nELBE
The neutron time of flight facility at ELBE

Nuclear Safety Research

Measuring nuclear data to reduce radioactive waste

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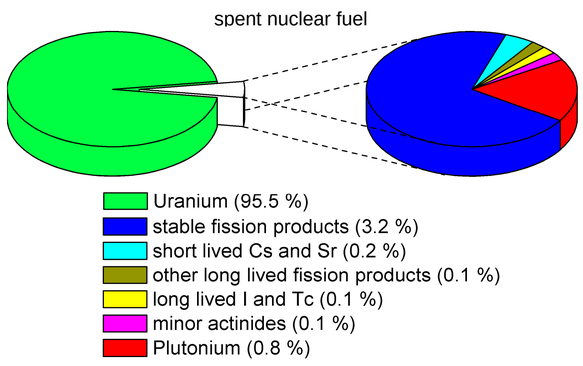
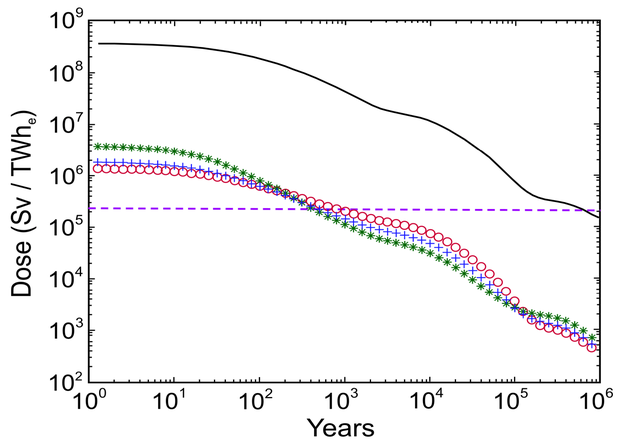
Transmutation of long-lived radio-nuclides

- **Transmutation** of radioactive waste **= convert long-lived radio-nuclides into short-lived ones** ➔ simplification of nuclear waste final disposal

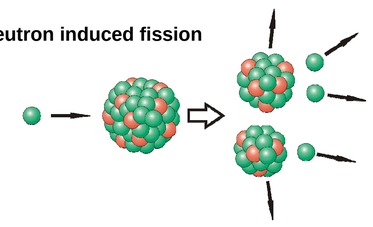




• ***Without transmutation***: *Radio-toxicity of untreated nuclear waste from conventional nuclear reactors reaches level of original Uranium after several **100 000 years** (—)*
• ***With transmutation*** *(*,+,o): Within less than **1000 years** level of original Uranium is reached (- -)*

- Possible sites for transmutation will be **Geration IV nuclear reactors and Accelerator Driven Systems (ADS)** → **using fast neutrons**

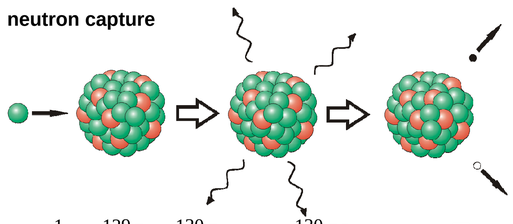
neutron induced fission



$^{1}_{0}n + ^{239}_{94}Pu \rightarrow ^{102}_{43}Tc + ^{135}_{51}Sb + 3\cdot ^{1}_{0}n$

$T_{1/2}$ = 2.4x10⁴ a 4.3 min 1.7 s

neutron capture



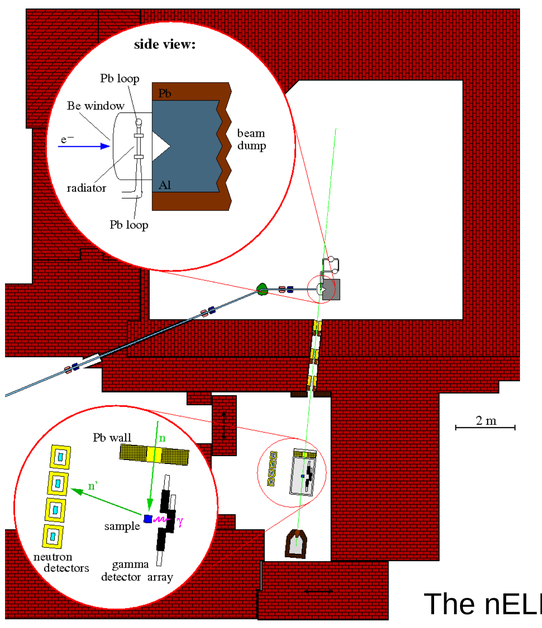
$^{1}_{0}n + ^{129}_{53}I \rightarrow ^{130}_{53}I + \gamma \rightarrow ^{130}_{54}Xe + e^{-} + \bar{\upsilon}$

1.6x10⁷ a 12.4 h stable

- **Fast**, non moderated **neutrons can both**:
  1. **transmute** long-live fission fragments
  2. **fission** transuranic elements: Plutonium (and other minor actinides) will be energetically used, too. Existing quantities can be burned up.

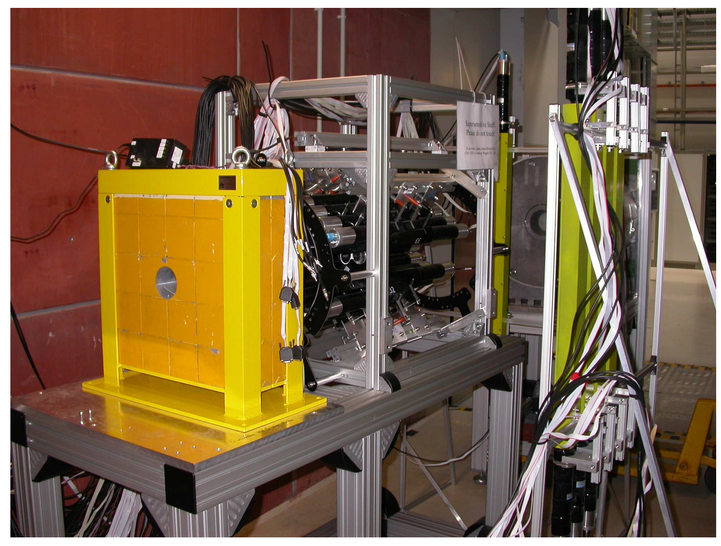
- **Fundamental processes** of inelastic neutron-scattering, neutron-capture and neutron induced fission **have to be well understood** to design transmutation facilities.

The nELBE neutron time-of-flight facility



The nELBE neutron time-of-flight facility

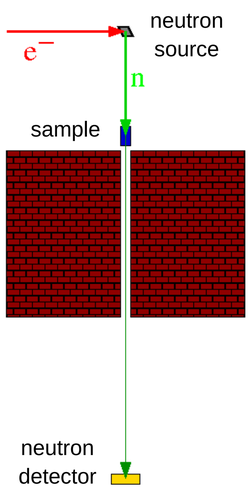
- Neutrons are produced by the ELBE electron beam impinging on a liquid lead target
- Repetition rate: 101-202 kHz
- Flight path: 5-7 m
- Neutron intensity: $1.5 \cdot 10^{7}$ cm^{-2} s^{-1}
- Neutron energy range: 100 keV < E_n < 10 MeV (energy range compare-able with fast reactors)
- Neutron energy resolution: $\Delta E/E$ < 1 %

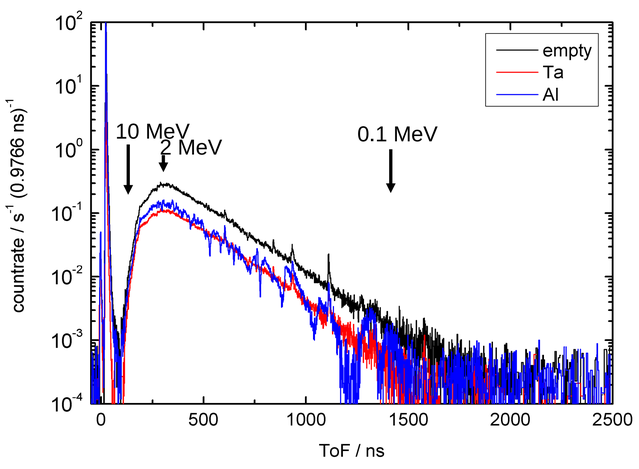


The nELBE detector setup:
- plastic scintillation detectors to detect the neutrons
- an array of BaF_2 crystals for photon detection

Transmission (n,tot)

➔ includes **every type of interaction**, that can happen





measured neutron time-of-flight spectra for different samples

➔ total neutron cross section determined by:

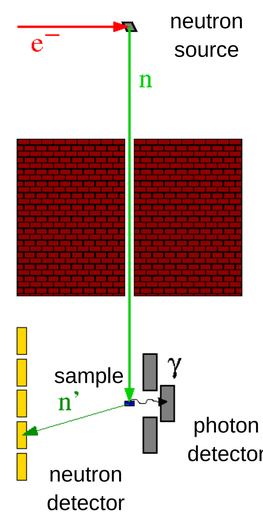
$$\sigma_{tot} = \frac{\ln \dot{N}_{empty} - \ln \dot{N}_{sample}}{\rho / M_{mol} \cdot N_A \cdot d}$$

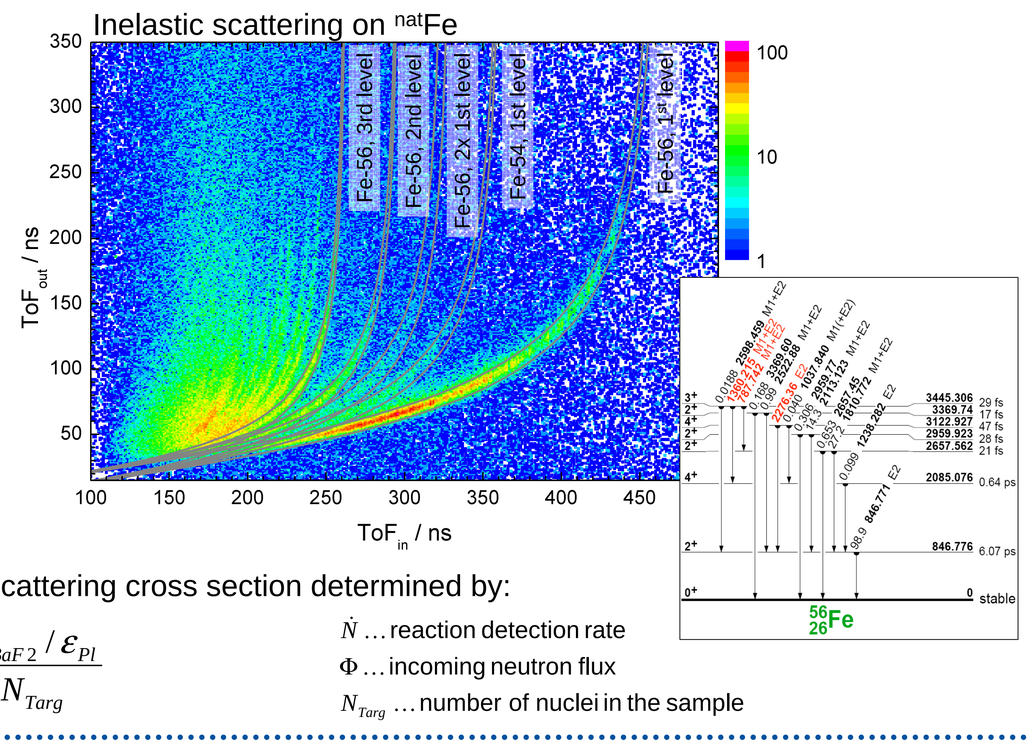
ρ … sample density
M_{mol} … molar mass
d … sample thickness

Inelastic scattering (n,n'γ)

$^{56}Fe(n,n'\gamma)^{56}Fe$ { $^{56}Fe + n \rightarrow ^{56}Fe^{*} + n'$; $^{56}Fe^{*} \rightarrow ^{56}Fe + \gamma$

➔ the neutron can loose a large fraction of its energy by one single interaction.





➔ Inelastic neutron scattering cross section determined by:

$$\sigma_{tot} = \frac{\dot{N} / \varepsilon_{BaF2} / \varepsilon_{Pl}}{\Phi \cdot N_{Targ}}$$

$\dot{N}$ … reaction detection rate
Φ … incoming neutron flux
N_{Targ} … number of nuclei in the sample

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EFNUDAT European Facilities for Nuclear Data Measurements

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung