

## Photonuclear cross-section / Compton scattering cross-section (Item No.: P2524615)

### Curricular Relevance



#### Difficulty



Difficult

#### Preparation Time



1 Hour

#### Execution Time



2 Hours

#### Recommended Group Size



2 Students

#### Additional Requirements:

- PC

#### Experiment Variations:

#### Keywords:

Gamma-radiation, interaction with material, photoelectric effect, Compton effect, pair formation, detection probability, scintillation detectors

### Overview

### Short description

#### Principle

The radiation of  $^{137}\text{Cs}$  and  $^{22}\text{Na}$  is measured with a scintillation detector and the energy spectrum determined with a pulse height analyzer. The fractions of the spectra caused by Compton scattering and those caused by the photoelectric effect are determined on the basis of their areas. The results are used for determining the ratio of the effective cross-sections and examining its energy dependence.



Fig. 1: Experimental set-up

## Equipment

Position No.	Material	Order No.	Quantity
1	Multichannel analyser	13727-99	1
2	measure Software multi channel analyser	14452-61	1
3	Radioactive source Na-22, 74 kBq	09047-52	1
4	Radioactive source Cs-137, 37 kBq	09096-01	1
5	Gamma detector	09101-00	1
6	PHYWE High Precision Power Supply 1.5 kV DC	09107-99	1
7	High-voltage connecting cable	09101-10	1
8	Support rod, stainless steel, 500 mm	02032-00	1
9	Right angle clamp expert	02054-00	2
10	Tripod base PHYWE	02002-55	1
11	Screened cable, BNC, l = 750 mm	07542-11	1
12	Universal clamp	37715-00	1

## Tasks

1. Measurement of the spectra of  $^{22}\text{Na}$  and  $^{137}\text{Cs}$ , using a scintillation detector.
2. Determination of the ratio of the specific effective crosssections due to the Compton effect and the photoelectric effect in photons having energy values of 511, 662 and 1275 keV.

## Set-up and Procedure

Set up the experiment as shown in Fig. 1. Before turning on the operating unit for the scintillation counter, connect the high voltage cable correctly to operating unit and photomultiplier and read the instructions in the manual of the gamma-detector. Set the voltage of the operating unit to **1.0 kV**. Connect the MCA to the computer's USB port and start the "measure" program. Select the Gauge "Multi Channel Analyser" and you will receive the start window, as shown in Fig. 2.

Start with the  $^{22}\text{Na}$  source directly on top of the detector. Select "Spectra recording" (see Fig.2), set the "Gain" to "Level 1", set the "Offset" to 0 %, choose "Channel number" as x-Data (see Fig. 3) and start data recording. The **1275 keV** peak should be observable in full at the right side of the spectrum. If not, alter the high voltage setting on the detector operating unit. If you are not sure, start with low settings and increase the high voltage, until the **1275 keV** peak wanders to the right side of the spectrum. If the impulse rate exceeds **800 cts/s**, increase the distance between source and detector.

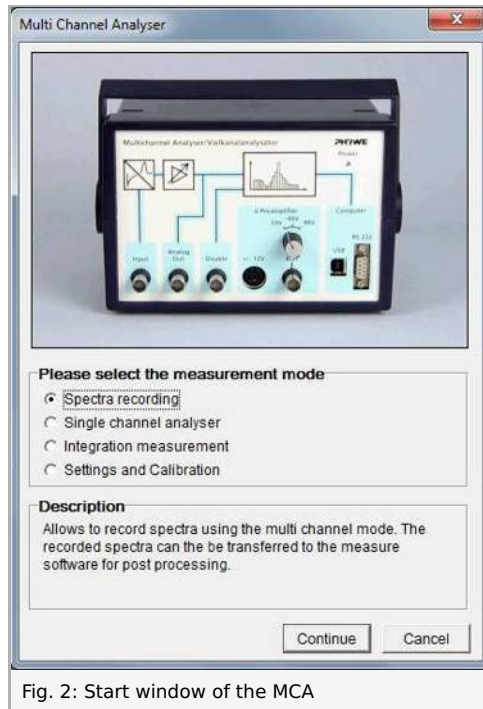


Fig. 2: Start window of the MCA

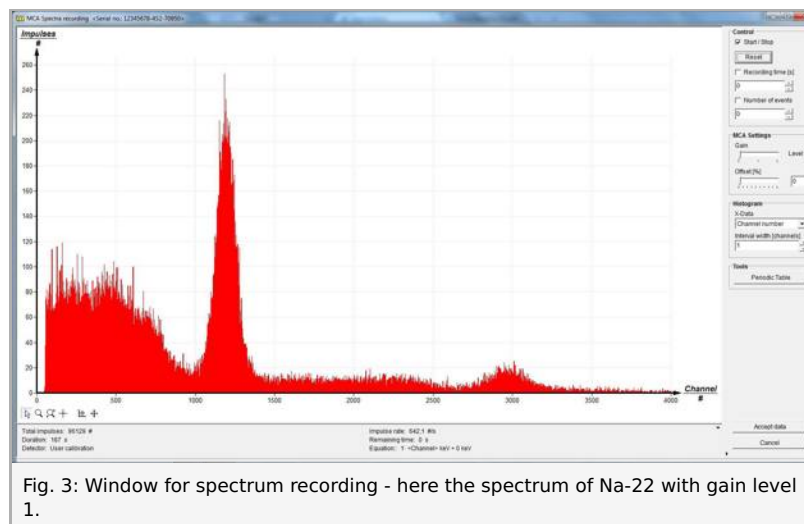


Fig. 3: Window for spectrum recording - here the spectrum of Na-22 with gain level 1.

Clear the counting data with the reset button and record one spectrum over some minutes, stop the counting and use the "Accept data" button.

Remove the  $^{22}\text{Na}$  source and put the  $^{137}\text{Cs}$  pellet directly on top of the detector, or, if the impulse rate exceeds **800 cts/s**, one or two centimeters away into the universal clamp. Increase the high voltage with the multiturn potentiometer until the **662 keV** peak gets to about channel **3500**. Reset (clear the screen) and record a spectrum for some minutes.

# Student's Sheet

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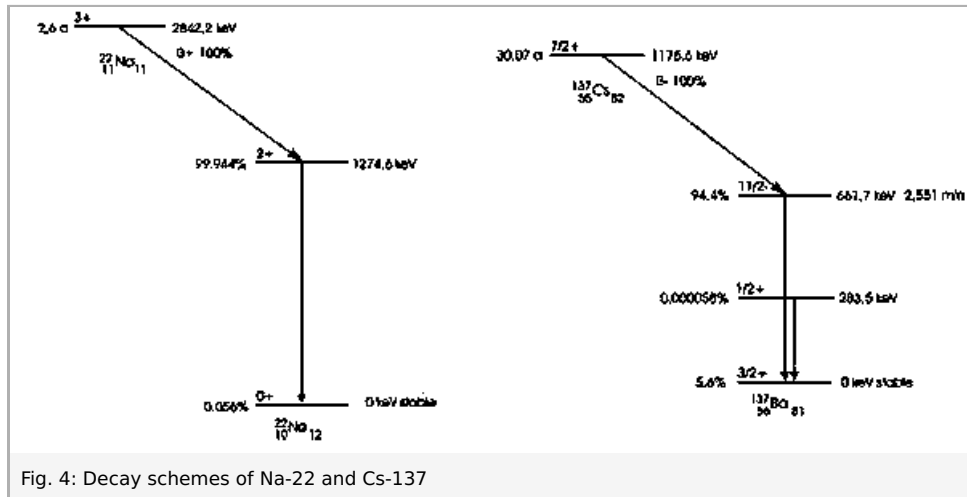
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## Theory and evaluation

Fig. 4 shows the decay schemes of the used nuclids. The proportions of the energy scale are not displayed correctly.

$^{22}_{11}\text{Na}_{11}$  decays to an excited state of  $^{22}_{10}\text{Ne}_{12}$  at 1275 keV under emission of a positron. During the following de-excitation process in  $^{22}_{10}\text{Ne}_{12}$  a 1275 keV  $\gamma$ -photon will be emitted. The positron will annihilate with an electron inside the source leading to a pair of 511 keV photons.

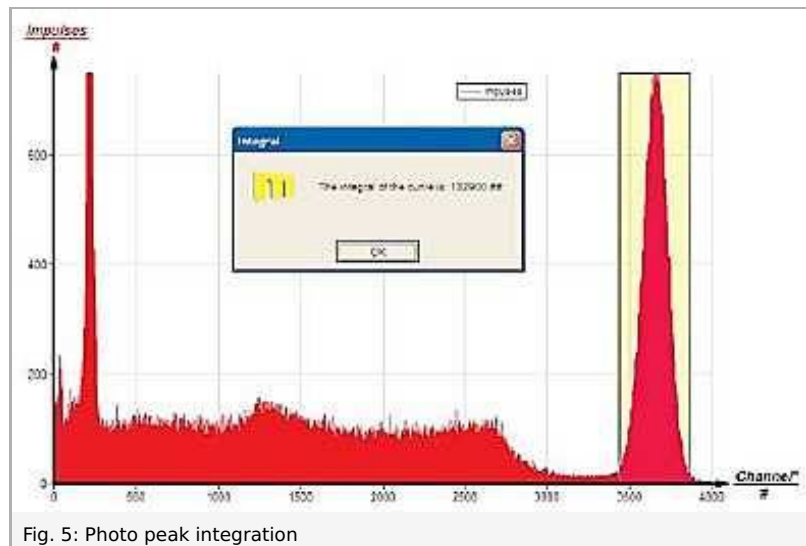
In a  $\beta^-$  process decays to an excited state of  $^{137}_{56}\text{Ba}_{81}$  at 662 keV. The 662 keV  $\gamma$ -quants emitted during the de-excitation process of is here of interest. Not of interest here is the (less probable) concurrence process of the photon emission the internal conversion (compare LEP 5.2.45-15) and the electron from the  $\beta^-$  decay.

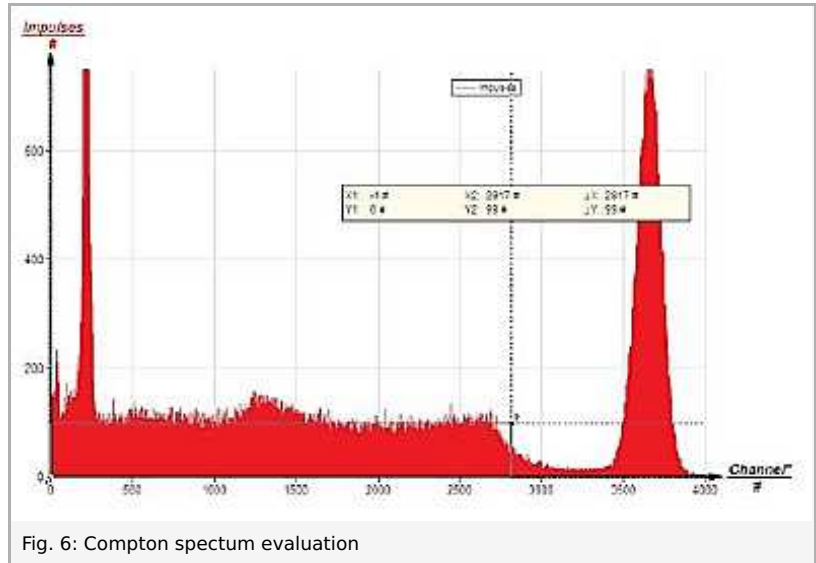


So  $\gamma$ -photons at the energies 511 keV, 662 keV and 1275 keV are given and will be detected with help of the scintillation detector and the MCA in this experiment. In the recorded spectra photo peaks with a corresponding Compton continua for the three different photon energies should be observable.

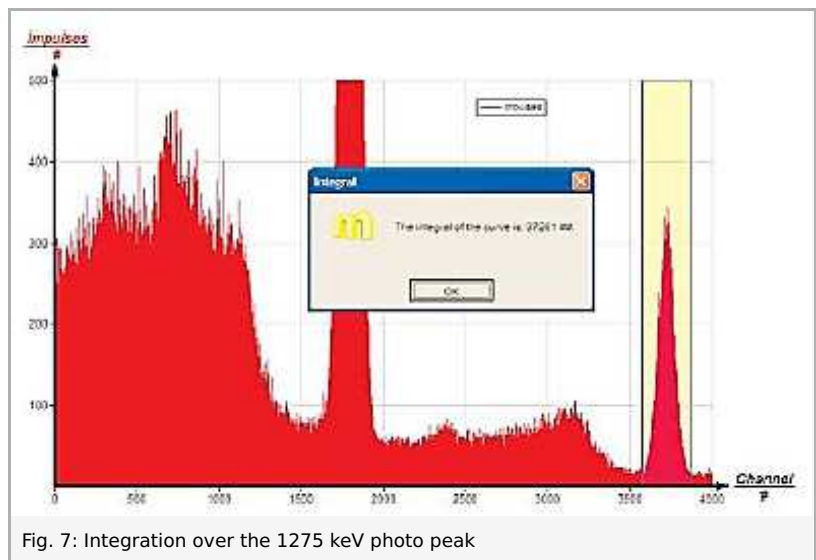
In the general introduction the appearance of photo peaks and Compton continua in the spectra due to the physical processes in the detector is described in detail. These processes are investigated in this experiment. Particularly we want to determine the ratio between the occurrence of a photo and a Compton process and the energy dependence of these ratio. Therefore we must separate and determine the areas for each photo peak and each Compton continuum in the spectra. The determined ratio is proportional to the ratio of the photonuclear and Compton scattering cross-section.

First take the spectrum of  $^{137}\text{Cs}$  and integrate over the photo peak by marking the photo peak with the "Mark" tool that looks like a cross and after that using "Analysis" > "Show integral..." (see Fig. 5) delivering the number of photons that have undergone photo effect. Then take the "Survey" tool to evaluate the number of Compton scattered photons (see Fig. 6).  $\Delta x$  times  $\Delta y$  yields the number of such incidents.





Then take the measured spectrum of  $^{22}\text{Na}$  and integrate over the 1275 keV photo peak and evaluate the number of Compton incidents as seen on Fig. 7 and Fig. 8 in the same manner. After this subtract the background of Compton incidents originating from 1275 keV photons with "Analysis" > "Channel modification..." by subtracting the value of what you have found to be the height of the Compton spectrum from all channels as seen in Fig. 10. Then integrate over the photo peak of the 511 keV photons and evaluate the number of Compton incidents belonging to 511 keV photons as seen on Fig. 10 and Fig. 11.



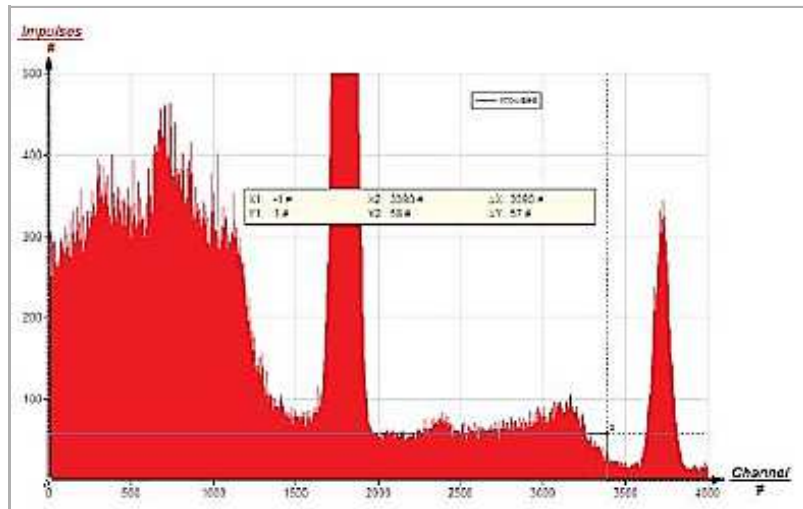


Fig. 8: Compton incidents belonging to 1275 keV photons

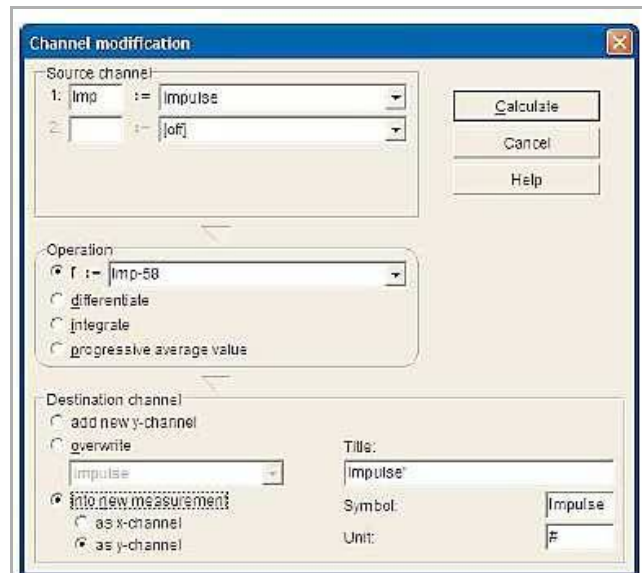


Fig. 9: Channel modification

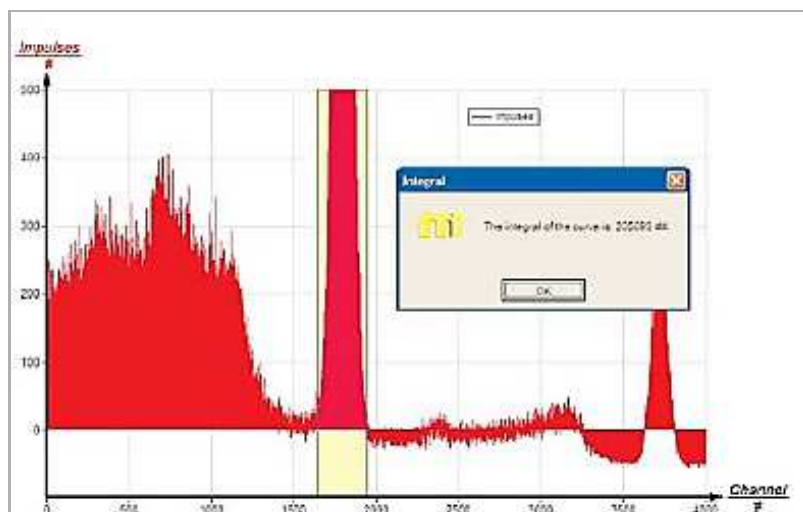


Fig. 10: Photo peak incidents of 662 keV

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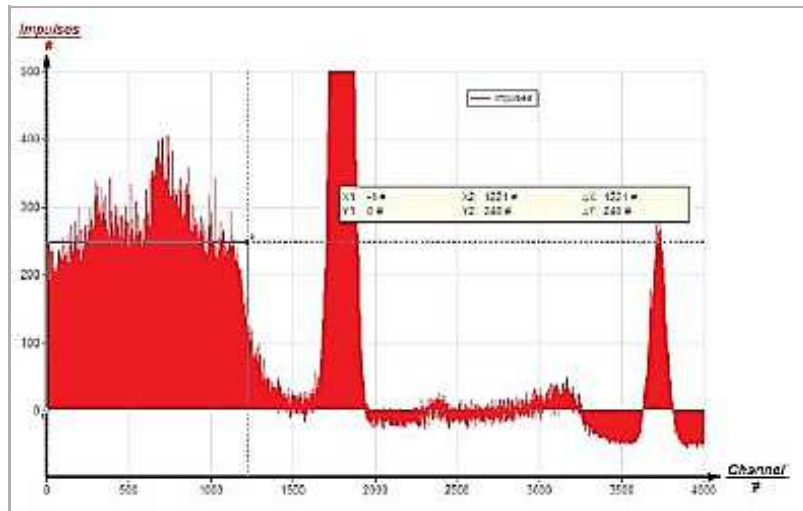


Fig. 11: Compton incidents from 662 keV photons

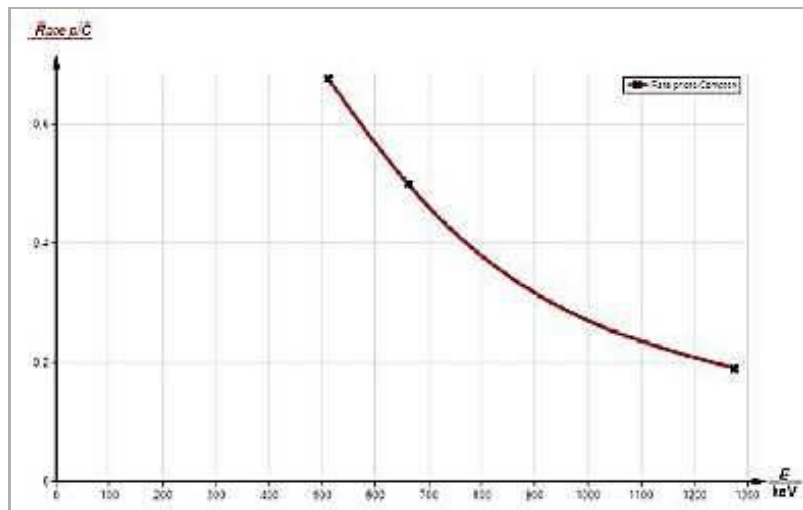


Fig. 12: Photo effect incidents per Compton effect incidents versus photon energy