Exercise J12 - Measurement of deuteron binding energy

October 2, 2024

1 Introduction

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

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

2 Required reading

1. Properties of the 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 the 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

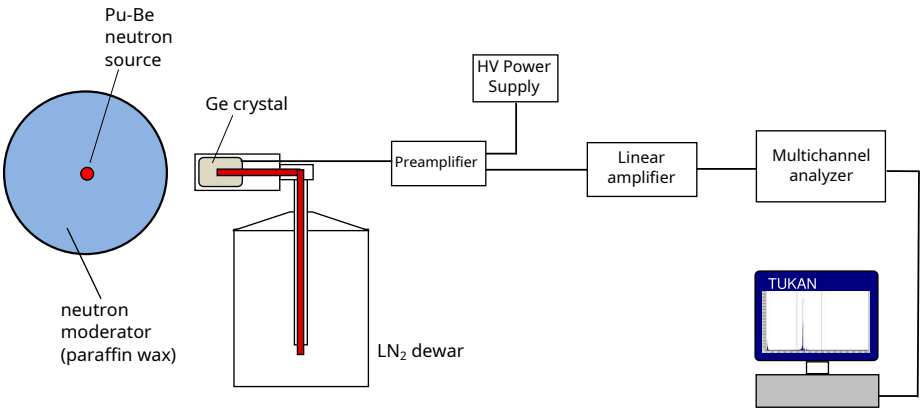

Figure 1: Overview of the experimental setup

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

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. 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/