Analysis of γ ray spectra with MCA

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I. Introduction

In this experiment, we perform γ ray epectroscopy using a scintillation detector and then measure the pulse heights using a multi channel analyser. In the previous experiment we used a single channel analyser by varying the window and baseline to measure pulses within the window. The Multi Channel Analyser(MCA) measures all the pulses in all the windows at the same time.

II. Theory

We lay out, in brief, the theory behind the decay of the radioactive sources that produce the γ rays in our interaction, and the Multi Channel analyser.

II.1. Decay Scheme of $^{137}_{55}$Cs and $^{137}_{55}$Co

We detail the γ ray decay scheme of the $^{137}_{55}$Cs and $^{60}_{27}$Co, both of which we will use in the experiment.

II.1.A. Decay scheme for $^{137}_{55}$Cs

Caesium-137 ($^{137}_{55}$Cs) or radiocaesium, is a radioactive isotope of caesium that is formed as one of the more common fission products by the nuclear fission of uranium-235. The decay scheme for the $^{137}_{55}$Cs is given in the schema below.

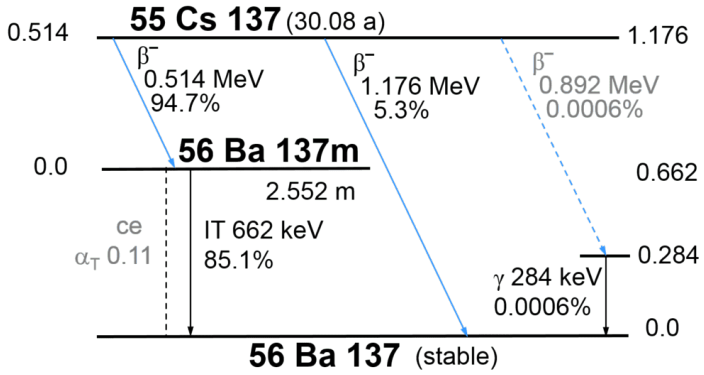

Figure 1 :: Decay scheme of $^{137}_{55}$Cs into $^{137}_{56}$Ba (Source: The Internet)

There are three decay schemes for $^{137}_{55}$Cs decaying into $^{137}_{56}$Ba. The most observed ones are the β decay into $^{137m}_{56}$Ba and then γ decay into $^{137}_{56}$Ba, and the direct β decay into $^{137}_{56}$Ba. We are observing the γ ray spectrum for the γ ray emitted on transition from $^{137m}_{56}$Ba to $^{137}_{56}$Ba. The 'm' in $^{137m}_{56}$Ba stands for metastable or unstable. The third decay scheme occurs only 0.0006% of the time, so, we can safely ignore that.

The decay leaves 94.7% of the parent Caesium nuclei into the metastable $^{137m}_{56}$Ba nucleus via a β^- ray interaction and the release of an anti-neutrino. Then a γ ray decay of energy 662 keV converts the metastable nuclei into the the ground state $^{137}_{56}$Ba. The nuclear reactions are written below.

$$^{137}_{55}\text{Cs} \longrightarrow {}^{137m}_{56}\text{Ba} + e^- + \overline{\nu}_e \longrightarrow {}^{137}_{56}\text{Ba} + e^- + \overline{\nu}_e + \gamma(661.65keV) \qquad [1]$$

II.1.B. Decay scheme for $^{60}_{27}$Co

Cobalt-60 ($^{60}_{27}$Co) is a synthetic radioactive isotope of cobalt with a half-life of 5.2714 years. It is produced artificially in nuclear reactors.

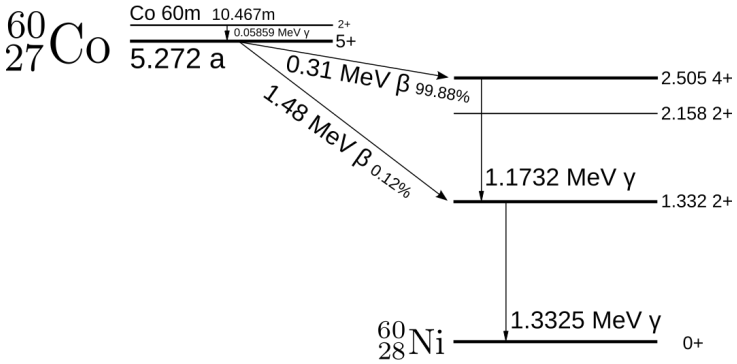

Figure 2 :: Decay scheme of $^{60}_{27}$Co into $^{60}_{28}$Ni (Source: The Internet)

This is produced on activation of $^{59}_{27}$Co via neutron activation. The dominant interaction here is a β^- decay to a intermediate state and then two consecutive γ ray decays to get to $^{60}_{28}$Ni. Then we get a multistep decay from $^{59}_{27}$Co to $^{60}_{28}$Ni. We observe a multistep decay due to some selection rules that do not allow transitions to certain states to take place. We thus get the following decay processes

$$^{59}_{27}\mathrm{Co} + n \longrightarrow {}^{60}_{27}\mathrm{Co} \quad [2]$$

$$^{60}_{27}\mathrm{Co} \longrightarrow {}^{60}_{28}\mathrm{Ni}^* + e^- + \overline{\nu}_e \longrightarrow {}^{60}_{28}\mathrm{Ni}^* + e^- + \overline{\nu}_e + \gamma(1.173MeV) + \gamma(1.333MeV) \quad [3]$$

II.2. Multi Channel Analyser

In this experiment we use a Multi Channel Analyser (MCA) to measure the energy spectrum of the particles emmitted in the nuclear decay process for C-137 and Co-60. The MCA is connected to a Scintillation detector which produces low energy photons which go through a photo multiplier tube (PMT) to amplify the signal. The number of electrons produced is proportional to the energy of the incident gamma ray. An MCA is used to analyse an input signal consisting of voltage pulses. As evident from the title, it can scan for voltage pulses accross different voltage channels. In our experiment, we had 1024 channels, each corresponding to a certain window of energy with a fixed window size. We calibrated the MCA using the known values for the energy peaks for the decay of a Co-60 nucleus.

A multichannel analyser stores information in one of two ways:

II.2.A. Pulse-Height Analysis

In pulse-height analysis mode (PHA), incoming pulses are characterised by their voltage ampitudes, and hence, the output spectrum is a histogram, corresponding to number of pulses counted within a certain window corresponding to each of the channels of the MCA. In this experiment, we used the MCA in PHA mode to get a energy spectrum for the gamma ray emmision from the nuclear decay process.

II.2.B. Multichannel Scaling Mode

In Multichannel scaling (MCS) mode, the MCA doesn't differentiate between pulses of different voltage amplitudes. Hence, we only get a pulse count rate over time as an output. The

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III. Data

IV. Analysis

IV.1. Calibration and determination of $^{137}_{55}\mathrm{Cs}$ peak

To find out the γ photon energy we calibrate the channel to the energy using known energy values for the photopeaks for the $^{60}_{27}\mathrm{Co}$ peaks. We will then use it the calibration to determine the energy of the γ ray photon emitted by $^{137}_{55}\mathrm{Cs}$.

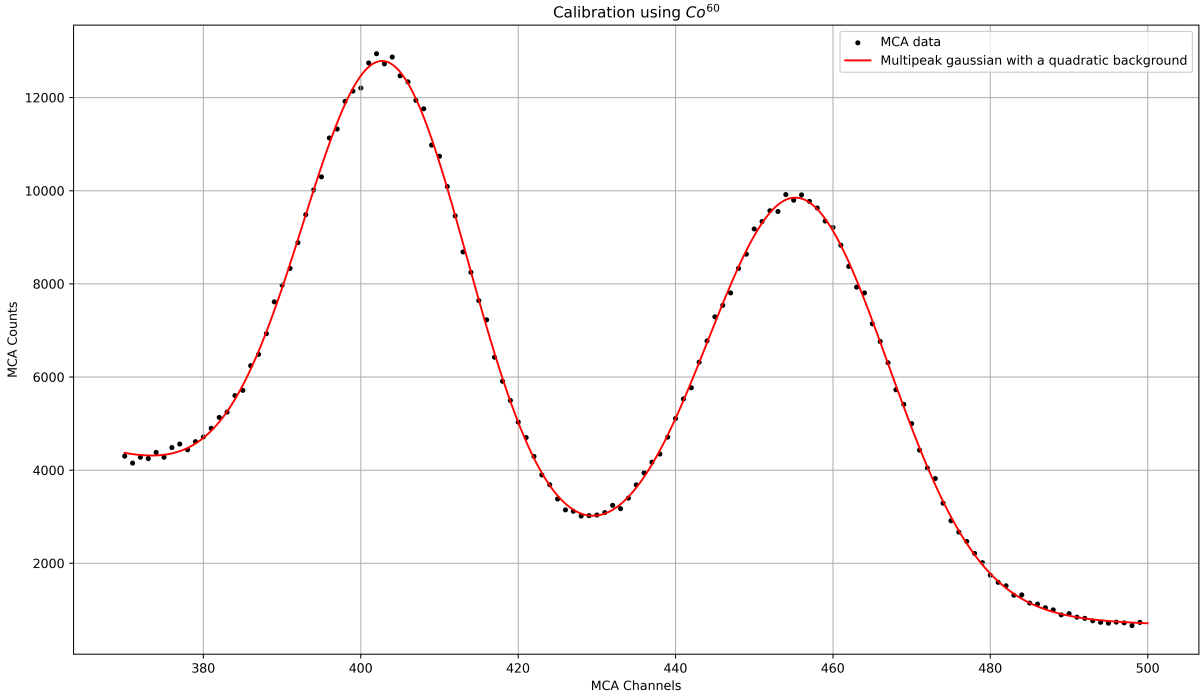

Figure 3 :: Calibration of MCA using $^{60}_{27}$Co

The centroids are given as

Centroid of 1.17 Mev peak $(C_1) = 403.26$
Centroid of 1.32 MeV peak $(C_2) = 455.542$

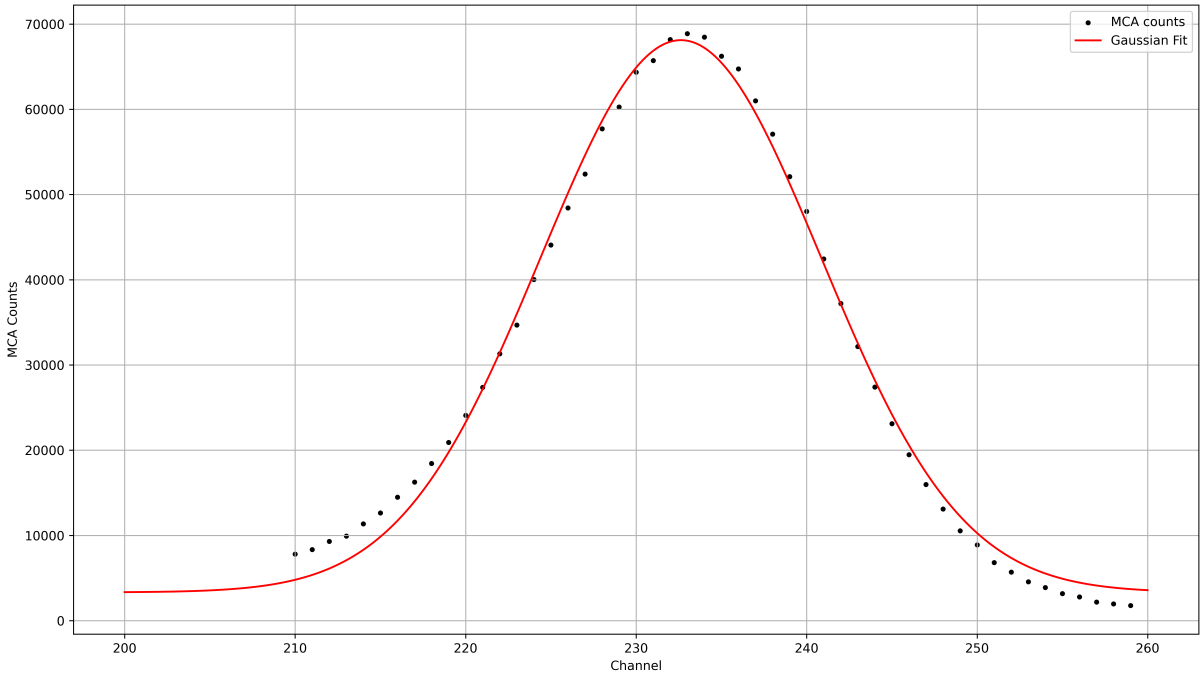

Figure 4 :: Determination of $^{137}_{55}$Cs γ photon

The Centroid of the the gaussian fit on the $^{137}_{55}$Cs spectrum is $(C_E) = 232.62 \pm 0.08$. Fitting the Caesium photo peak with a gaussian and then using the calibration done above we get the energy of $^{137}_{55}$Cs γ photon to be

$$\boxed{E = \frac{1.33 - 1.17}{C_2 - C_1} \times (C_E)\text{MeV} = 0.003 * C_E \text{ MeV} = 0.697 \pm 0.159 \text{ MeV}}$$

The energy of the γ ray photon emitted by $^{137}_{55}$Cs is 0.697 ± 0.159

IV.2. Photo-peak Efficiency

Photo-peak efficiency is defined as the ratio of the area under the peak to that of the area of the whole spectrum.

For the 1.17 MeV peak the photopeak efficiency is 30.595%
For the 1.32 MeV peak the photopeak efficiency is 21.242%

IV.3. Variation of resolution with PMT Voltage

We vary the PMT voltage over

V. Conclusion

In conclusion we have successfully callibrated the MCA and used it to measure the emmision peak for Cs-137 with the aforementioned error. We have also calculated the photopeak efficiencies at 690 Volts for both of the peaks for Co-60. We have also generated a graph of the PMT voltage vs the resolution of the gaussian fits of the Co-60 photopeaks.

VI. Sources of Error

1. We did not measure the background radiation. This may cause an error in our measurements of the counts of the electric pulses.
2. Any electrical disturbances in the setup could contribute to some error in the measurement.
3. The distributions around the peak may not be perfectly gaussian. Also, the way we have fitted the gaussians, they effect each others amplitudes, which may also lead to an error.
4. The standard deviation due to the fit of the centroids in the graph, can be safely ignored since they are smaller than 1.
5. The least count of the voltage dial in the PMT setup was 3 Volts. This can also lead to innacuracies in the measurement of the photopeak resolution for varying PMT voltages.