Exercise J11 - Measurement of thermal neutron induced fission fragment spectra of ^{236}U

October 3, 2024

1 Introduction

The phenomenon of fission was discovered in 1939. Among all nuclear physics discoveries, it probably has the largest impact on a whole society. The studies of nuclear fission are continued today, as this process focuses almost all our knowledge of nuclear physics, and we still cannot describe it theoretically well enough. In this exercise, we will measure one of the basic observable of the fission process - the fission fragment spectra. For this we shall use the method described by publication [1], closely following the described therein procedure.

2 Required reading

1. Radioactive decay, decay constant, half-life.
2. α decays of uranium and actinium chains
3. Fission
   a) binding energy in liquid drop model,
   b) conditions for fission,
   c) dependency of the potential energy of the fissioning nucleus on deformation,
   d) neutron binding energy,
   e) activation energy,
   f) energy released in fission.
4. Pu-Be neutron source, neutron moderation ([2]-1.V).
5. Heavy charged particle detection with semiconductor detectors. ([2]-11.IV.2) Principles of operation ([3]-14.1, 14.2, [2]-16.III, 18-III) of
   a) surface barrier silicon detector
   b) charge preamplifier,
   c) linear amplifier,

d) multichannel analyzer.

6. Statistical and systematical uncertainties in radiation measurements ([2]-3.II).

7. Publication [1].

3 Outline

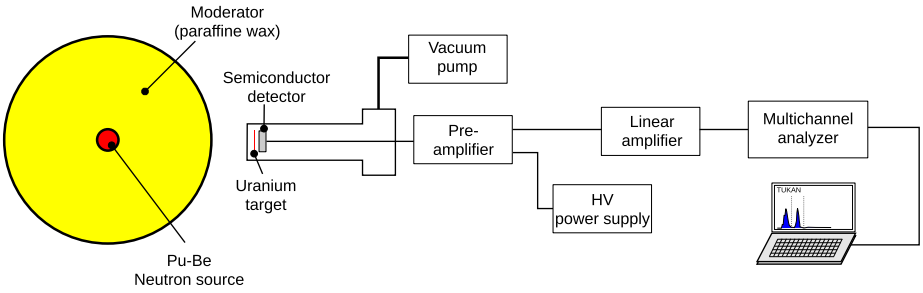

Figure 1: Overview of the experimental setup

1. Introduction to experimental setup: neutron source, calibration sources, detectors, HV power supplies, amplifiers, analyzer and computer program.

2. Preparation of in-house calibration source

3. Determination of measurement conditions

   a) optimization of energy resolution

   b) energy calibration with α particles and generator.

4. Measurement of α particles spectrum from uranium target

5. Measurement of ^{236}U fission fragment spectrum

4 Data analysis

A laboratory report is a kind of essay, and it should be written with correct spelling and grammar. It should follow logical reasoning, keeping in mind that a person that never done the exercise before, should understand what were the objectives, methods and results.

It should be structured with sections like introduction, methods, results, and conclusions. The introduction should define the purpose of the experiment, put possible hypotheses to be tested, refer to previous studies, and briefly describe the method to be used. The main part, consisting of a more detailed description of the procedure and results, should include figures, and schemes, clearly presented, including labels, legends, units, and other elements. It is not needed to

copy textbook knowledge, instead, it is better to select the key information on used methods and equipment and focus on the actual experiment and results. Numerical values should be presented with uncertainties. In the conclusions, one should discuss whether the result confirms expectations or predictions, how it compares to the literature, what is the source of discrepancies, or the main component of uncertainty, if something could be improved, etc.

Main analysis steps

1. Energy calibration of the detector
2. Analysis of statistical and systematical uncertainties of calibration
3. Analysis of α particles spectrum
4. Analysis of fission fragment spectrum
5. Calculation of thermal neutron flux
6. Comparison of the results with literature data and discussion

To estimate the thermal neutron flux inside the moderator we will make the following assumptions

- fission cross-section of ^{235}U with thermal neutrons $\sigma = 582$ b,
- target isotopic content ^{234}U (1%), ^{235}U (10 %), ^{238}U (89%),
- target thickness 200 μg/cm^2, radius 5 mm
- detector efficiency for particles emitted from target 32%.

References

[1] W. R. French Jr. and R. L. Bunting, American Journal of Physics 37 (1969) 637

[2] G. Knoll "Radiation detection and measurement", ed. III or IV, J. Wiley and Sons

[3] C. Leo, "Techniques for Nuclear and Particle Physics Experiments" ed. II, Springer 1994

[4] S. Brandt "Data analysis", ed. IV, Springer 2014

[5] Chart of Nuclides, www.nndc.bnl.gov/nudat3/