Experiments with Neutrons at ELBE

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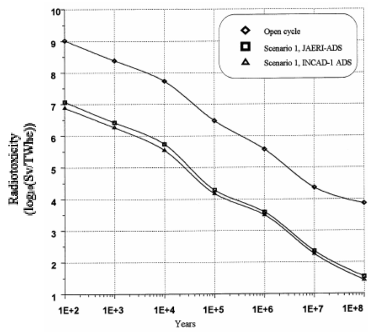
Transmutation of Long-lived Radioactivity

Transmutation of long-lived highly radiotoxic isotopes into short-lived ones, is one of the very important issues to be solved, if nuclear power in any form is considered a choice for future energy needs. Construction materials are activated in both, fusion and fission reactors and large amounts of radioactive remnants are produced from fissionable fuel in the latter.

Thermal neutrons in conventional light-water reactors cannot induce that many transmutation reactions and thus a wider neutron energy domain has come into focus for transmuting plutonium, minor actinides, and long-lived fission products remaining in a traditional power reactor after burn-up. In the search for new concepts to produce less waste via the design of fuels for very high burn-up the Generation IV International Forum (GIF) has selected several nuclear energy systems which shall reach this goal by employing fast, un-moderated neutrons in the MeV range. In the past, this energy domain was not investigated with high priority because of its minor importance for conventional light-water reactors.

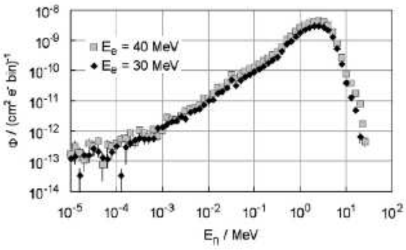
At ELBE neutron beams can be produced with such high intensity that cross sections of importance for fast reactors or for other transmutation devices can be measured with sufficient accuracy. Important reactions are neutron radiative capture, neutron-induced fission and other neutron induced reactions, e.g. (n,α). At Rossendorf expertise exists in handling of radioactive targets, so that actinide targets can be investigated.



Radiotoxicity of transuranium elements in radioactive waste without (upper curve) and with reprocessing (lower ones). The radiotoxicity can be reduced by two orders of magnitude and thus the time of disposal is shortened by several 100 thousand years. [Graph taken from: Salvatores et al. "Long-lived radioactive waste transmutation and the role of accelerator driven (hybrid) systems" Nucl. Instr. Meth. A 414 (1998) 5-20]

Production of a Pulsed Neutron Beam

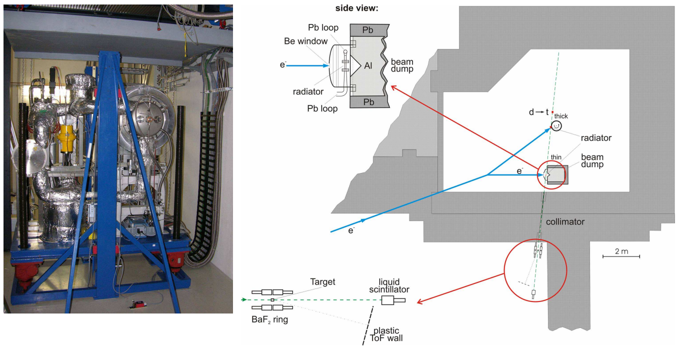
The high-intensity continuous-wave electron beam from ELBE allows the production of a pulsed neutron beam through bremsstrahlung production and subsequent (γ,n) reactions in a liquid-lead radiator. The excellent time structure of the electron beam can be used to achieve a high time-of-flight resolution on a short flight path (5 m) to maximize the neutron flux: Usable neutron spectrum 0.2 MeV < E_n < 7 MeV (1.6 MHz). The energy resolution will be $\Delta E/E \approx 1\%$ for 0.2 MeV < E_n < 2 MeV. The neutron flux will be in the order of 10^6 / (s cm² E-decade).



Neutron fluence entering the collimator (for each neutron bin, per electron started). [Graph taken from: J. Klug et al. "Development of a neutron time-of-flight source at the ELBE accelerator", Nucl. Instr. Meth. A 577 (2007) 641-653]

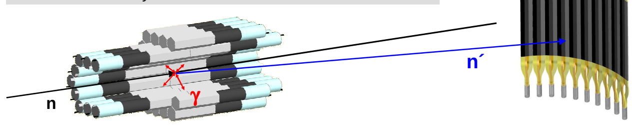
Neutron Time of Flight Measurements

A special feature at ELBE will be the possibility of energy dispersive measurements by time of flight. Two detector setups have been developed: an array of BaF_2 scintillation detectors to detect photons from neutron capture reactions and a setup of plastic scintillation detectors to detect neutrons scattered from the target. Both detector types offer time resolutions less than one ns to guarantee an energy resolution below 1 % necessary suitable results.

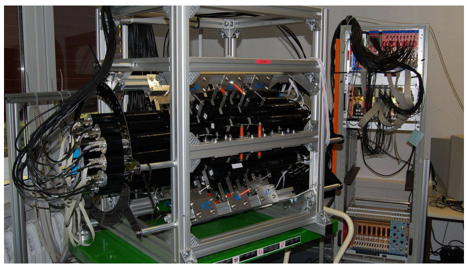


Layout of the neutron time of flight facilities in the neutron cave at ELBE. The electron beam is directed to a liquid Pb target, where neutrons are produced from (γ,n) reactions. After a short flight path through a collimator they hit the sample surrounded by fast photon detectors (BaF_2) and plastic scintillators for neutron detection. The photograph shows the setup of beam dump with radiator housing inside the neutron cave. The liquid lead target assembly is located on a spindle lift platform. It can be raised out of a lead shielding into the electron beam.

Detector setup for a (n,n´γ) experiment with a BaF_2 array to detect photons and a plastic scintillator wall to detect neutrons scattered inelastically.



A VME based data acquisition setup has been developed to record correlated TDC and QDC data list-mode from 50 detector channels with a deadtime below 1 μs per event.



1 m long plastic scintillation detectors with efficiencies of more than 10 % even for 25 keV neutrons have been developed and will be used to measure the incoming neutron as well as neutrons scattered from the experimental sample.

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