Z32 - Measuring the spectra of beta radiation using a simple magnetic spectrometer

Physics Laboratory II – academic year 2017/2018
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University

The aim of the exercise is to measure the spectra of beta radiation emitted in the decay of ^{22}Na and ^{90}Sr and their theoretical description. This exercise is an example of application of a simple magnetic beta spectrometer for measuring momentum and energy spectra for charged particles.

Preparatory questions

1. Beta decay – types and selection rules [2, 3].
2. Description of the energy spectra of of electrons from beta decay – the theory of beta decay, Fermi-Kurie plot [2, 3, 4].
3. Decay schemes for ^{22}Na, ^{90}Sr and ^{90}Y radioactive sources[1].
4. The operation principle of a magnetic spectrometer [3].
5. Interaction of electrons with matter [1, 3].
6. The operation principle of a Geiger- Müller detector [3].

Computational assignments

The dependence of the number of counts per interval of momentum $dN/dp(p)$ is measured. Comparison of measurement results with the theory is usually carried out using the number of counts per interval of kinetic energy $dN/dW(W)$. Find the transformation between those dependencies expressing momentum in units of mc (where m is the mass of electron, c - speed of light) and the kinetic energy is expressed in units mc^2.

Apparatus and materials

Experimental setup is presented in figure 1. It consists of:

- Magnetic spectroscope consisting of a metal core and a coil. The radius of curvature (circular orbit along which the particles travel) is $r = 50mm$.
- Electromagnet power supply.
- Digital multimeter (used as an ammeter).
- Counter.
- Geiger- Müller detector.
- Teslameter with Hall probe.
- Radioactive sources ^{22}Na and ^{90}Sr each of $74kBq$ activity.

Experiment

1. Mount the experimental setup according to Fig. 1.
2. Perform magnetic field calibration for two polarities of the power supply voltage.
3. Measure momentum spectrum of beta radiation emitted in ^{22}Na decay.
4. In order to estimate background, perform additional measurements with opposite polarity of the power supply voltage .
5. Change radioactive source to ^{90}Sr and repeat measurements from point 3-4.

Data analysis

1. Plot the intensity of the magnetic field as a function of the current flowing through the electromagnet.
2. Using the calibration curve calculate the value of momentum of registered particles. From the measured number of counts subtract the number of counts of averaged background (if relevant). Transform the dependence of the number of counts per momentum interval to the dependence of the number of counts per kinetic energy interval. Plot this quantity as a function of kinetic energy.
3. Make Fermi-Kurie plots.
4. Use simple parameterization of the Fermi function from Ref. [4] (equation 3 for ^{22}Na decay and equation 8 with parameters given below for ^{90}Sr decay). Make the Fermi-Kurie plot (without shape factor for forbidden transitions). To the resulting graphs fit linear dependence selecting appropriate data range.
5. For the data obtained for ^{90}Sr source take into account shape factor for first-forbidden transition. Make the corrected Fermi-Kurie plot and fit linear dependence selecting appropriate data range.
6. Using the parameters obtained from fit, determine the maximum energy of electrons together with its uncertainty.

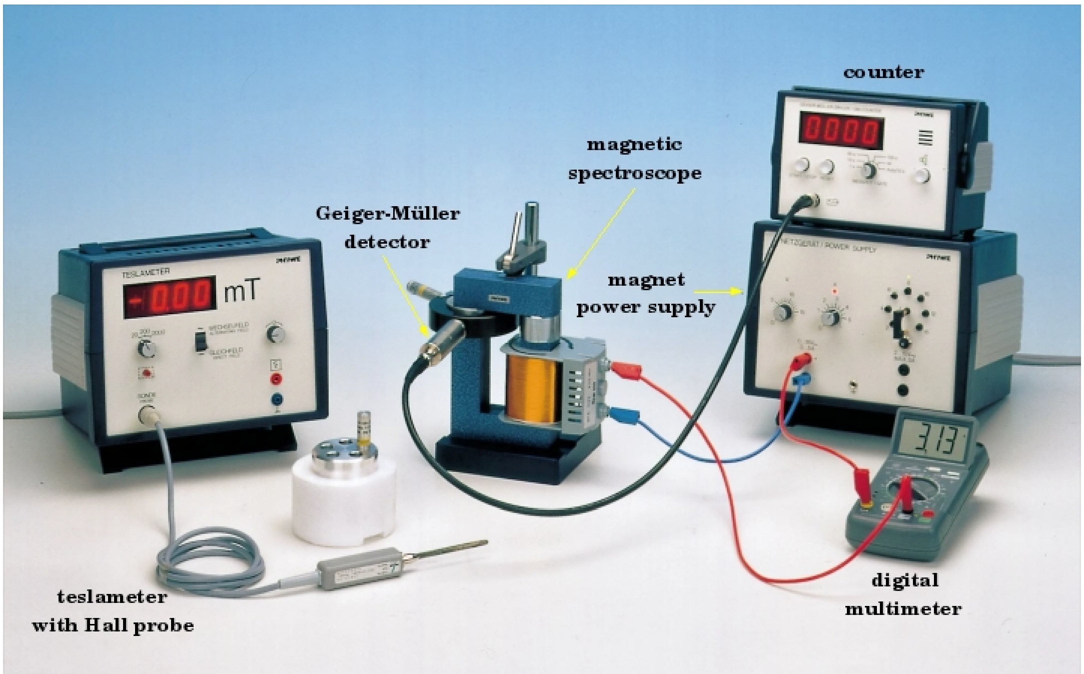

Figure 1: Experimental setup

Safety rules

Avoid unnecessary exposure to radiation, i.e. do not store radioactive sources in the vicinity of your body, after setting up the experiment build a wall of lead bricks between your working position and the radioactive source. Do not consume any food or beverages in the Students Laboratory.

References

[1] K. Siegbahn, *Alpha-, Beta- and Gamma-Ray Spectroscopy*, North-Holland Publishing Co., Amsterdam 1965.

[2] Donald H. Perkins, *Introduction to High Energy Physics*, Addison Wesley Company Inc., 1987.

[3] K. S. Krane, *Introductory Nuclear Physics*, John Wiley & Sons.

[4] P. Venkataramaiah et al., J. Phys. G: Nucl. Phys. 11 (1985) 359.