Rutherford Scattering

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Abstract

This paper is written as the *first* of four mandatory repports during the course *Experimental Physics III*.

In the experiment we will be working with ...

At last ....

This resulted in ... in confirmation of the theory

1 Introduction

Almost all of our knowledge in the field of nuclear and atomic physics, has been discovered by scattering experiments. Scattering theory underpins one of the most ubiquitous tools in physics.

This paper has a limited extend, and to keep our discussion simple and relevant, we will only examine elastic collisions in the semi-classical regime, governed by the Sommerfeld criterion for classical scattering.

This is usually fine for low energy physics, in which internal energies remain constant and no further particles are created or annihilated.

Our experiment involves a single Van-de-Graaf accellerator and the energy is in the order of 400 keV.

In low energy physics, scattering phenomena provide the standard tool to explore solid state systems, and historically this was used as a first step towards our current understanding of the atom.

2 Experimental Setup

The following equipment, as described in this section, can be seen on fig. 1, fig. 2 and fig. 3.

We will be accelerating particles by the Van-de-Graaf accelerator up to 400 keV. The variety of incomming particles are limited by the source, which is a flask of gas connected to the accelerator tank. We will not change this flask, for which our experiment is limited to protons, and the hydrogenic ions: H^+ and H^{++}. By changing the magnetic field, one can choose which of these particles will interact with the target.

When calibrating,

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Calibration

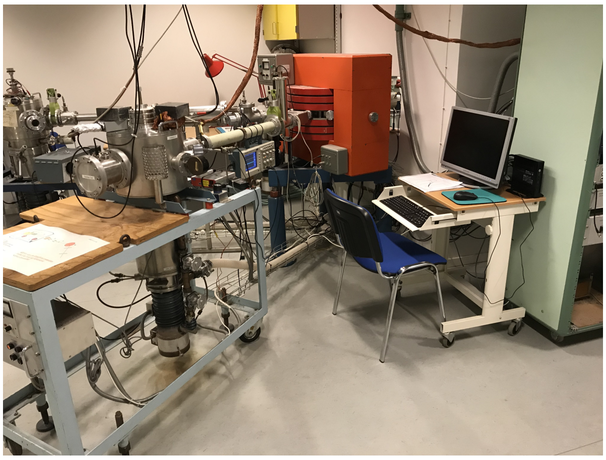

Figure 1: Experimental setup 1: The detector and a computer for the data analysis.

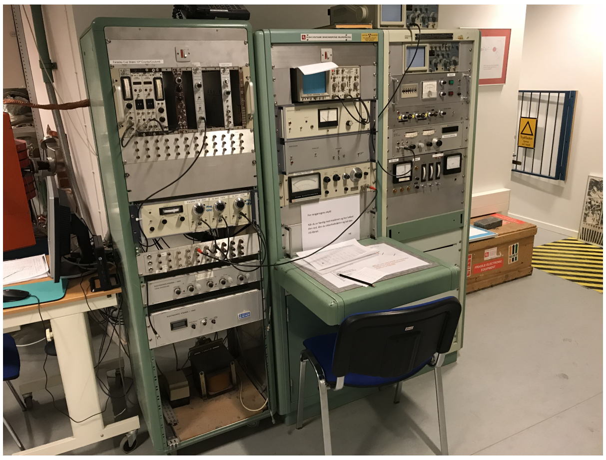

Figure 2: Experimental setup 2: All components with variables.

Figure 3: Experimental setup 3: The single Van-de-Graaf accelerator.

3 Data

4 Discussion

5 Conclusion

References

Griffiths, David J. *Introduction to Electrodynamics*. Cambridge, 2017. ISBN: 978-1-108-42041-9.

Jensen, Jens Ledet. *Statistik viden fra data*. Aarhus Universitetsforlag, 2012. ISBN: 978-87-7124-0245.

6 Appendix

Logbook

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1 Overview

On this page, the reader will find the whole experiment summed up on a single page. It should be used to get an overview before the reader moves on to the rest of the lab script. It does not tell the reader why you need to do these procedures, but this can be found in the following pages. It is suggested that you have this page at hand, while you are doing the experiment.

2 Calibration

The calibration relates the channelnumbers, which is the output of the detector program, to measured photon energy.

1. Measure the activity of the calibration sources with a Geiger-counter.

2. Choose fitting calibration sources, measure these with the NaI detector. Measure the Cs-137 radiation source with the BGO detector. 30-60 minutes should be enough for these measurements.

3. Identify and read the channel number of the calibration sources photo-peaks of the calibration sources, for both the BGO detector and the NaI detector.

4. Find the relation between channel number and photon energy, in each detector.

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3 Coincidence measurement

The measurement of coincidence between the two detectors is where the effects of Compton-scattering can be seen.

1. Set up the program for coincidence measurements. Choose an angle to measure at.
2. Let the measurement run for preferably more than 10 hours.
3. Use the calibration values to merge the datafiles from the two detectors with ROOT-script TTree- Builder.c.
4. Use the given scripts to plot the cloudplot for the measurement.
5. Identify the area of the cloudplot where Compton-scattering has happened in the BGO-detector, and the Photoelectric effect has happened in the NaI-detector. Read the scattered-photon energy.
6. repeat steps 1 through 5 for differing angles.
7. Compare the measured shift in energy with the theoretical value given by the Compton effect. Results

4 Results

1. Plot the coincidence measurements as cloudplots, and identify the overlap between Compton- scattering in the first detector (BGO), and photoelet- ric effect in the second detector (NaI).
2. Interpret the movement of this area at varying angles.

5 Experimental Procedure

Before you begin

You should find the characteristic energy diagrams for those atoms you have chosen to investigate. It is the γ–peaks of theese atoms you later will have to compare with. When we did the experiment, we found the energy diagrams for $Cs - 137$ (1 peak), $Na - 22$ (2 peaks) and $Co - 60$ (2 peaks). All information can be found at `http://www.nndc.bnl.gov/`.

Calibration

The scintillators do not themselves measure the energy of the photons, but the power supply converts the signals to a channel number, which corresponds to a discrete energy. The purpose of the calibration is to convert the given channelnumbers from the AC–converter to a specific energy. To do so, it is necesary to compare the data of measurements, with the known energies at a given photopeak. You can find an illustrated review of the following description in the appendix.

Hardware

1. Check that both detectors are linked to the power supply, and make sure to note which channel each of their cabels are connected to. The power supply should also be connected to the computer.
2. Extend the arm between the BGO and the NaI in an angle relative to the BGO.

Software

1. To set up the software for the calibration, open MC2Analyser.
2. Go to "Acquisition Setup", make sure the Online Spectrum is ticked, click "New Board Connection".
3. "Device Conection" will open in a new window. Click "connect".
4. Now turn "PWR" on.
5. Go to "Acquisition Setup", click "Coincidences", and make sure that all spaces are unticked and the drop downs are all on "NONE". Press "Apply". Go to output, and fill in a directory and the name of the filename to save data.
6. At last, click "RUN". Let it run for as long as possible, a couple of hours or more.

The calibration has to be done for both the BGO and the NaI–detector. For the calibration of the BGO–detector, use the $Cs-137$ source encaptured within the lead enclosement. DO NOT start fiddling with the lead enclosement! For the calibration of the NaI–detector, place a radioactive source on top of it. The γ-radiation source can be varied. Ask your lab-instructor for the other sources. It is recommended to use a Geiger–counter to find the most active radiation sources. From our experience, the $Co-60$ was great as opposed to the $Na-22$, which could barely show any photopeak with the background effects of a $Cs-137$ radiation source. Let the calibration run for at least 30 minutes.

Nonetheless, the longer it runs, the more precise. When the calibration is done, click “Stop” and remember to reset curve before continuing with the rest of the experiment. Now it is time to open the “Histogram” script in MatLab – you will find the instructions for the script written in MatLab. To convert the arbitary unit to a unit of energy, it is necesary to calculate the linear proportionality constant, κ.

$$E_{\text{source}} = \kappa E_{\text{Channel}}$$

The conversion factor should not be material dependent, but this might be a point of interest to investigate further. To find κ, you should first find the γ–peaks for each radiation source and then use then use the matlabcaliscript. When calculated, the κ–factor is constant for all measurements.

Practical/ Technical notes

One should be aware of the following:

I The optical breadboard with all its components is very heavy, so take care when taking it out of the cabinet and back again.

II Remember laser light can be harmful, so be careful also with parasitical beams!

III Remember not to touch any optics on the surfaces on which light in impinging!

IV Do only apply voltages in the range 0-10V to the control input of the piezodriver, and do not drive it at a frequency of more than 200 Hz. Hence, check and adjust the output of the function generator with the Pico Scope before connecting it to the piezo-driver. The voltage delivered to the piezo should be a factor of 10 higher than the control voltage (check backside of the piezo-driver).

V Remember to take clear pictures of you various setups, including the electronic wiring.

VI At the end of each experimental session, remember to safely fix all the optical elements to the breadboard in positions similar to those on Fig. 1., and bring everything back in good order in the cabinets!