Neutronics experiments for validation of activation and neutron transport data for fusion application at the DT neutron generator of TU Dresden

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Outline

- Brief comments on history of the lab
- Context of the fusion-related experiments
- Recent blanket mock-up experiments
- Experiments for validation of activation cross sections
• New neutron laboratory of TUD was constructed in the early 2000s
• Successor of the neutron laboratory of TUD located in the city of Pirna-Copitz
• Neutron generator: DD operation since 2004, DT operation since 2005

Current utilization:

→ For activation experiments relevant for double-beta decay (see A. Domula: HK 55.4, Thursday HG VI)
→ Validation experiments for activation data libraries (EAF-2007, others) and neutron transport data libraries (JEFF, FENDL) in the frame of the European fusion program (EFDA / Fusion for Energy) (this talk)
Important nuclear parameters for fusion reactor blankets

- Tritium production rate / Tritium breeding ratio
- Nuclear heating
- Shielding capabilities
- Material activation
- Gas production
- others

Data libraries require validation

→ mock-ups irradiated in well-characterized DT neutron fields
**Accelerator:** 300 kV, 10 mA
- up to $10^{12}$ n / s
- continuous or pulsed operation
- fixed and rotating T-Target

**Targets:**
- Tritium: 3, 30, 250 Ci
- Deuterium
HCPB TBM mock-up experiment

Collaboration with
ENEA Frascati, FZ Karlsruhe, TU Dresden, FNS/JAEA

Sample holder inserts
NE-213 / $^3$He detector positions

Li$_2$CO$_3$
DT neutron source

Beryllium

$15.8$ cm
$31$ cm

$15.8$ cm
$31$ cm
Mock-up consists of layers of LiPb, Eurofer and polyethylene Detectors placed along the axis of the mock-up

MCNP model: Detailed description of the neutron source and the detectors (Li$_2$CO$_3$ pellets and all LiF-TLD)
HCLL mock-up experiment: Set-up for the measurement of fast neutron and gamma-ray fluxes

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.
HCLL TBM mock-up experiment
Fast neutron flux spectra

Pulse height spectra recorded with the NE-213 detector
Unfolding with MAXED code, response matrix (validated at PTB)
Calculations with MCNP5 and JEFF-3.1.1 and FENDL-2.1
Normalization of unfolded spectra by fitting 14 MeV peak height
Pulse height spectra recorded with the NE-213 detector
Unfolding with MAXED code and response matrix
Calculations with MCNP5 and JEFF-3.1.1 and FENDL-2.1
Normalization from neutron spectrum
Activation behavior of fusion reactor materials central topic for safety-related issues and decommissioning

- Most induced activation from slow neutrons (cross sections large) and fast neutrons (many open reaction channels)
- Assessment of induced activities usually based on inventory codes and activation data libraries

**This work:**

- Activation of **titanium** with DT neutrons and comparison with calculated values from **EASY-2007** (FISPACT and EAF-2007) for the isotopes contributing most to the contact dose rate
- Titanium contained in several materials in the blanket, for example Li\(_2\)TiO\(_3\)
Calculation with FISPACT-2007 and EAF-2007

Assuming 1 year of irradiation with 1 MW/m² wall load (primary neutrons)

Li₂TiO₃
important isotopes $^{48}$Sc, $^{46}$Sc, $^{42}$K
recycling limit after about 3.2 yr
hands-on-limit after about 17.7 yr

Titanium only
important isotopes $^{48}$Sc, $^{46}$Sc, $^{42}$K
recycling limit after about 4.4 yr
hands-on-limit after about 109 yr
Irradiation of Ti sample in fusion peak field of DT generator

Sample size: 1 cm$^2$ x 0.5 mm thick
Irradiation time: 2.46 hrs, fluence $5.41 \times 10^{11}$ n/cm$^2$
Measurement: $\gamma$-ray spectra at several times after irradiation with HPGe spectrometer

Set-up

Si detector (Monitor)  
(d-beam)  
Tritium target  
Ti sample  
Monitor foil (Nb+Zr)
Preparation for experiments with Neutronics TBM in ITER

Detector development and testing

Neutron flux by dosimetry reactions
- selection of suitable sets of foils (short and long irradiation time)
- testing of gamma activation measurement regime
- practical demonstration of automated system

Status
- system is currently set up at TUD-NG
- investigation of suitable foil sets for different measurement regimes (i.e. 10..30 sec, entire pulse, several pulses) underway
Thank you very much for your attention!

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