Accelerator Based Technique of Fission Fragment Implantation for Wear Studies

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Thin Layer Activation (TLA) Technique Principles

- Radioactivity is induced in a thin layer of atoms on the component surface.
- Wear is measured by monitoring a decrease in the component's radioactivity.

The TLA technique is applied in three steps:

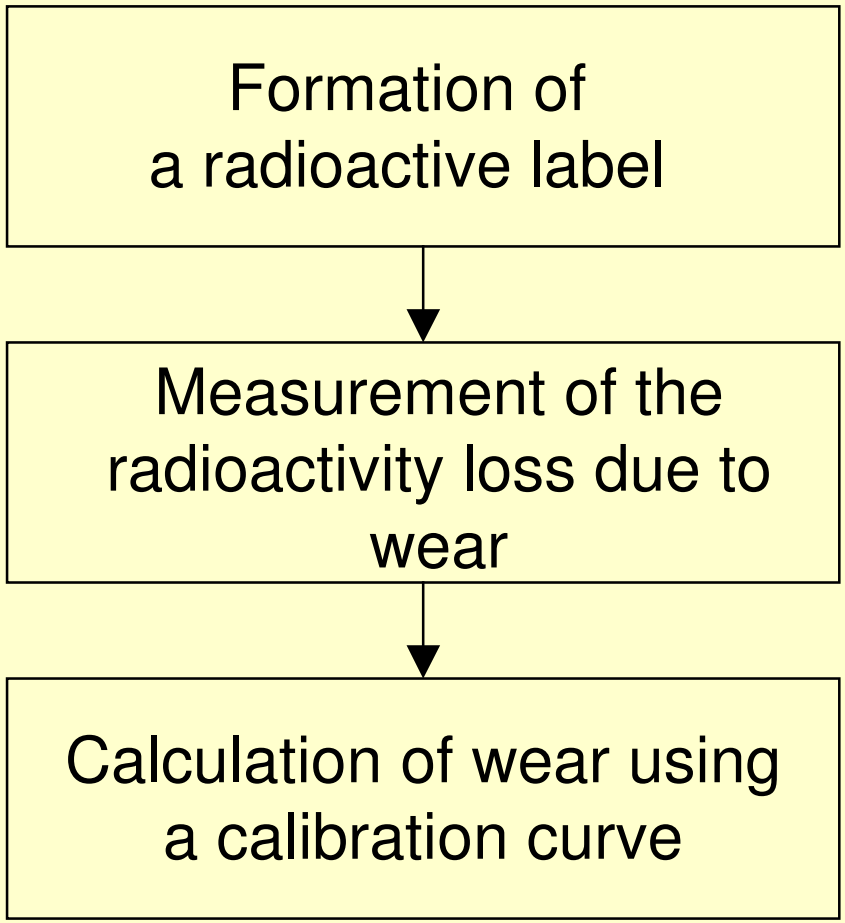
- 1- PRELIMINARY STUDY
- 2- LABELING WITH RADIOISOTOPES
- 3- MONITORING OF WEAR

Preliminary Study

What are:

- **Location of the critical wear area?**
- **Composition of the component?**
- **Expected wear depth?**
- **Radiation hardness of the material?**

Flowchart of the TLA



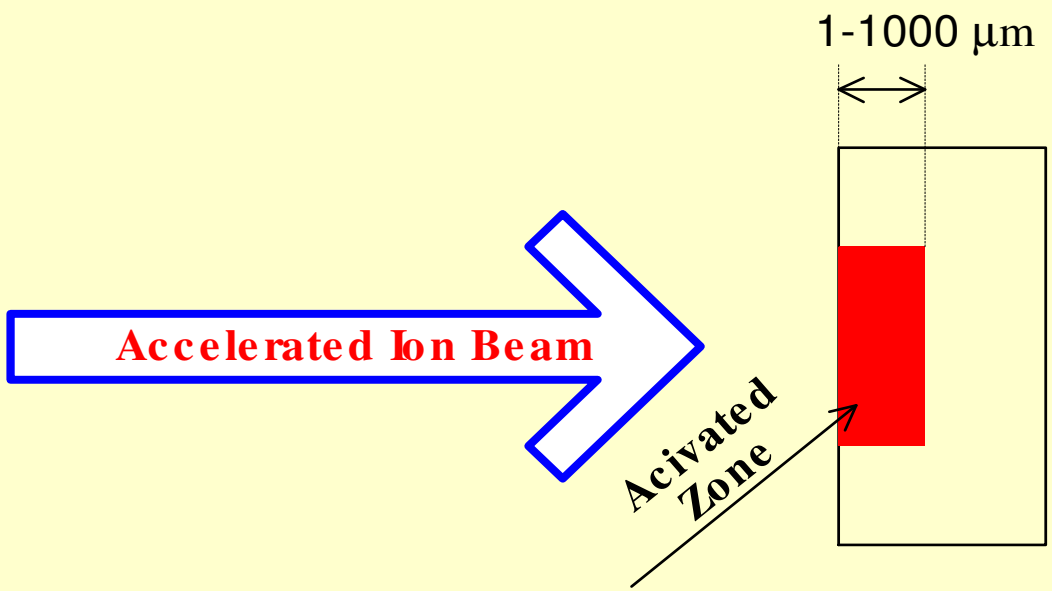
Required Properties of the Radioactive Label

Half life	1 –100 days
Energy of γ-rays	100 keV – 1 MeV
Activity	1 – 10 μCi

Methods potentially applicable in order to create a radioactive label

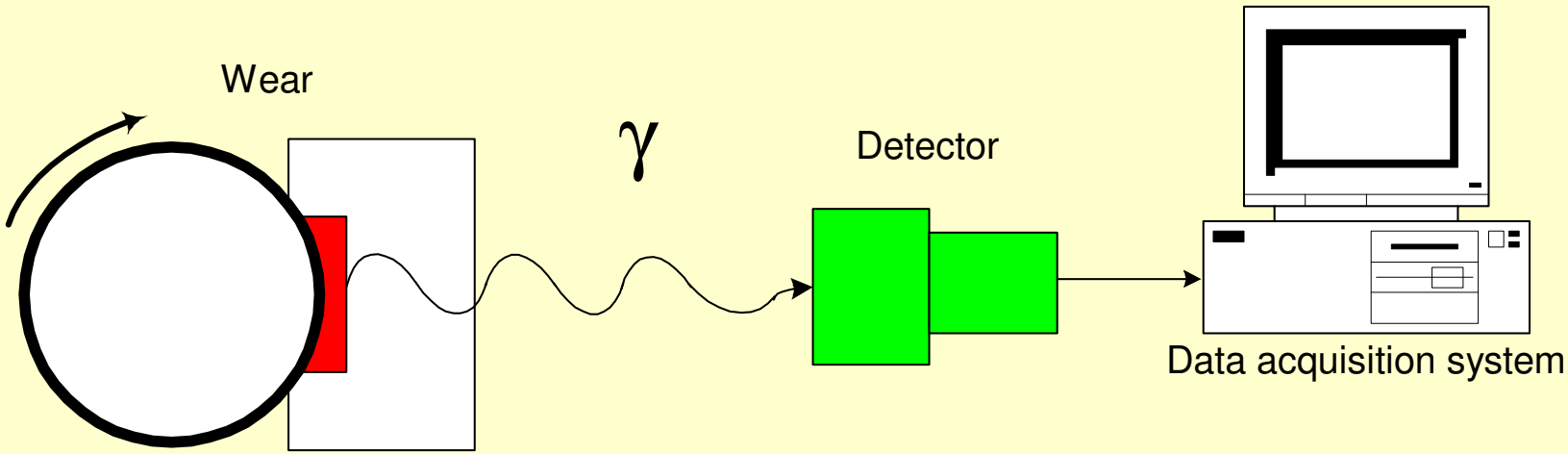
- irradiation with accelerated ions;
- surface absorption of a radionuclide;
- thermo diffusion;
- implantation;
- other…..

Thin Layer Activation by an Accelerated Ion Beam

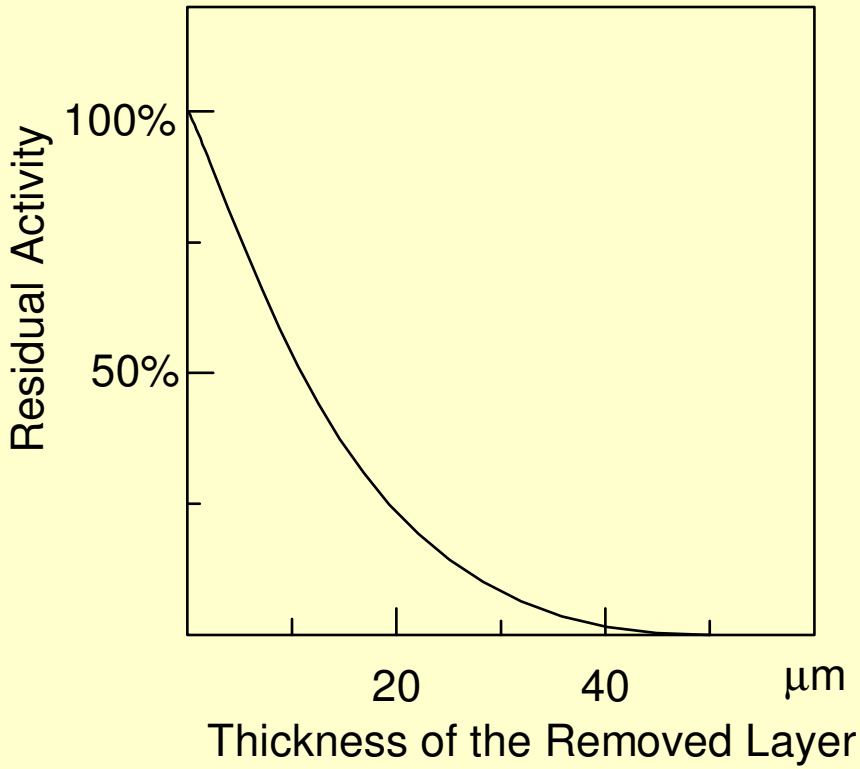


- The sample material should contain an element suitable for activation
- Wear properties of the sample should not change in result of the irradiation

Measurement of the γ-activity of the label



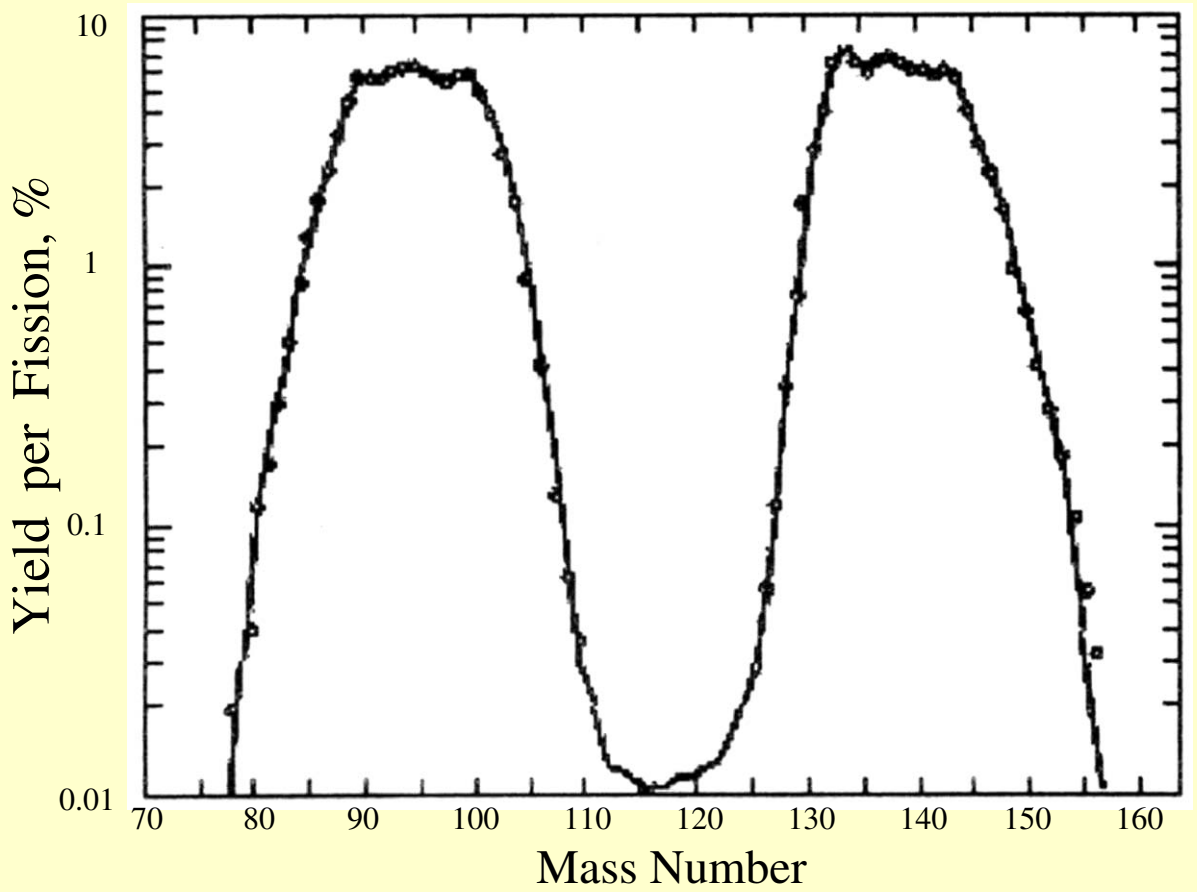
Calibration Curve



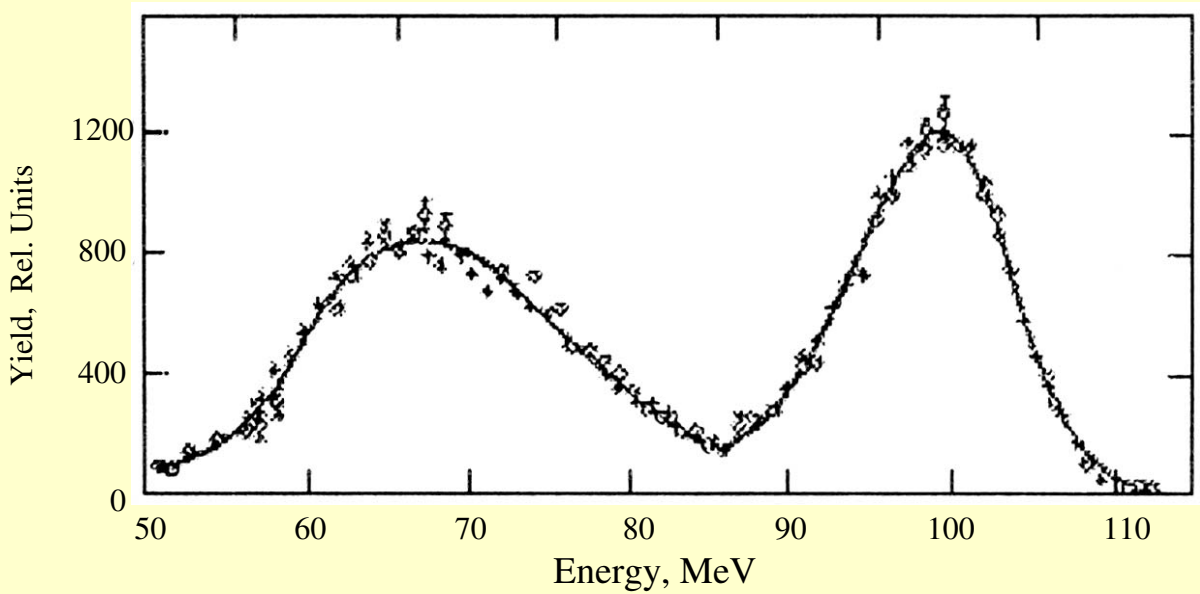
Comparison of the material properties

	Heat resistance	**Conductivity**	**Radiation hardness**
Metals	Good	Conductor	High
Plastics, rubber, etc.	Bad	Isolator	Low

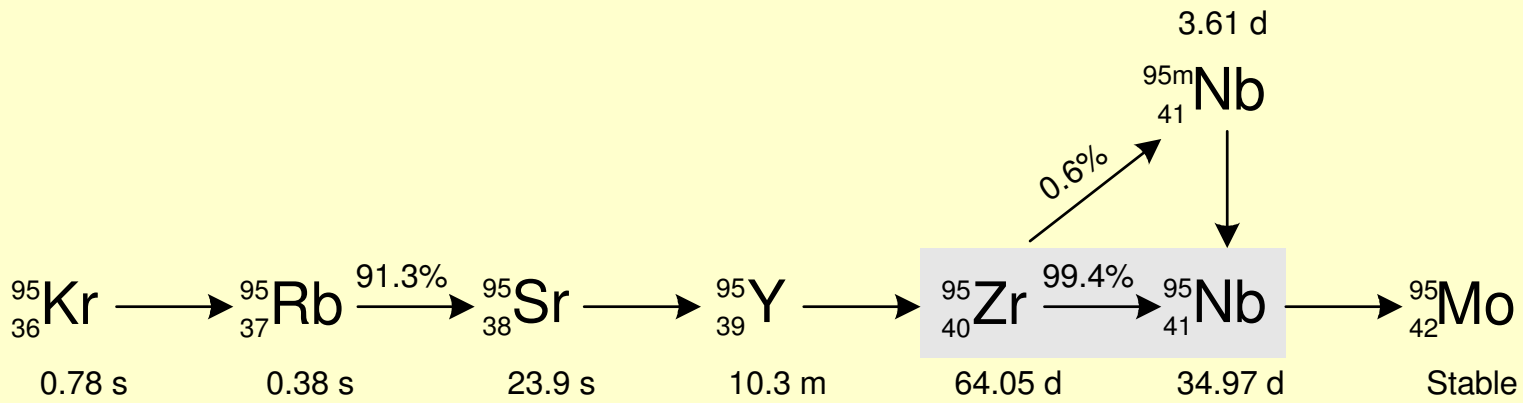
Mass Distribution of Fragments for the ^{235}U Fission by Thermal Neutrons



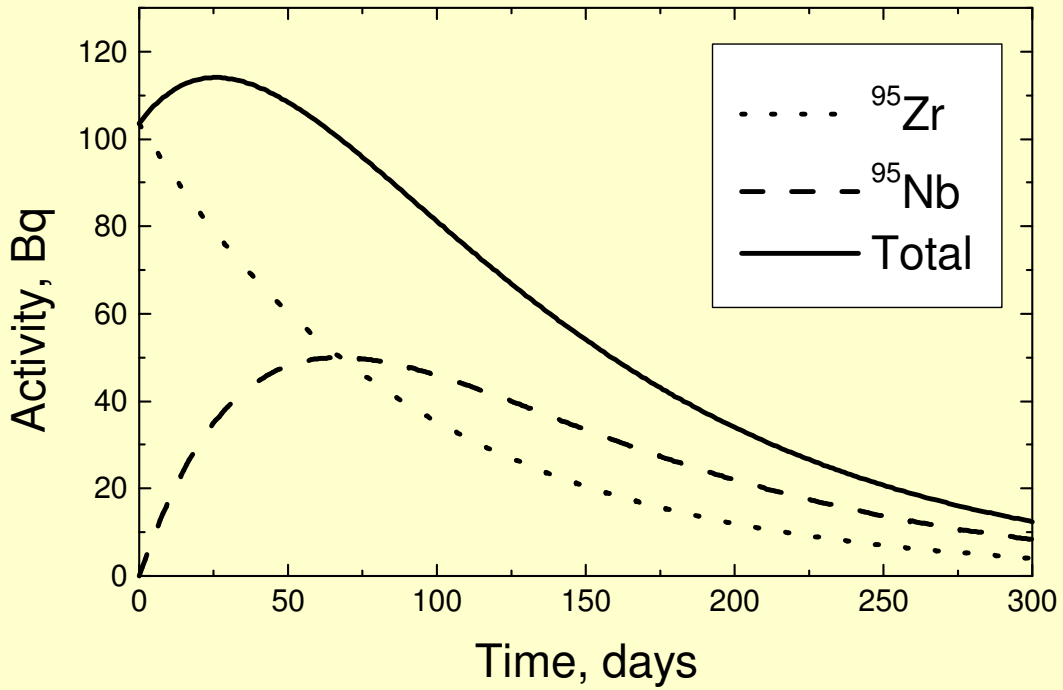
Energy Distribution of Fragments for the ^{235}U Fission by Thermal Neutrons



Decay of the 95 Mass Chain

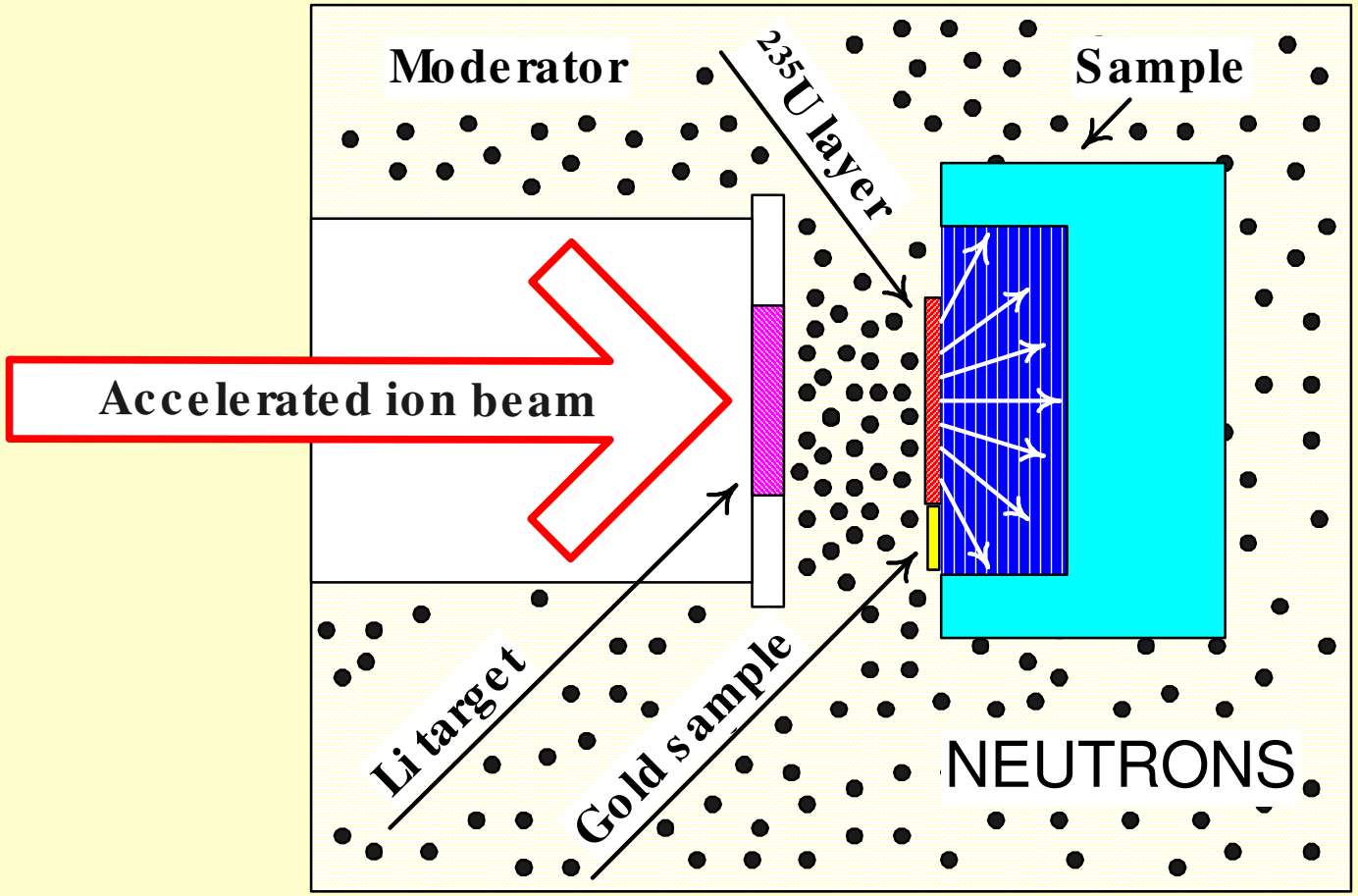


Dependence of the activity of the ^{95}Zr and ^{95}Nb isotopes on time

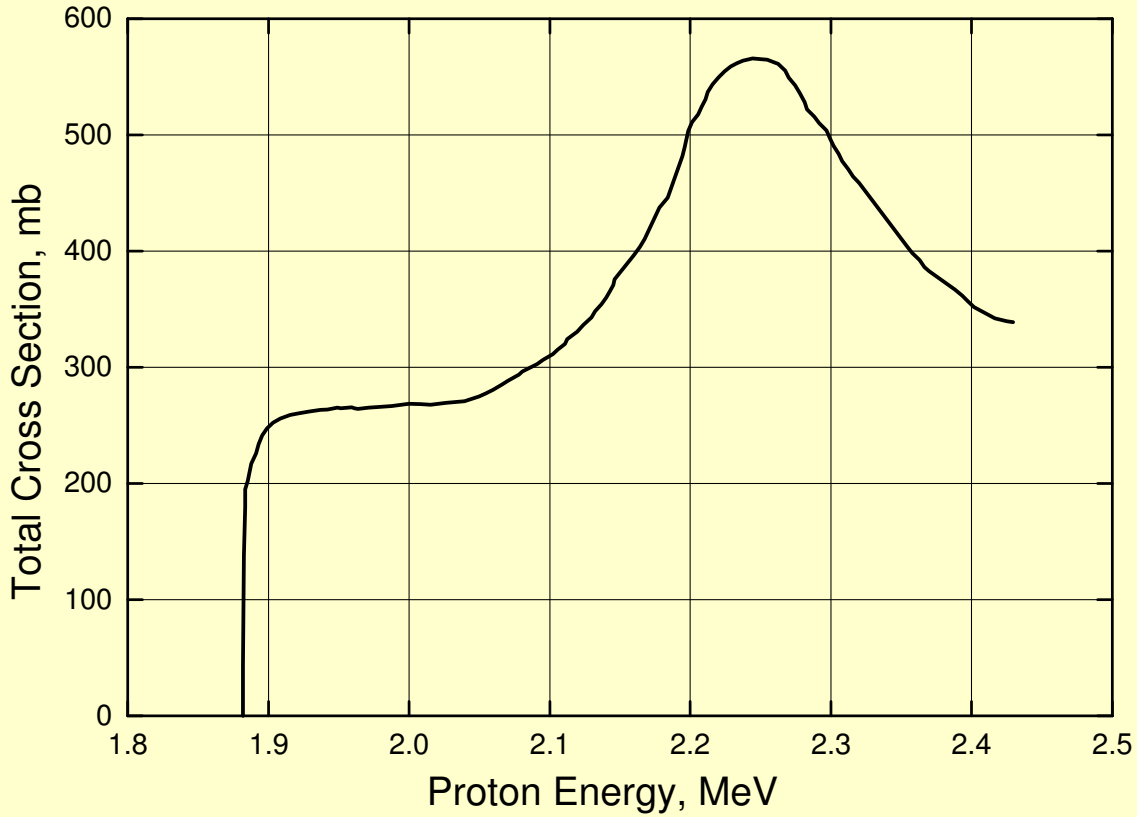


$$N_{Nb}(t) = N_{Nb}^{0} e^{-\lambda_{Nb} t} + \frac{\lambda_{Zr} N_{Zr}^{0}}{\lambda_{Nb} - \lambda_{Zr}} (e^{-\lambda_{Zr} t} - e^{-\lambda_{Nb} t})$$

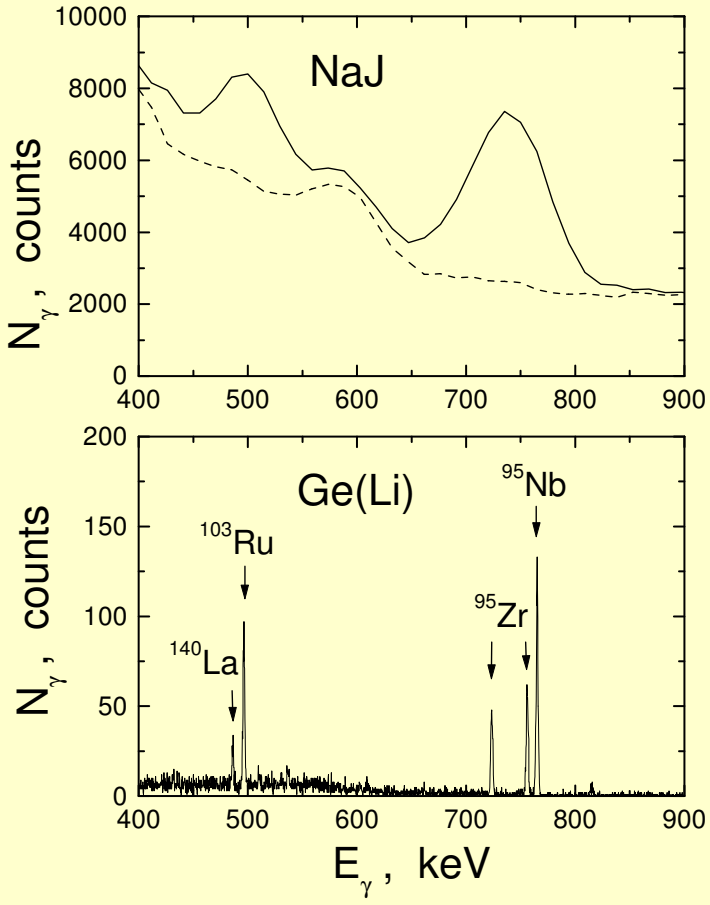
Experimental Layout for Fission Fragments Implantation



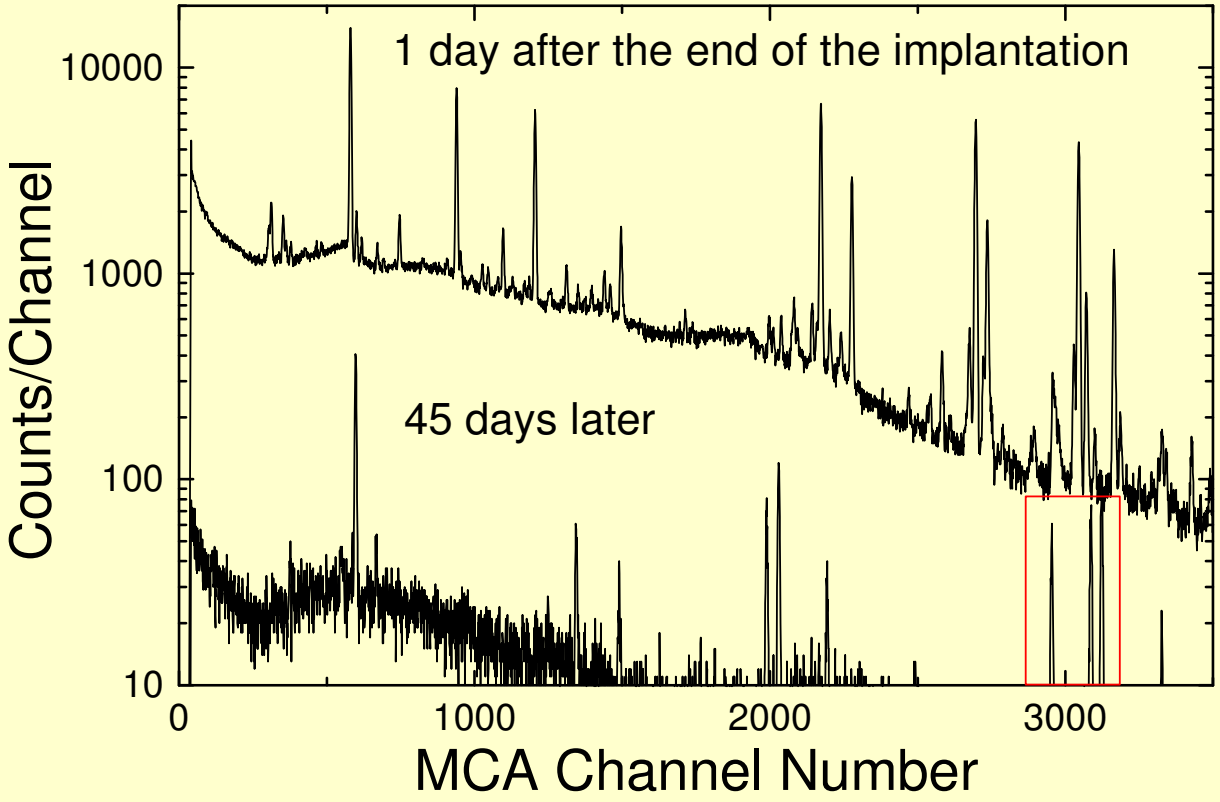
Total Cross Section for the $^{7}Li(p,n)^{8}Be$ Reaction



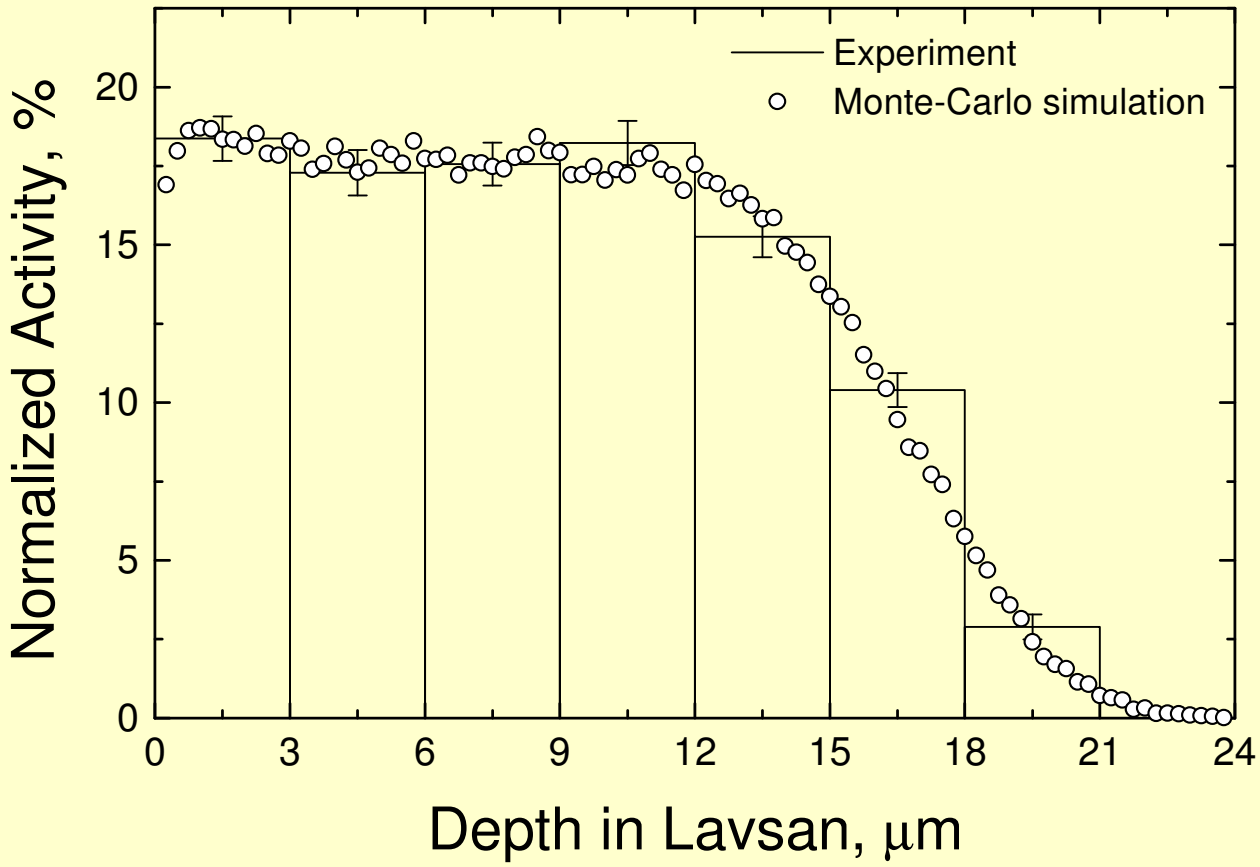
Range of interest of the gamma-ray spectrum from the fragments implanted in a stack of Lavsan films obtained with NaI and Ge(Li) detectors on the 60th day after the implantation



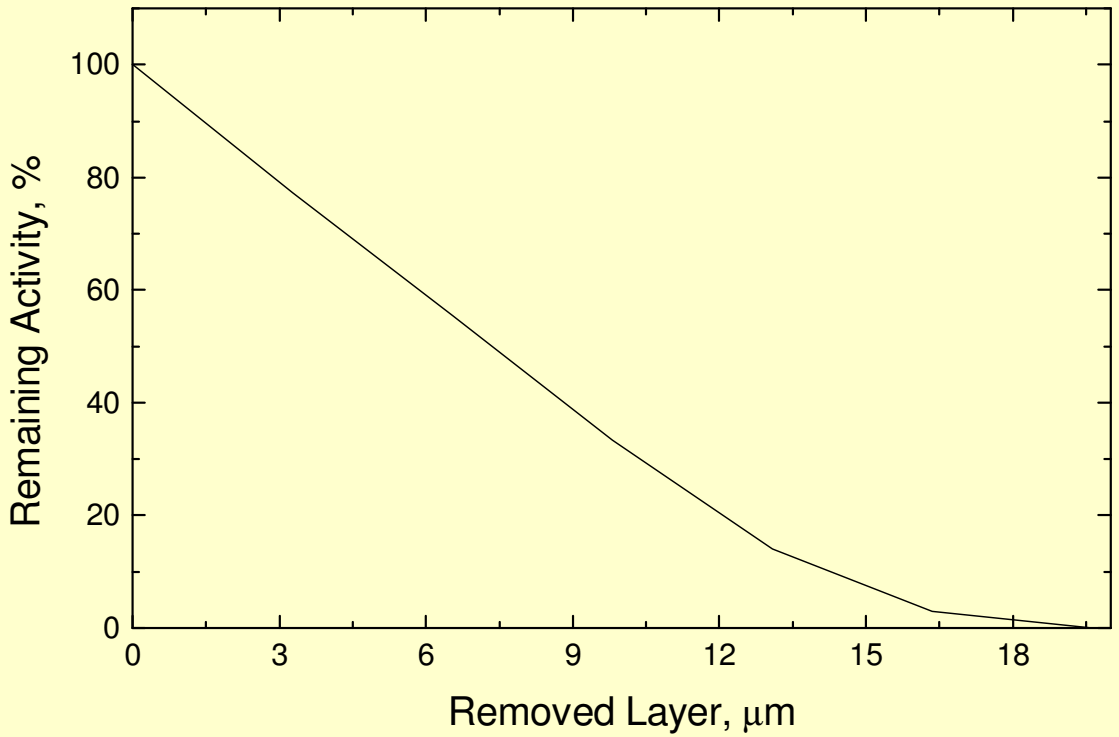
Background Conditions for γ-rays Registration



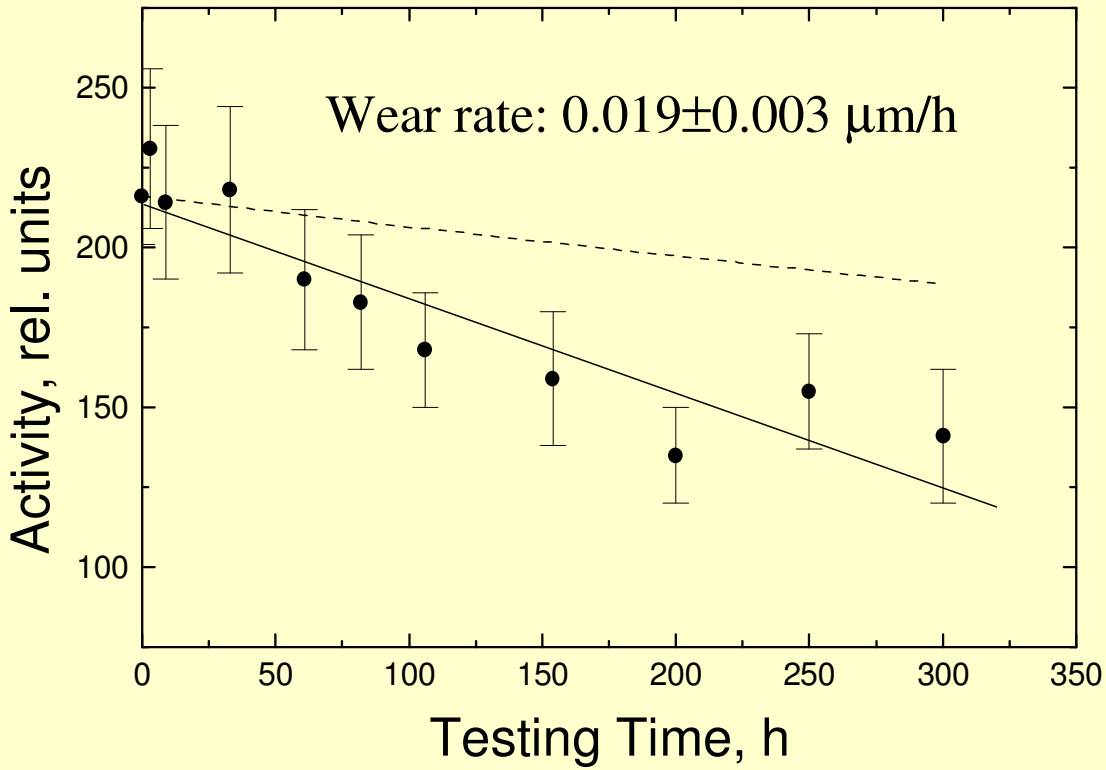
Measured and simulated depth distribution of the $^{95}Zr/^{95}Nb$ activity in Lavsan (polyethylene terephthalate)



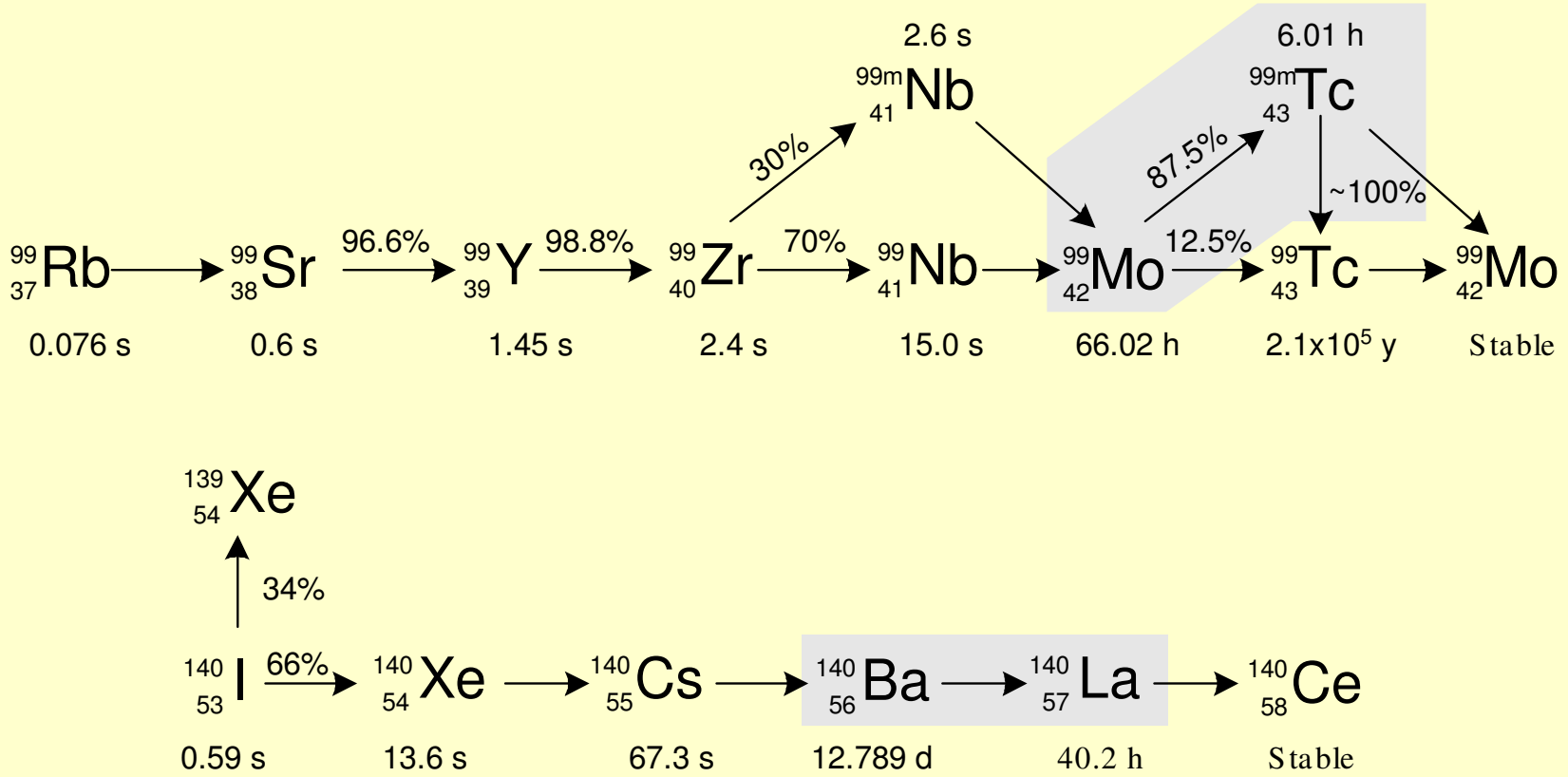
Calibration Curve for Conversion of the Residual Activity into Thickness of the Removed Layer



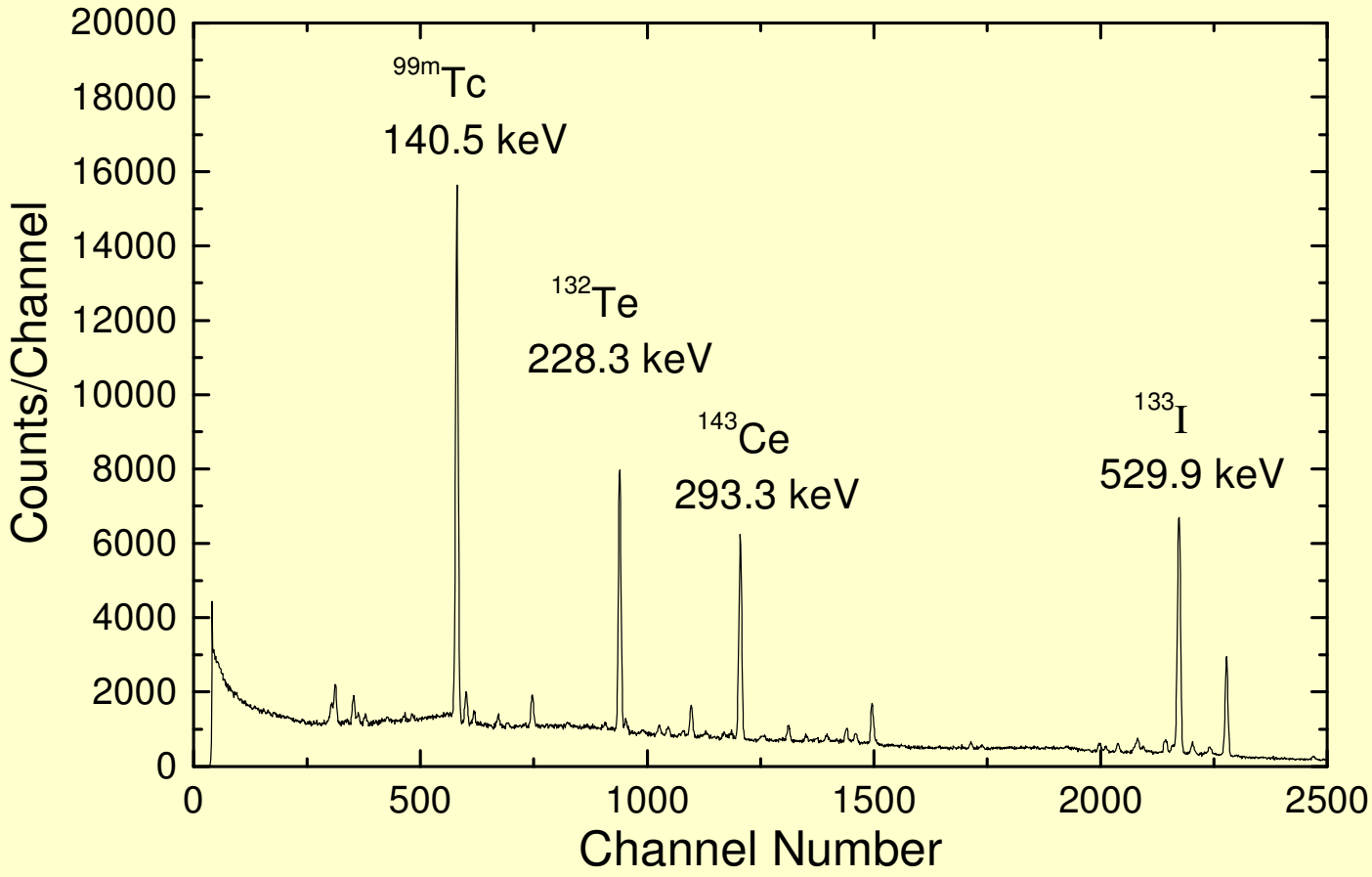
Residual Activity of the Sample as a Function of a Net Time of the Abrasion Testing



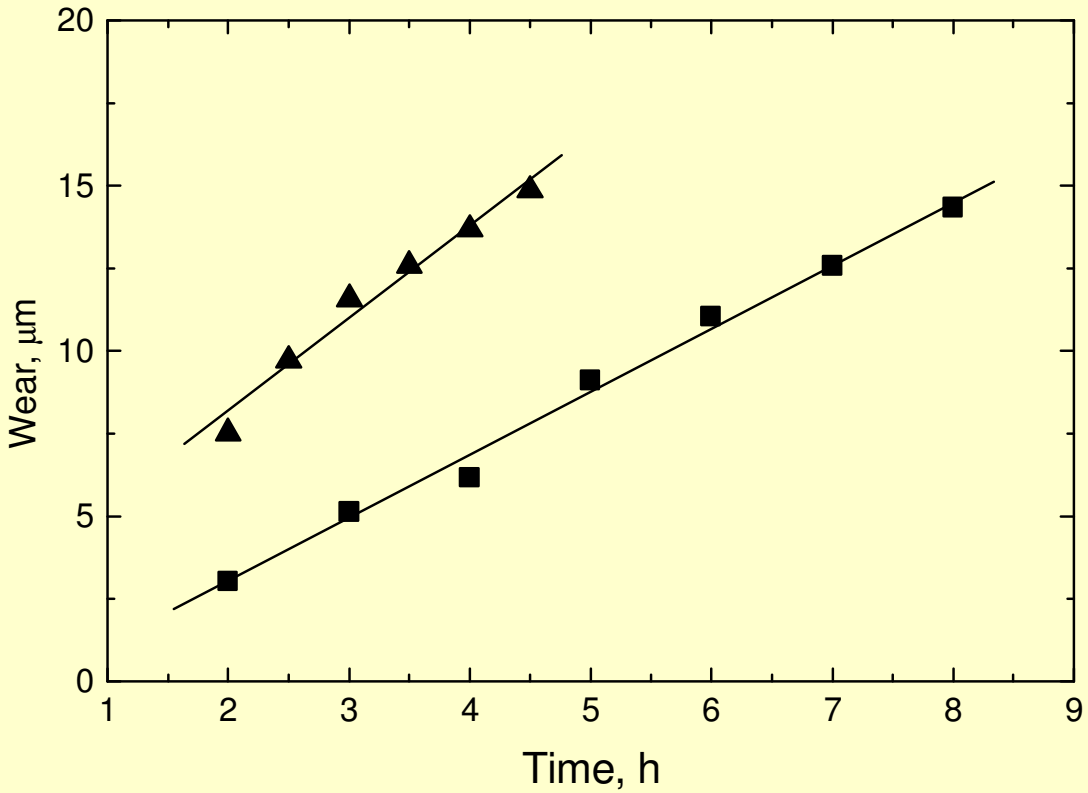
Decay of the 99 and 140 Mass Chains



Low energy part of gamma-ray spectrum showing the most intensive radiation from fission fragments implanted in a stack of Lavsan films in a day after the implantation



Comparison of wear kinetics for a pair of the investigated samples



Conclusions

- The induced fission fragments implantation proved to be a convenient tool for introducing thin radioactive layers in the surface of the samples which cannot withstand activation by ion beam bombardment.
- A vast variety of radioactive nuclei produced in fission make it easy to find a tracer with suitable half-life and γ-ray energy.
- The technique is based on widely available small accelerators and is rather simple in materialization.
- The radioactivity introduced into the samples under investigation is extremely small and so the wear testing can be made with no danger to the environment and staff.