Worksheet 2:

What kinds of energy do electrons actually have?

The video "Neutrinos (2016)" mentions that physicist Lise Meitner was able to experimentally determine the energy of beta particles as early as 1911.
We will now try to understand this with a similar experiment. For this purpose, we will use the deflection of the electrons in a magnetic field, which is generated by a U-shaped electro-magnet and can be changed by varying the coil current. The beta emitter and counter tube are always arranged at a fixed angle of 90° to each other (see drawing). The square pole pieces are 4cm x 4cm large.
In a preliminary experiment, it was determined how the coil current **I** and the magnetic field strength **B** are related to each other in this electromagnet. The following formula applies:
$B = 0.012\,\frac{T}{A} \cdot I.$

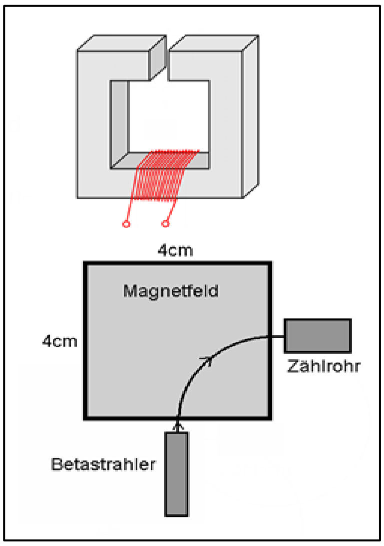


Photo credit: Matthias Borchardt

a) Explain the idea of the experiment and how the experiment could potentially be conducted. How is the magnetic field polarised?

b) The current for the magnet coils is gradually increased and the count rate of the incoming electrons is recorded. This can be seen in the adjacent table.
We want to calculate the kinetic energy of the recorded electrons for two currents. For this purpose, we select the current at which the count rate is maximum, i.e. at I = 0.7A and a value at the end of the measurement series at I = 1.9A.

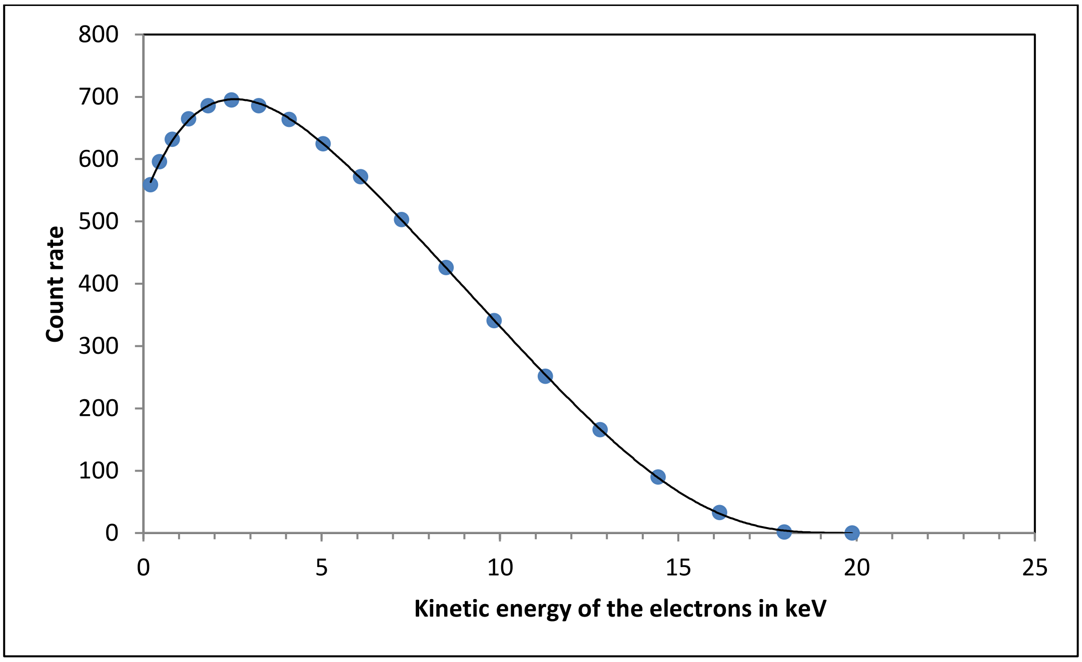
Current I/A	Count rate
0.2	559
0.3	596
0.4	632
0.5	665
0.6	686
0.7	695
0.8	686
0.9	664
1	625
1.1	572
1.2	503
1.3	426
1.4	341
1.5	252
1.6	166
1.7	90
1.8	33
1.9	2
2	0

1. First derive:
   The speed of the electrons is given:
   $$v = \frac{e}{m} \cdot B \cdot r$$
2. Calculate the speeds of the electrons for the two marked currents and indicate what percentage of the speed of light is the electron speed in each case.
3. If you have calculated correctly, the most high-energy electrons have velocities of about 27% of the speed of light. Actually, the following calculations should already be carried

out relatively. The deviations are not as large as you might fear – they are less than 2%. We can therefore continue to use classical physics formula, which considerably simplifies the calculations.

Now use the classical formula $E_{kin} = \frac{1}{2} m \cdot v^2$ to calculate the energies of the electrons for the marked count rates. Give the results in keV.

c) The diagram below shows the complete evaluation of the measurement series. It shows how the energies of the emitted electrons are distributed.
Describe the energy spectrum in words and comment on the ways in which the test result does not match your considerations and results from Worksheet 1.



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