes to DT neutrons at high temperatures

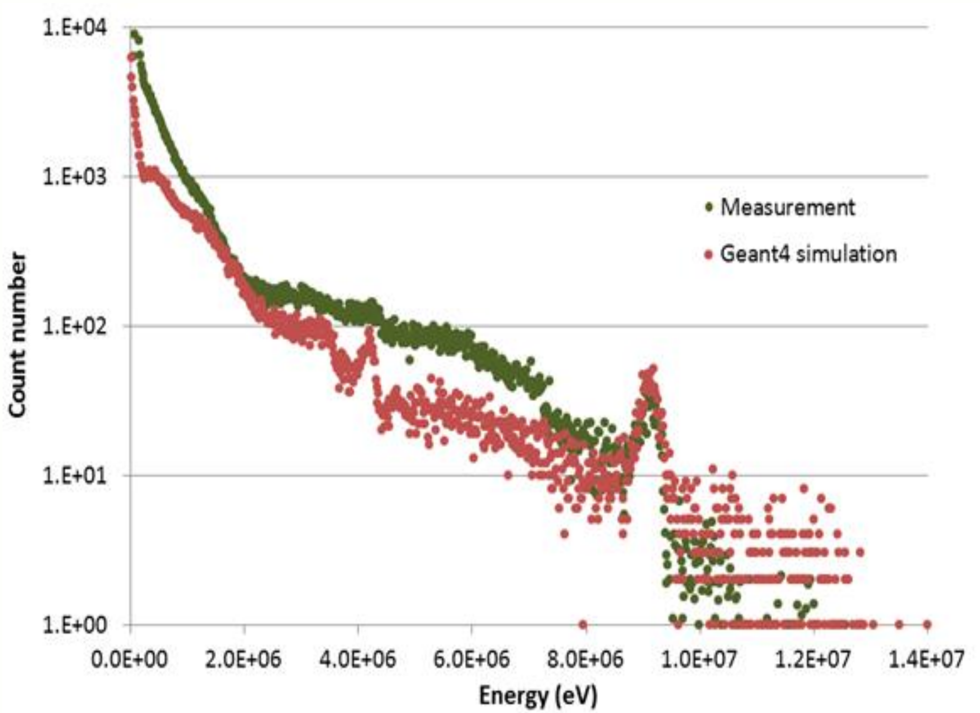


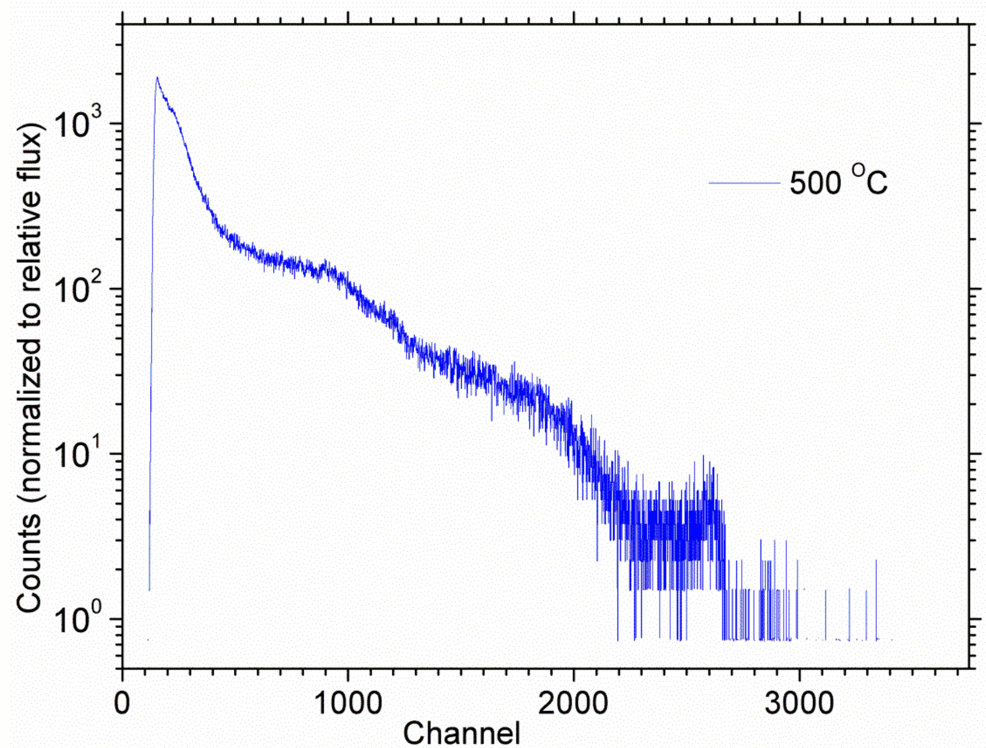


Measured and modeled (GEANT-4) pulse height spectrum under irradiation with 14 MeV neutrons

Measured pulse height spectra under irradiation with 14 MeV neutrons and at temperatures relevant for the ITER TBM

Response of the ISMART diodes to DT neutrons at high temperatures



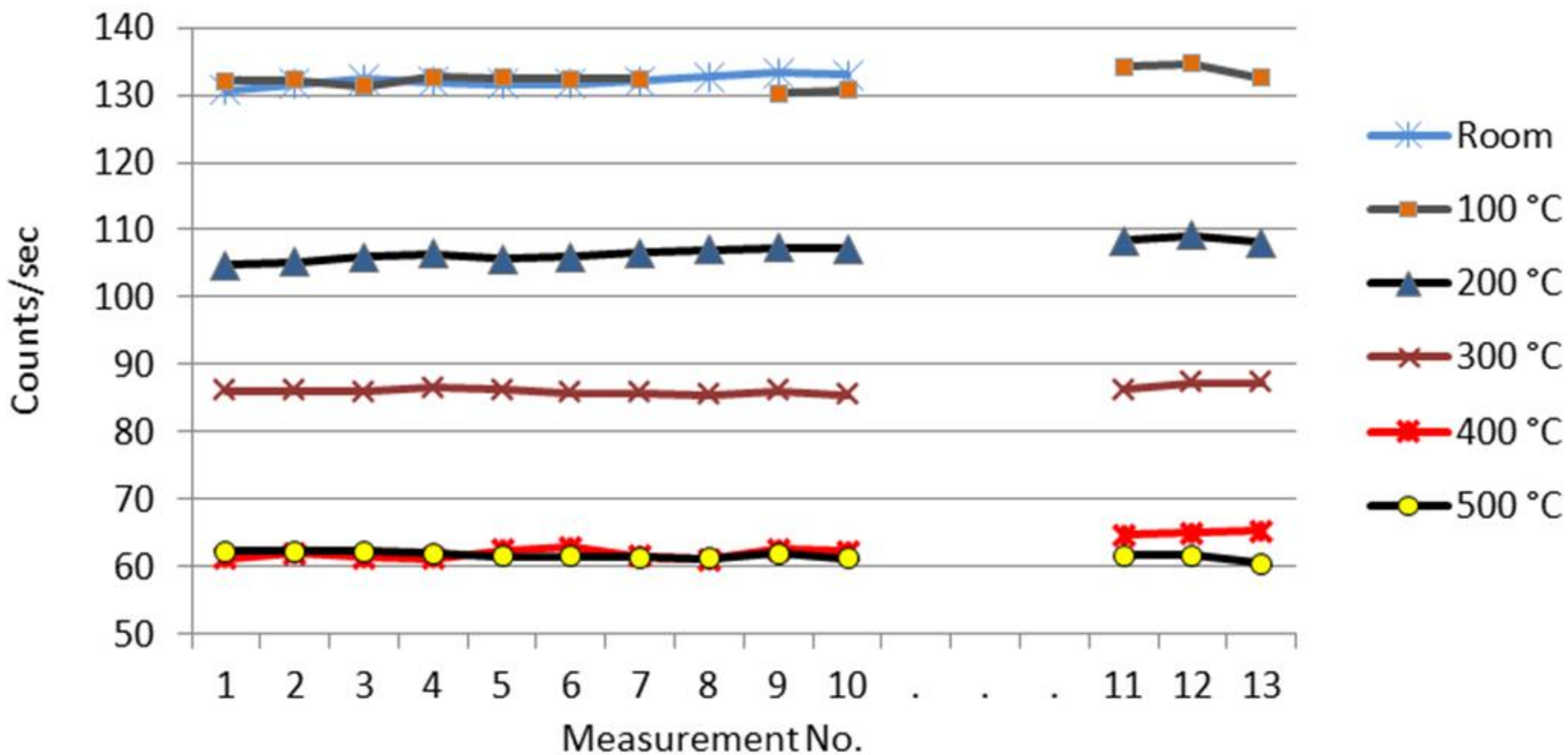


Measured and modeled (GEANT-4) pulse height spectrum under irradiation with 14 MeV neutrons

Measured pulse height spectra under irradiation with 14 MeV neutrons and at temperatures relevant for the ITER TBM

Even at 500 ^{O}C spectroscopic behaviour is retained to some extend.

Response of the ISMART diodes to fast neutrons at high temperatures

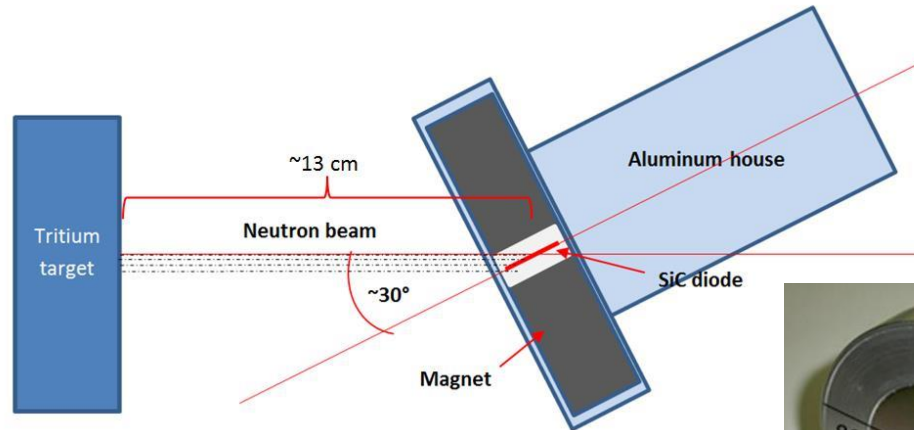


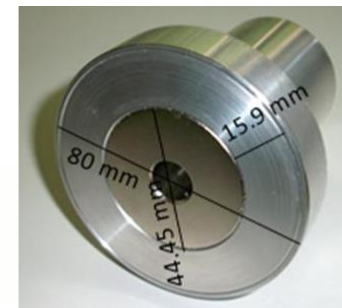
Stability tests at elevated temperatures under DT neutron irradiation:
10 × 10 minutes, 1-3 hours interruption, 3 × 10 minutes

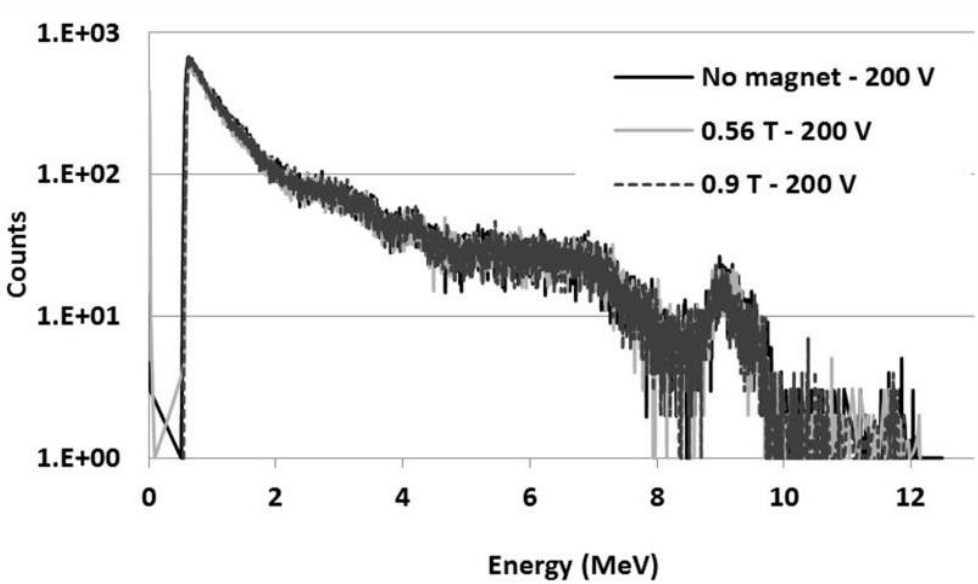
Response of the ISMART diodes to fast neutrons in high magnetic fields

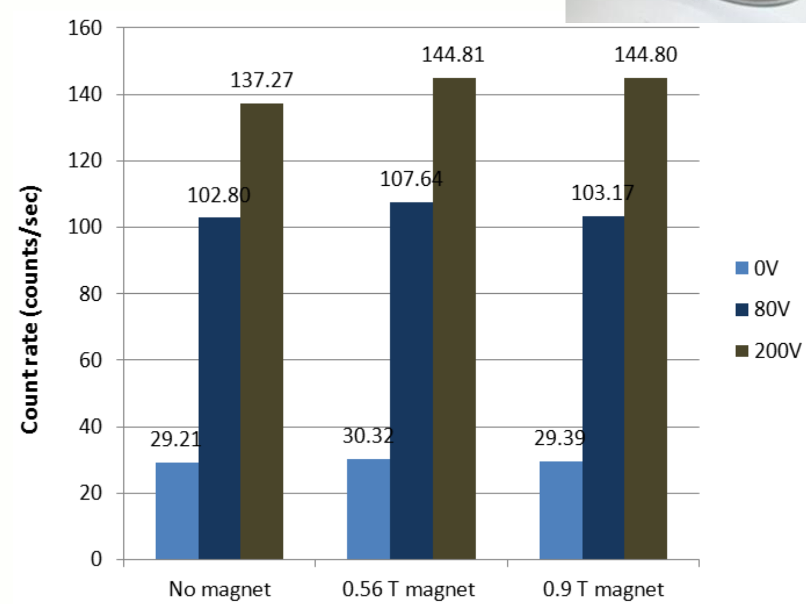
- DT neutrons from TUD-NG
- Room temperature
- Permanent magnets

No significant changes in pulse height spectrum





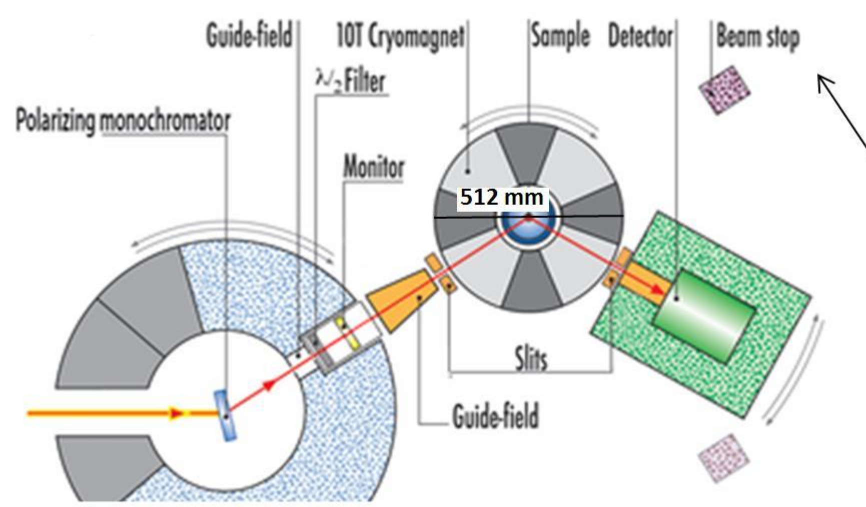


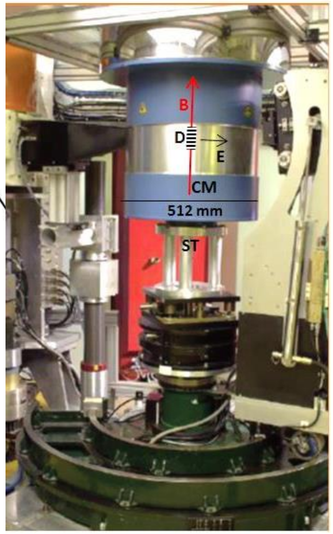


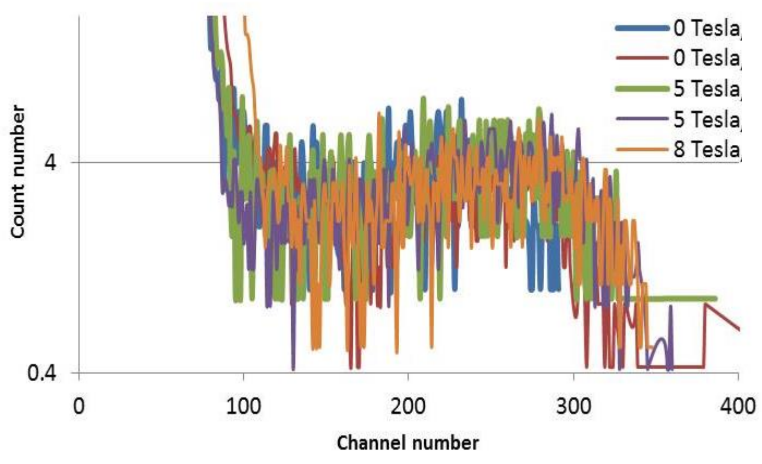
Response of the ISMART diodes to fast neutrons in high magnetic fields

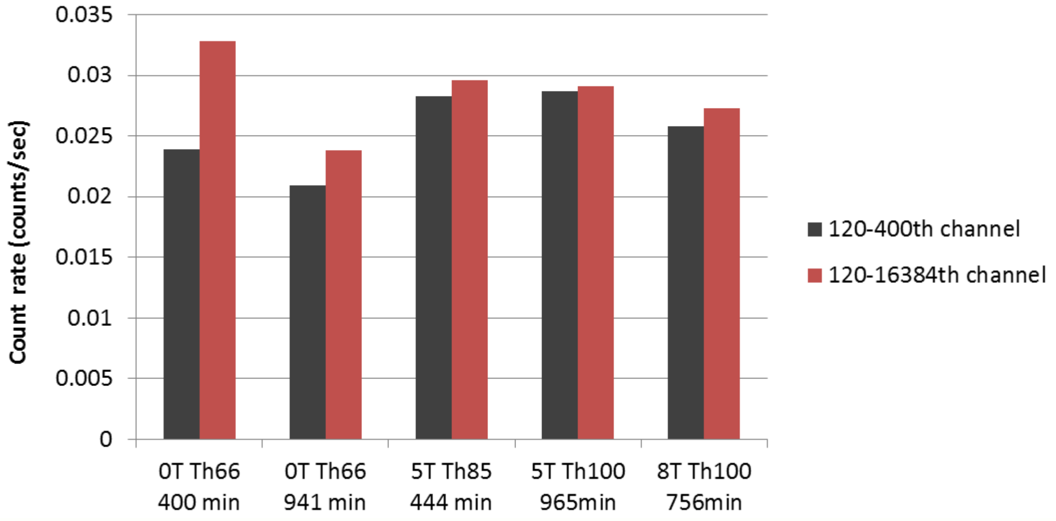
- Epithermal neutrons from D3 facility at ILL Grenoble
- Room temperature
- Magnetic field up to 8 T

No significant changes in pulse height spectrum









Main results

- Stable operation up to 300°C with 4H-SiC detector at high bias voltages
- Beyond 300°C up to 500°C operation at reduced bias voltages
- Stable count rate over several hours at several steps from room temperature up to 500 °C.
- Operation at high magnetic fields did not show significant count rate changes