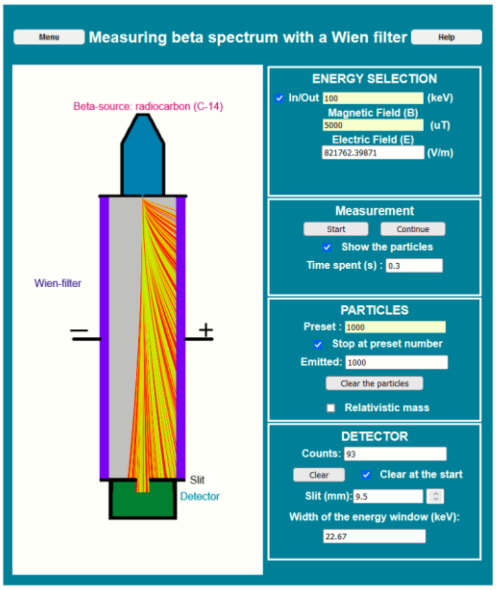
National Leo Szilárd Physics Competition 2024
Computer simulation task
Use of the program and Tasks

Measurement of the spectrum of beta-radiation using a Wien-filter

Description of the device and use of the program

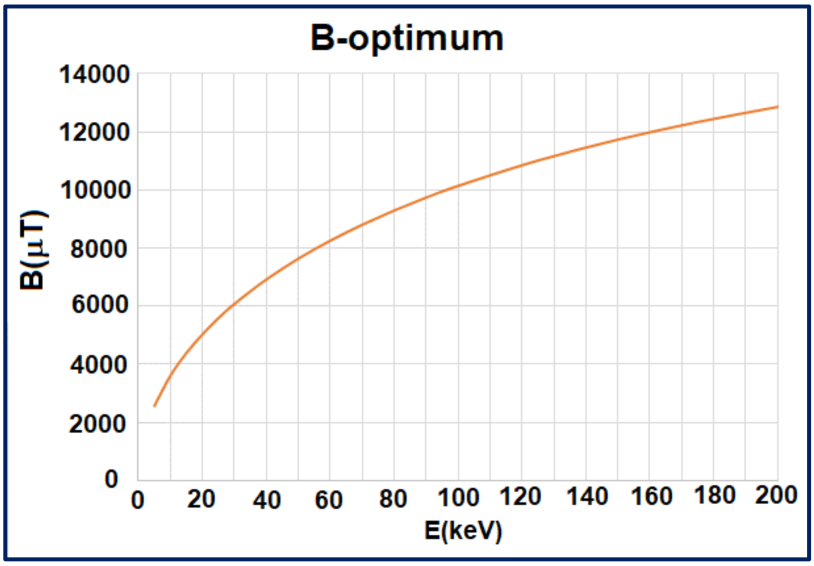
The structure of the equipment is very simple (see figure). The electrons emitted by the source enter the Wien filter from the beta radiation source at the top. In the region of the filter, the magnetic field strength is perpendicular to the image plane, and the electric field strength vector points from right to left. At the bottom of the filter, directly opposite the entrance slot, there is a slit (aperture) of adjustable width, through which beta particles pass directly into the detector. Since high-energy electrons are relativistic, we tried to make the handling as simple as possible: not the selected (filtered) speed, but the energy can be directly selected in the "**Energy selection**" panel. However, the selected speed (and energy) in a Wien-filter depends on two parameters (electric and magnetic field strengths), therefore at least the **magnetic field** strength must also be specified. The program automatically determines the electric field strength required for filtering the given energy.



The rest is pretty self-explanatory. In the "**Measurement**" panel the "**Show the particles**" flag can be turned off during the measurement, because this may somewhat speed up the program. However, there are certain settings where the particle trajectories will be quite strange, so at the beginning of each run, it is worth observing for a while whether the particle trajectories are correct. In the "**Particles**" panel you can preset the number of particles emitted for the run. Finally, the "**Detector**" panel shows the number of particles that have entered in the detector. Here we can also set the size of the aperture (slit) in front of the detector. The width of the "**energy window**" for the setting is also shown in this panel.

Optimal magnetic field

In the theoretical part we learned that it is important to know the width of the **energy window**. It turns out that it depends on the energy selection and also on the magnetic field (B) at which the selected energy is measured. The vertical axis of this graph shows the optimal magnetic field (where the energy window is the smallest), in function of the selected energy. (This graph is provided as an aid for the measurement.)



Tasks

1) **Task** (0 point)
   Read the theoretical summary and the measurement instructions! **Get to know** the program!
2) **Task** (6 points)
   Set the magnetic field for **5000 μT** and, starting from an energy of 10 keV, find approximately the maximum beta energy that can still enter the detector! **Observe** the trajectory of the beta particles (a low number of particles is sufficient for this). **Answer** the question, in what direction do deviate the particles whose energy is larger than the currently selected energy, and those whose energy is less? **Write down** your observations!
3) **Task** (2 points)
   What are the advantages and disadvantages of having a narrow energy window? Think about it and **write down** whether a wide or a narrow energy-window is more favorable for measuring the spectrum (with the same number of beta particles entering the device)!
4) **Task** (6 points)
   The "B-optimum" graph above shows the values of the magnetic field (B) where the narrowest energy window (ΔE) can be reached at given energy selection. Choose an energy of **100 keV** and first determine the minimum width (ΔE_{min}) of the energy window (use the graph to determine the appropriate magnetic field). After that, find the magnetic field **in both directions** for which ΔE will be **at least four times** as large as ΔE_{min}. By observing the particle trajectories, explain (and write down) why a minimum is formed (i.e. what could be the reasons why ΔE increases on one or the other side of the minimum).
5) **Task** (8 points)
   Measure the energy spectrum of the given beta source in at least 12 measurement points so that the statistical uncertainty in each point is preferably below 5%! Enter the data in the white fields of the EXCEL table (downloadable from here)! Observe and describe the shape of the resulting energy spectrum with your own words! The EXCEL table also automatically prepares the **Fermi-Kurie diagram** of the measured energy spectrum. With the help of this, **determine** the energy released during decomposition! **Compare** it to the maximal energy you determined in Task 2.
6) **Task** (3 points)
   Document your work either in a paper-based or in electronic protocol, **describe** your thought process and the results! **Save** the EXCEL file as *n.xlsx*, where n is the competitor's code. If you use Word for writing, save the minutes as *n.docx*!