Exercise J18 - Mini PET

February 27, 2024

1 Introduction

PET (Positron Emission Tomography) is an imaging technique, commonly used in nuclear medicine, typically for cancer diagnosis. In this exercise, like in real PET scanning, we shall try to localize the radioactive source placed in a body (a phantom).

A typical PET scanner is built using many scintillation detectors forming a ring, which detects radiation from radioactive tracers. We have only two detectors, but we are free to move and rotate the phantom in many different positions. This is equivalent to having many pairs of detectors like in a PET scanner.

2 Required reading

1. Interaction of γ-rays with matter: photoelectric absorption, Compton scattering, pair production ([1]-2.III.A).
2. What are the types of radioactive decay? Which ones can be used for PET scanning? ([3]-11.2)
3. How the PET image is created? ([3]-11.2)
4. What are positrons, how do they annihilate, what radiation is emitted in that process, and what are their properties?
5. Principles of operation of scintillation detectors ([1]-8.II, 9.I)
6. Electronic signal processing (multichannel analyzer) ([2]-14.2).
7. Energy resolution, energy calibration, efficiency calibration ([1]-4.V, 4.VI)
8. Statistical and systematical uncertainties in radiation measurements ([1]-3.II).
9. Decay schemes ([2]-1.1, 1.3).

3 Outline

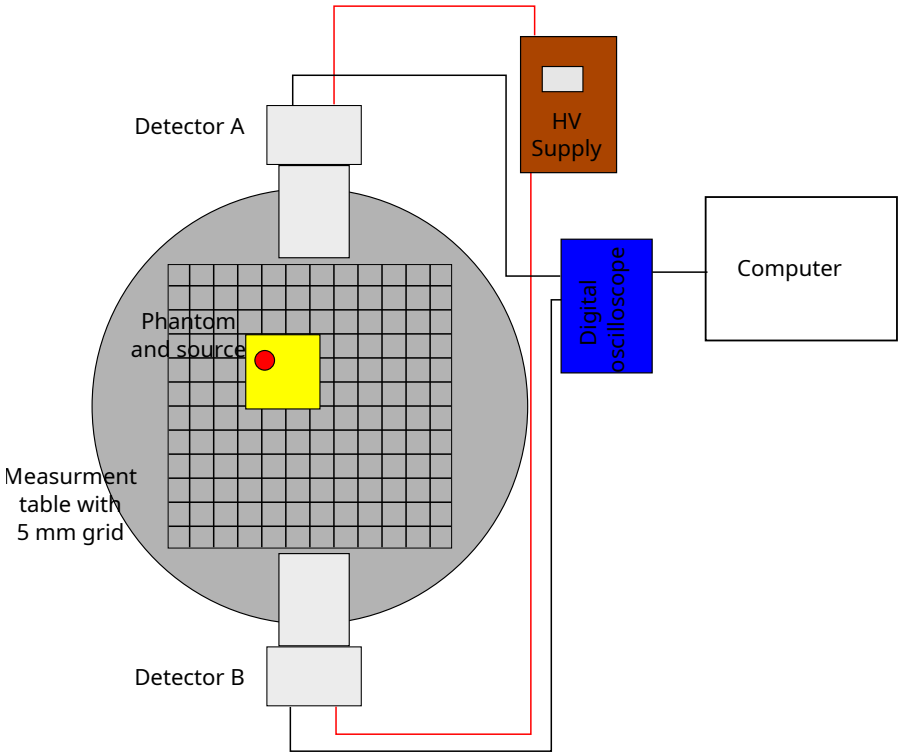

Figure 1: Overview of the experimental setup

1. Introduction to experimental setup: phantom, calibration sources, detectors, HV power supplies, analyzer and computer program.
2. Measurement of calibration γ sources ^{60}Co, ^{137}Cs, ^{133}Ba.
3. Calculation of preliminary calibration
4. Preliminary measurement of ^{22}Na source radiation.
5. Series of measurement along the axis
6. Selection of ax with maximum counts and series of measurement along Y axis

4 Analysis

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1. Calibration of detectors
2. Selection of criteria for a good event

3. Determination of the number of counts in measurement series

4. Determination of source position

5. Uncertainty 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.

References

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

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

[3] C. Leroy, P.-G. Rancoita "Principles of Radiation Interaction in Matter and Detection", ed. II, 2009

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

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