Exercise J12 - Measurement of deuteron binding energy

1 Introduction

Deuteron is a simplest non-trivial atomic nucleus. It is no wonder that it attracts a lot of attention, both from theoretical and experimental point of view, from the very beginning of the nuclear physics.

One of the most basic nucleus properties is a binding energy, and the aim of the following exercise is to find its value for deuteron with best accuracy that our equipment allows. We shell use the method described by publication [1], but we will try to greatly improve obtained therein results.

2 Required reading

1. Properties of deuteron: spin, quantum wave function structure.
2. Definition of nuclear binding energy, dependence on atomic mass number
3. Method to determine deuteron binding energy in publication [1]. What approximations were used by authors? What is the order of magnitude of these effects? Which should be taken into account?
4. Interaction of γ-rays with matter: photoelectric absorption, Compton scattering, pair production ([2]-2.III.A).
5. Principles of operation of semiconductor germanium detectors ([2]-12.II.C, 12.III.A, 12.IV.A)
6. Electronic signal processing (preamplifier, amplifier, multichannel analyzer) ([3]-14.1, 14.2, [2]-16.III, 18-III).
7. Energy resolution, energy calibration, efficiency calibration ([2]-4.V, 4.VI)
8. Statistical and systematical uncertainties in radiation measurements ([2]-3.II).
9. Decay schemes ([3]-1.1, 1.3).
10. Pu-Be neutron source, neutron moderation ([2]-1.V).

11. Neutron activation.

12. Publication [1].

3 Outline

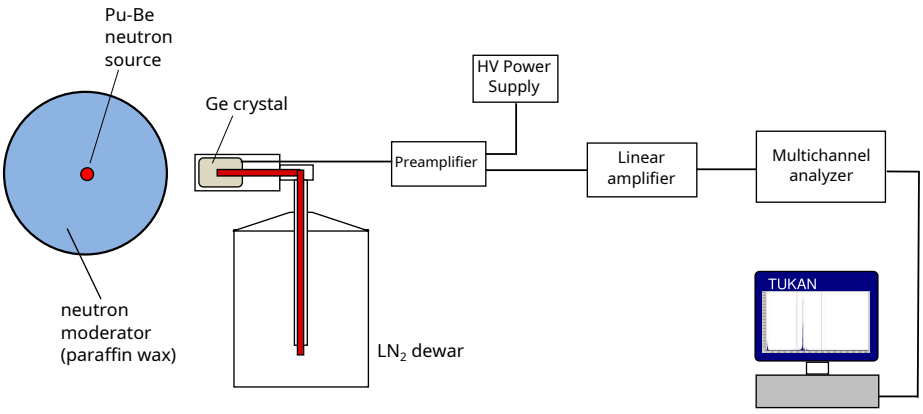

Figure 1: Overview of the experimental setup

1. Introduction to experimental setup: neutron source, calibration sources, detectors, HV power supplies, amplifiers, analyzer and computer program.
2. Preparation of custom calibration source
3. Determination of measurement conditions
   a) selection of amplification ratio
   b) optimization of energy resolution
4. Measurement of calibration sources.
5. Measurement of deuteron binding energy.

4 Analysis

Laboratory report is a kind of an essay, and it should be written with correct spelling and grammar. It should follow a logic reasoning, having 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. Introduction should define the purpose of the experiment, put possible hypothesis to be tested, refer to previous studies, and shortly describe the method to be used. The main part, consisting of more detailed description of 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 main component of uncertainty, if something could be improved, etc.

Main analysis steps

1. Selection of calibration data and determination of best calibration
2. Analysis of statistical and systematical uncertainties of calibration
3. Determination of deuteron binding energy
4. Comparison of the results with literature data and discussion

References

[1] E. Oritz, American Journal of Physics 29 (1961) 684

[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/