Jordan University of Science & Technology
Faculty of Engineering
Department of Nuclear Engineering

Radiation Detection and Measurement Lab 2

(NE314)

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Experiment (1)

Basic NIM Measurement Experiment

1.1 Objectives:

1. Learn how to apply the Pulsar output signal into the linear portion of the measurement system (the preamplifier and amplifier) and observe the linear shaping of these modules.

2. To learn how to use MCA, SCA and GEN2000 software.

3. To learn the effect of changing the fine gain in the pulsar out put.

1.2 Equipment Required:

- Pulsar
- Scintillation Preamplifier
- NIM Bin and Power Supply
- Spectroscopy Amplifier
- MCA
- Timing Single-Channel Analyzer
- Oscilloscope
- BNC connectors and cables

1.3 Introduction

The first part of this experiment provides familiarity with the oscilloscope, which is the instrument used for observing the input and output pulses for the various modules in the system to determine whether the wave shapes, amplitudes, and timing are correct with respect to the rest of the equipment. Next is an introduction to a pulse generator, which is an instrument that simulates the pulses originating in a nuclear radiation detector and furnishes the pulses with the known characteristics to the input of the system.

Most nuclear counting equipment uses transistorized modules (NIM) which derive their power from a bin into which the module is plugged. Never insert or remove modules without turning off the bin power, otherwise modules may be damaged. Never apply D.C. voltages to signal inputs otherwise transistors may be damaged.

Different connectors and cables are used for high voltage lines and signal lines. MHV and SHV (shielded) connectors are for high voltage; SHV connect HV supply through TC 164 preamp. BNC connectors are usually used for signal lines. There is a drawer in the laboratory which contains folders with instruction manuals for all the equipment in the lab. If you are

Unfamiliar with the equipment, read the manual before using the equipment.

Power Supplies: NIM bins provide power for most counting circuits. High voltage power supplies provide voltage for GM tubes, proportional counters, and photomultiplier tubes. Connect HV supply only with power turned off and voltage controls at lowest available setting. Turn on power after connections are made. Some HV supplies have a time delay which assures that rectifier tubes have warmed up before voltage can be applied. Gradually increase voltage. Listen for voltage breakdown and, if possible, watch for breakdown on scope.

Amplifiers amplify and shape pulses from counter. Gain typically 5-1000. Gain must be low enough that amplifier does not overload. When overloading occurs amplification deviates from linearity and pulse shape changes: pulses develop flat tops. Gain must be high enough that smallest pulses which are to be counted have an amplitude greater than 0.2 v.

Preamplifiers are low gain amplifiers. Their principal function is to provide impedance matching to drive the signal cables between the counter and the amplifier. They also shape the pulses. The preamplifiers derive their power from the supply of the main amplifier. Preamplifiers often provide a connection
from the HV power supply to the counter and contain a high voltage capacitor which insulates the high voltage from the preamplifier input.

(Integral) Discriminator produces pulses of uniform height from input pulses larger than the (adjustable) discriminator level or bias. Be sure that amplifier output pulse has correct sign for discriminator input (usually positive).

Single Channel Analyzer (SCA) produces pulses of uniform height from input within a range of heights. This range of height is referred to as the window. Both the width of the window and its position are adjustable. SCA's can also serve as integral discriminators if the window can be opened wide enough.

Multichannel Analyzer permits simultaneous analysis of the entire pulse height spectrum and consists effectively of many (512, 1024) SCA's all of which have the same window width.

Scaler (also called counter/timer) counts pulses from discriminator SCA output. Be sure that input pulses have proper sign. Scalars often have built-in adjustable discriminators.

Timer turns scalars off after preset time. (Canberra 2071A scalar has internal timer).

Coincidence Analyzer records two (or three) pulses which occur within an adjustable time interval. Pulses of uniform height are produced when the input pulses meet the coincidence requirement. Analyzer may also be used in anticoincidence mode, i.e., it puts out a pulse when the input pulses do not occur within a preset time interval.

Delay Circuit delays a pulse by a selected length of time (200 ns to 6 :s). This circuit is used in connection with the coincidence analyzer to compensate for time differences in different counters.

Procedure:

1.1 Part 1: Using a Single-Channel Analyzer

1. Pulser output should be on positive output. (note , when you change the pulser height the peak value will change you can improve this using the oscilloscope) plot your outputs .

2. For SCA you have two types Canberra and Ortec module they have same output results put different procedure .(for Canbbera SCA lower level and **ΔE☐ Lower** level but on ortec you have lower level and upper level not that **ΔE☐ Lower** is equal to subtract upper level and lower level . also SCA switch should be on normal position

1. Use the Lower-Level control of the amplifier to adjust the discriminator levels for various settings of the 480 Pulse- Height control. With this connection, the 551 operates the same as it did in the Integral mode. Then fill Table (1.4).

2. Make a plot of the lower level settings as a function of pulse height. This will prove that the lower-level portion of the SCA operates the same as the integral discriminator.

(Note upper level should be to the maximum 10)

Table (1.1): Relation between pulse Height and SCA Lower Level

480Pulse-HeightDial Settings	551 Lower Level	SCA output
10	1,2,3…….10	
8	1,2,3…….10	
6	1,2,3…….10	
4	1,2,3…….10	
2	1,2,3…….10	

.

3. Set the SCA in the Window (differential) mode. Set the Lower-Level control at 1 volt and change the Window (Upper- Level) control as on table

4. At first, the pulsar height should be at 10 volt.

Table (1.2): Relations between Levels and ΔE

Lower Level	Window or Upper Level	ΔE Upper	ΔE☐ Lower
1	1		
1	3		
1	6		
1	8		

5. Decrease the Pulse-Height controls until the counter starts to count. Record this setting in Table (1.4) as ΔE Upper.

6. Continue to decrease the 480 Pulse-Height control until the counter stops counting. Record this value as ΔE Lower in Table 1.2

7. Make a plot of the Window settings vs. ΔE Upper – ΔE Lower on linear graph paper.

8. Repeat these measurements with the Lower-Level control set at 2 .

(Note, for the ortec module the switch should be on normal position , now change the switch to Window Position and integral position repeat the above procedure and compare   the outputs results .)

EXPERIMENT 2

GAMMA-RAY SPECTROSCOPY USING NAI(Tl)

1.1 Objectives:

The Objectives of this experiment is to acquaint the student with some of the basic techniques used for measuring gamma rays. It is based on the use of a sodium iodide (NaI) detector that is thallium-activated (Tl). GAMMA EMISSION
Most isotopes that are used for gamma measurements also have betas in their decay schemes. The typical decay scheme for the isotope will include a beta decay to a particular level followed by gamma emission to the ground state of the final isotope. The beta particles will usually be absorbed in the surrounding material and not enter the scintillator at all. This absorption is normally assured with aluminum absorbers. For this experiment the betas offer no real problem, and so absorbers are not specified.
There will be some beta absorption by the light shield over the phototube. The gammas, however, are quite penetrating and hence will pass easily through the aluminum light shield.

Generally there are two unknowns that we would like to investigate about a gamma source. One is the energy of the gammas from the source. The other is the number of gammas that leave the source per unit of time. In this experiment the student will become familiar with some of the basic NaI(Tl) measurements associated with gamma emitting unknowns.

1.2 Equipment Required:

- Canberra NaI(Tl) Crystal, Phototube Assembly Model 802 – 2 x 2 and
- Canberra Photomultiplier Tube Base(Preamplifier Model 2007P)
- High Voltage Power Supply
- Canberra 2022 Amplifier
- gamma sources,
- Connecting cables
- Multichannel Analyzer (MCA)

Part (A) Inverse Square Law

introduction

There are many similarities between ordinary light rays and gamma rays. They are both considered to be electromagnetic radiation; hence they obey the classical equation

$E = h.v$

where

E = energy of the photon in ergs,

v = the frequency of the radiation in cycles/second,
h = Planck's constant (6.624 x 10–27 ergs • s).

Therefore, in explaining the inverse square law it is convenient to make the analogy between a light source and a gamma-ray source.
Let us assume that we have a light source that emits light photons at a rate, N0 photons/second. It is reasonable to assume that these photons are given off in an isotopic manner, that is, equally in all directions. If we place the light source in the center of a clear plastic spherical shell, it is quite easy to measure the number of light photons per second for each cm2 of the spherical shell. This
intensity is given by

$$I_0 = \frac{N_0}{4\pi R_0^2}$$

$$A_0 = 4\pi R_0^2$$

Where N0 = the total number of photons/second from the source, and A0 = the total area of the sphere in cm2.

Since $A_0 = 4\pi R_0^2$

where R0 is the radius of the sphere

then $I_0 = \frac{N_0}{4\pi R_0^2}$

Since N0 and 4π ☐ are constants, I0 is seen to vary as $1/R_0^2$

5.2.2 Procedure

1. Set the Scintillator at the proper operating voltage (.75)volt , and place the Cs source 1 cm away from the face of the window.

2. Count for a period of time long enough to to get reasonable statistics (5)

3. Move the source to 2 cm and repeat the measurement for the same amount of time. Continue for the distances listed in Table 2. (Note that for the longer distances the time will have to be increased to obtain the same statistics

On linear graph paper, plot the corrected activity (x axis) as a function of distance. Since the intensity is proportional to the activity, this plot should have the 1/R2 0 characteristics exhibited by

From the corrected activities in Table,

$$A = \frac{K}{R^2}$$

Where

R = the distance for the measurement (cm),
A = the correct activity, and
K = a constant which is to be determined from the individual entries in Table

5. Find K for each entry in Table 2. Calculate an average K (K) from the eight values. What is the percent deviation of each individual K value from K?

Table		
Distance (Cm)	Counts	
1		
2		
3		
4		
5		
6		
7		
8		
9		

Procedure

Set up the detector assembly, high voltage,   and computer as shown below in Fig. l. There are three parameters that ultimately determine the overall gain of the
system: the high voltage that is furnished to the phototube and the gain of the preamplifier and the amplifier .

The Lab Instructor will assist you in connecting the signal cable, pre-amp cable, and high voltage cable. The signal cable is connected directly from the pre-amplifier to the Amp in connector of the UCS. The high voltage cable is connected to the high voltage power supply. The pre-amp cable is connected to the back of an amplifier module in the nuclear bin. The gain of the photomultiplier tube is quite dependent upon its high voltage. A rule of thumb for most phototubes is that a 10% change of the high voltage will change the gain by a factor of 2. The high-voltage is set at about the middle of the acceptable operating range (normally about +1000 V). If the voltage is not adequate or does not cover the range in the UCS , see Lab Instructor. Do not change it on your own.

The UCS system consists of a computer, display, keyboard, and software to run the data acquisition program. Ask the Lab Instructor for help before using the system. To start the data acquisition system, follow the procedure below

Start the computer by pressing the black button the rear of the computer box. (Usually this computer will already be on.) Wait until the Windows operating system appears on the display. Click on the UCS20 icon to start the UCS20 program.
An abbreviated manual of how to use UCS20 is on the lab bench. Do not remove it from the Lab. Ask the Lab Instructor to help interpret the panels on the display for you.
 A detailed manual for UCS20 is also available on the computer as a PDF file.
You may start acquiring data by clicking on GO. There is sufficient radiation in the room that the detectors will count even without the radioactive source in place. Click on stop to stop accumulating and display the spectrum.

PROCEDURE (You will need to ask the Lab instructor for assistance in getting started)
1. Request the 137Cs source from the Lab Instructor and place it about 2 cm in front of the NaI(Tl) crystal using the available holder. A the predominant gamma ray photopeak energy in the data is 0.662 MeV.

2. Set the voltage gain (Click on Settings and then on Amp/HV/ADC)) of the system such that the centroid of the 0.662-MeV photopeak for 137Cs is approximately in channel 500. Since the system is linear, this will correspond to about 0.0013 MeV per channel. This is different than in the illustrations shown in Figs. 3.1a and 3.2b where the gain of the system has been set so that 0.662 MeV falls at channels around 331.

3. Accumulate the 137Cs spectrum for a specified period time that is long enough to determine the centroid of the position of the most prominent peak. The spectrum will look similar to the one shown above. You may set the time on the computer so that it

accumulates data for a specified time. (Click on the clock and click on live time.)
 I would suggest about 300 sec.

4. Save the spectrum .

5. Determine the centroid (channel numer) of the 0.662 photopeak and write it down in Table 1 . Do the same for the 0.032 MeV x-ray photopeak. Now calibrate the x-axis in KeV.
Click on Settings ,Expand Energy Calibrate and click on Uncalibrate
Click on Energy Calibrate again
Click on 2 point
Enter the energy in KeV and the Channel number of the two peaks. A linear fit will be made to calibrate the x-axis in KeV. Click on the peaks to be sure they read the correct energy in KeV. Your numbers should agree with the spectrum below in Fig 2 if you calibrated it correctly.

Figure 2   Illustrates a typical 137Cs spectrum in 1024 channels that has been plotted On linear scale.
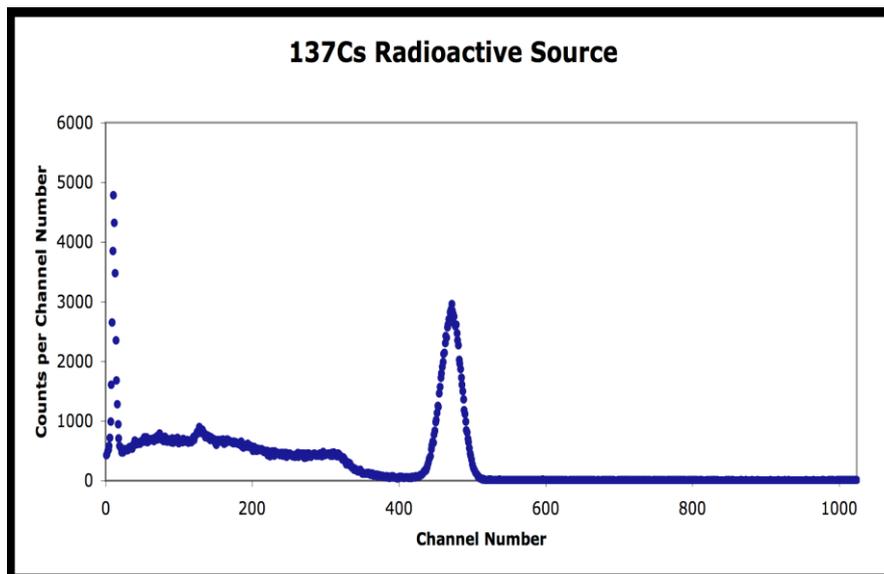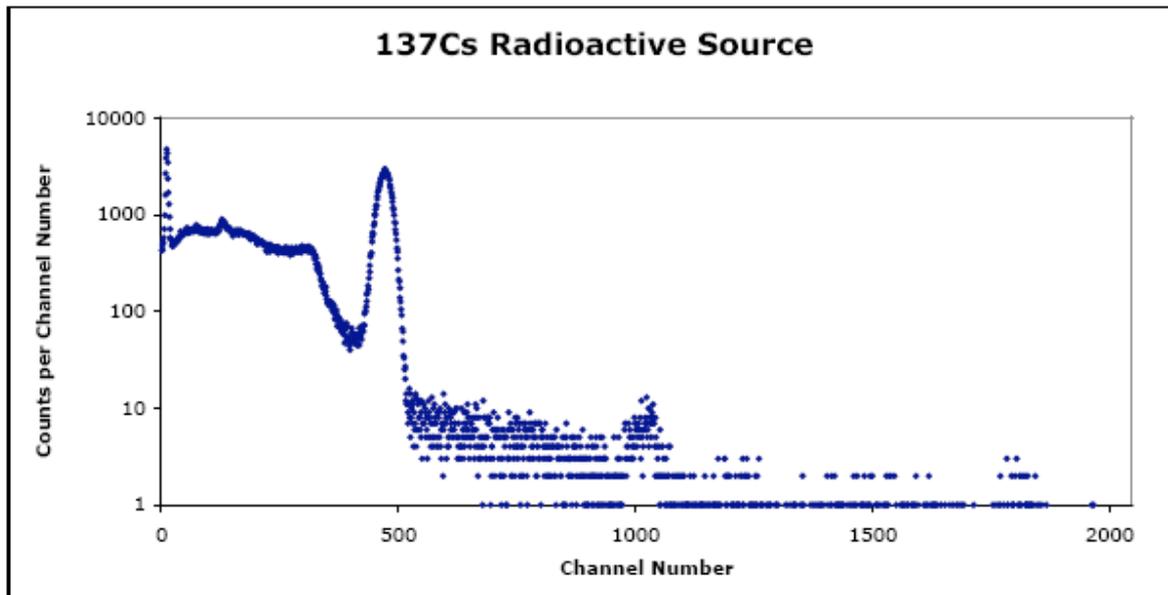

Fig 2 shown below shows the full 2048 channels using a logarithmic scale for the vertical axis This scale emphasizes the channels with the fewest counts and shows background counts in v channel 1000 and also up around 1800. These counts are not coming from the 137Cs source but are probable coming from background in the room.

137Cs Radioactive Source

6. The next is to determine the background in the room that you also accumulated with the Cs spectrum. Click on the Eraser and delete the Cs data in the computer that is being displayed. Accumulate a spectrum with the 137Cs source completely removed from the detectors. It is necessary to do this to determine the cosmic ray and room background. Record it for the same amount of time as 137Cs. Record the live time again.

Save this spectrum on the computer and follow the same procedure as above in order to plot it as a scatter plot in Excel . You may also use the Strip Background feature of the computer instead of Excel. Ask your instructor for assistance.

7. Multiply the number of counts in each channel in the background spectrum by the ratio of the live times. If the live times are the same, then this number is 1. Now subtract the background spectrum from the 137Cs spectrum. The subtracted 137Cs spectrum should look even closer to Fig 3.2 in the ORTEC Application Note 34.

8. Repeat steps 3, 4, and 5 with a 60Co, and 22Na source. Compare the 60Co to that in Fig.3. They should be similar. What are the energies of any prominent peaks in the background. Estimate the centroids and determine the energies.

Exercise a. Plot the 137Cs, 60Co, and 22Na spectra and fill in items 1, 2, 3, 4, and 5 in Table 3. How do your measured energies of the peaks compare with known values.

Explain why there are differences? What is the error in determining the centroid of a photopeak? How does this error propagate to error in energy in your calibration?

Exercise b. From items 1, 2, 3, 4, and 5 in Table 3 make a plot of energy of the photopeaks vs. channel number. Figure 3.4 shows this calibration for the data taken from Figs. 3.2 and 3.3. Using the methods in Ref 9 to perform a linear least squares fit of the data to a straight line so that the y variable predicts the energy as a function of the x variable which is the channel number. Determine the slope and y-intercept of the straight line that best fits the data in Table 3.1A and the error on the slope and yintercept.

Determine the overall Chi squared and comment on your goodness of fit. You may use the computer program WinCurveFit on the desktop to do the least squares fit..
Ask you instructor for assistance.

Items	Event Photopeak Energy (MeV)	Channel Number of Centroid of Photopeak	Error in Channel Number
1	Cs 137 0.032		
2	Cs 137 0.662		
3	Co 60 1.17		
4	Co 60 1.33		
5	Co 60 2.50		
6	Na 22 0.511		
7	Na 22 1.275		
8	Other sources		
9			
10			

Exercise c. What feature in the 137Cs spectrum is equal to the energy of the backscattered peak plus the Compton edge? This is true for any gamma ray spectrum.

EXPERIMENT 3

SPECTRUM ANALYSIS OF 60CO AND 137CS

The purpose of this experiment is to explain some of the features other than the photo peaks, that are usually present in a pulse-height spectrum. These are the Compton edge, backscatter peak, and x-rays.

The Compton interaction is a pure billiard-ball type collision between a gamma photon and what might be termed a free electron in the NaI(Tl) crystal. By this process the incident gamma gives up only part of its energy to the electron.
 The amount given to the recoil electron (and hence the intensity of the light flash) depends on whether the collision is head on or glancing. For a head-on collision the gamma imparts the maximum allowable energy to the free electron. The energy of the scattered gamma can be determined by solving the energy and momentum equations for this billiard-ball collision.
The solution for these equations in terms of the scattered gamma ray energy can be written as

$$E_{\gamma'} = \frac{1}{\dfrac{1}{E_\gamma} + \dfrac{1-\cos\theta}{m_e c^2}} \tag{1}$$

where

$E_{\gamma'}$ = the energy of the scattered gamma-ray in MeV,

θ = the scattering angle of the gamma ray,

E_γ = energy of the incident gamma-ray in MeV.

$m_e c^2$ = 0.511 MeV the rest mass energy of the electron.

This formula can be written approximately as

$$E_{\gamma'} = \frac{E_\gamma}{1 + 1.96 E_\gamma (1 - \cos\theta)} \tag{2}$$

Compton Edge
If = 180 degrees due to a head-on collision in which the gamma ray is scattered directly back, Eq. (2) becomes

$$E_{\gamma'} = \frac{E_\gamma}{1+3.96E_\gamma}$$

(3)

As an example, we will calculate $E_{\gamma'}$ for an incident gamma energy of 1 MeV:

$$E_{\gamma'} = \frac{1}{1+3.96} = 0.202\,MeV$$

By conservation of energy , the energy of the recoil electron (E_e) is given by

$$E_e = E_\gamma - E_{\gamma'}$$

(4)

In the above example the energy given to the recoil electron is 0.80 MeV and consequently the Compton edge is located at 0.80 MeV.
 Hence the position of the Compton edge, which is the maximum energy that can be imparted to an electron by the Compton interaction, is given by Eq. (4).

Backscatter Peak Consider a 1.0 MeV gamma ray emitted from a radioactive source in opposite direction than that of the detector. It now undergoes a 180 degree scattering from another material such as a lead shield and goes back into the detector with a gamma ray energy of 0.202 MeV. It gets totally absorb producing a photopeak at 0.20 MeV. Called the backscatter peak.

Exercise

a. Calculate the energy of the Compton edge for the 0.662-MeV gammas from 137Cs. Enter this value in Table 3.1. From your plot and calibration curve, does this calculation agree with your measured value? Explain.

Exercise

b. Figure 3.5 was taken from Reference 8 and is a good illustration of the various events that can take place using a typical radioactive source with a NaI(Tl) detector and a lead shield arrangement. Backscattered gammas from these interactions make photoelectric interactions in the NaI(Tl) when they enter the crystal.

Calculate the energy of the Compton edge and backscattered peaks using Eqs. (2), (3), and (4) and fill in Table 3.1B. Using your energy calibration based on the photopeak data, how do your measured energies compare with the calculated energies from Eq. (2)? If the backscatter peak is not very pronounced in your spectrum, it can be improved by accumulating a spectrum with a sheet of lead placed closed to, but on the far side of the source. You will see another small peak above the Barium x-ray. Where does it come from? Explain

Items	Event	Known Energy (MeV)	Measured Channel Number	Predicted Energy (MeV)
1	Compton Edge ^{137}Cs			
2	Backscatter ^{137}Cs			
3	Backscatter ^{60}Co			
4	Barium x ray			
5.	Lead x ray			

EXPERIMENT 4

ENERGY RESOLUTION

Objectives:

The resolution of a spectrometer, R, is a measure of its ability to resolve two peaks that are fairly close together in energy. Figure 3.2 shows the gamma spectrum that was plotted for the $_{137}$Cs source. The resolution of the photopeak is found by using the following equation:

$$R = \frac{\delta E}{E} \text{x } 100$$

where

R = the resolution in percent,

δE = the full width of the peak at half of the maximum count level (FWHM), measured in number of channels,

E = the channel number at the centroid of the photopeak.

Exercise

a. Calculate the resolution of your system from the Cs$_{137}$ spectrum. Record this value. What is the error on your measurement?

EXPERIMENT 5

ACTIVITY OF A GAMMA EMITTER (ABSOLUTE METHOD)

Objectives:

The activity of the standard used in Experiment 3.5 can be determined by the absolute method. The purpose of this experiment is to measure the absolute activity of $_{137}$Cs and determine the error on your measurement.

PROCEDURE

1. Place the U1 source ($_{137}$Cs) about 10.0 cm away from the face of the detector.

2. Accumulate a spectrum and note the live time that is used.

3. Read out the multichannel analyzer and determine the number of events under the photopeak, which we designate as ©□ □. Then erase the spectrum, remove the source, and accumulate background for the same live time and determine the number of events in the same range of channel number, which we designate as ©b.

4. Use the following formula to calculate the activity of U1 in disintegrations per sec. Convert it to microcuries and compare with the value given on the source itself.
Activity of U1

$$\text{Activity of U1} = \left(\frac{\Sigma_{U1} - \Sigma_b}{t} \right) \frac{1}{G\varepsilon_p f}$$

(7)

where

t   = live time in seconds

ε_p = intrinsic peak efficiency for the gamma energy and detector size used

f = the decay fraction of the unknown activity, which is the fraction of the total disintegrations in which the measured gamma is emitted .

$$G = \frac{\text{Area of detector face in cm}^2}{4\pi s^2}$$

s = source-to-detector distance in cm.

Isotope	Gamma Energy (MeV)	f
^{137}Cs	0.662	0.92
^{51}Cr	0.323	0.09
^{60}Co	1.17	0.99
^{60}Co	1.33	0.99
^{22}Na	1.276	0.99
^{22}Na	0.511	0.99
^{54}Mn	0.842	1,00
^{65}Zn	1.14	0.44

Exercise a. Estimate the error on your measurement. Use simple error propagation theory. Explain why your value is much lower and probably outside the bounds of your error?

Exercise b. Name two possible sources of error and discuss how much in percent do you think they affected your experimental value.

EXPERIMENT 6

MASS ABSORPTION COEFFICIENT

1.1 Objectives:

The purpose of the experiment is to measure experimentally the mass absorption coefficient in lead for 662-keV gamma rays and determine the error on your measurement. The source of the gamma rays is 137Cs. References 2, 3, and 4 point out that gammas interact in matter primarily by photoelectric, Compton, or pair production interactions. The total-mass absorption coefficient can be measured easily with a gamma-ray spectrometer. In this experiment we will measure the number of gammas that are removed from the photopeak by photoelectric or Compton interactions that occur in a lead absorber placed between the source and the phototube.

From Lambert's law the decrease of intensity of radiation as it passes through an absorber is given by :

$$I = I_0 e^{-\mu x} \tag{8}$$

where

I = intensity after the absorber,

I_0 = intensity before the absorber,

μ = total-mass absorption coefficient in cm^2/g,

x = density thickness in g/cm^2.

The density thickness is the product of the density in g/cm3 times the thickness in cm. The half-value layer (HVL) is defined as the density thickness of the absorbing material that will reduce the original intensity by one-half. From Eq. (8):

$$\ln I / I_0 = -\mu x \text{ or}$$
$$\ln I = \ln I_0 - \mu x \tag{9}$$

If $I/I_0 = 0.5$ and $x = $ HVL, $\ln 0.5 = -\mu$ (HVL) and hence HVL $= 0.693/\mu$.   (10)

In this experiment we will measure ⬜⬜⬜in lead for the 0.662 MeV gammas from 137Cs and determine the error on ⬜. The accepted value is 0.105 cm2/g. Values for other materials can be found in ref. 6.

PROCEDURE

1. Place the Cs137 source about 1.5 in. from the NaI(Tl) detector. Place the lead brick with a hole in it in front of the detector so that only parallel paths of gamma rays enter the detector. This will lower the count rate but guarantees you only detect gamma rays that traverse the lead sheets normal to the surface. Accumulate the spectrum long enough for the sum under the 0.662-MeV peak ($\square$Cs $-\square\square$b) to be of the order of 4000 to 5000 counts. Record the live time, Read out the multichannel analyzer, and determine ($\square$Cs $-\square\square$b).

2. Erase the spectrum in the multichannel analyzer and insert the first piece of lead (the thickness should be 1/16 in. or less) between the source and the detector. Accumulate the spectrum for the same period of live time as in step 1 above. Read out the multichannel analyzer and determine ($\square$Cs $-\square\square$b).

3. Erase the multichannel analyzer and insert another piece of lead, making the total thickness about 1/8 in. Determine ($\square$Cs $-\square\square$b). Repeat with additional thicknesses of lead until the count-sum is less than 1000. Fill in the data in Table 3.3.

Absorber	Absorber Thickness (g/cm^2)	$(\Sigma_{Cs}-\Sigma_b)$
1		
2		
3		
4		
5		
6		
7		

Exercise a. Using Excel to plot I vs. absorber thickness in g/cm2, where I = ($\square$Cs $-\square\square$b)/ Live time. Determine the HVL from this curve and calculate $\square\square$from Eq (10) and estimate the error on μ. How does your value compare with the accepted value of 0.105 cm2/g? Now determine $\square\square$and its error from a linear least squares fit of eq. 9 to the data. Let y = ln I and b = ln I0 and $\square\square$= slope. Compare the two values. Which do you think is a better determination? Explain.

Exercise b. Name two possible sources of error and discuss how much you think they affected your experimental value.

EXPERIMENT 9

TIME COINCIDENCE TECHNIQUES

This is another exercise designed to familiarize you with the electronics with emphasis on timing.

9.1 SIMPLE FAST-COINCIDENCE EXPERIMENT

Equipment Needed
Pulser Ortec 480
Two Amplifier Canberra 2022
Two Timing Single-Channel Analyzer (SCA) Canberra 2037A
Canberra 2040 Universal Coincidence
Counter (or Scaler) Canberra 2071A
NIM Bin and Power Supply Ortec 401
Oscilloscope

PURPOSE

This experiment will utilize some of the basic instrument configurations for time coincidence studies.

PROCEDURE

1. Connect up the circuit shown in Fig. 9.6, and make the following module settings: Amplifiers: Positive Input, Bipolar Output. Timing Single-Channel Analyzers: Lower Level = 50/1000, Delay 0.5 $\square$s, Window full CW, CO.
Coincidence: Inputs A and B switch up and Coinc, switch C and D down. Resolving Time maximum (1 $\square$s).
Pulser: Positive output, power on, attenuated output approximately 0.5 V (measured with an oscilloscope).

2. Adjust the gain of each Amplifier so that it's output pulse is about 5 V.

3. Set the Counter/ Timer for a long time (100 s). Vary the delay on either SCA until the maximum counting rate is observed on the Counter. The two branches are now approximately coincident.

4. Clear the scalar. Set the timer for 10 s and count. If the maximum counting rate was set properly in step 2, the scalar should read about 600 (60 Hz for 10 s). Change the delay in either SCA by 50 ns (50 dial divisions) and repeat the 1 0-s count.

Exercise a. Continue changing the delay for enough readings to plot a time coincidence curve similar to that shown in Fig. 9.7. You may have to narrow the delay 35 near the beginning of the window and near the end of the window in order to see exactly where it begins and ends.

Exercise b. Narrow the resolving time of the Coincidence module to 0.5 s and plot the coincidence curve, which is similar to Fig. 9.7 (note: take readings every 20 ns).
You may have to narrow the delay near the beginning of the window and near the end of the window again in order to see exactly where it begins and ends.

Exercise c. Narrow the resolving time of the Coincidence module to 100 ns and measure the coincidence curve (take readings every 10 ns). You may have to narrow the delay near the beginning of the window and near the end of the window again in order to see exactly where it begins and ends. The student should now begin to understand the concept of simple fast time coincidence spectroscopy.
Fig. 9.6. Electronics Block Diagram for Experiment 9.1.
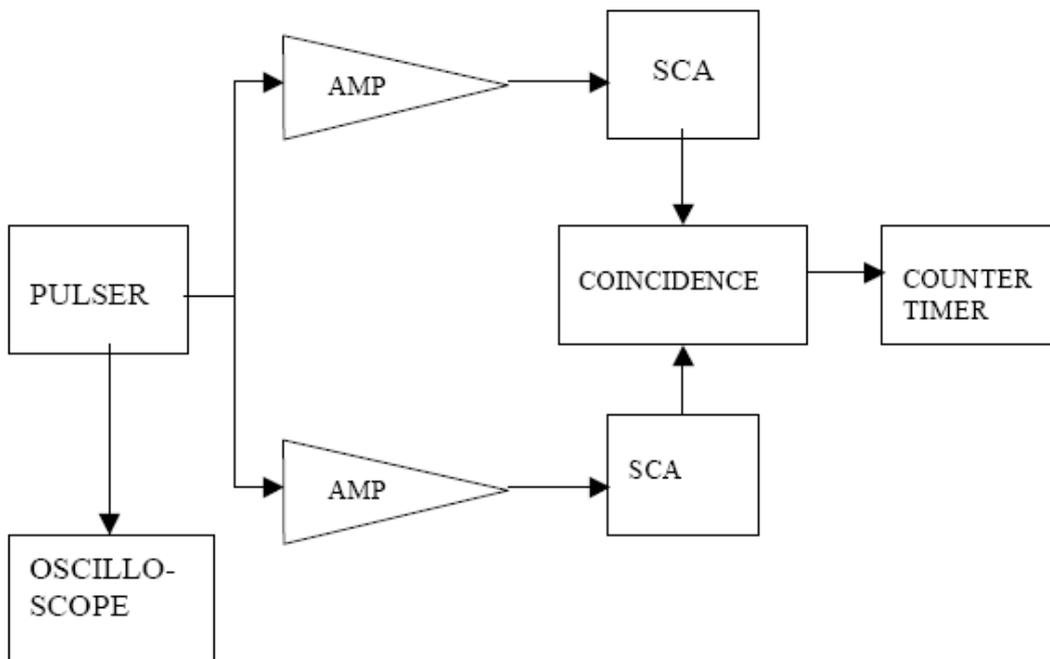
EXPERIMENT 13
OVERLAP COINCIDENCE METHOD FOR MEASURING
GAMMA-GAMMA COINCIDENCE OF 22NA

1.2 Equipment Required:

- Two Canberra NaI(TI) Crystal, Phototube Assembly Model 802 – 2 x 2 and
- Canberra Photomultiplier Tube Base(Preamplifier Model 2007P)
- Two Hewlett Packard 6516A High Voltage Power Supply
- Two Amplifier Canberra 2022
- Two Timing Single-Channel Analyzer (SCA) Canberra 2037A
- Canberra 2040 Universal Coincidence
- Counter (or Scaler) Canberra 2071A
- NIM Bin and Power Supply Ortec 401
- Oscilloscope
- Na22 source

1.1 Objectives:

Two annihilation quanta are radiated from a Na 22 source in coincidence with each other for each radiation event that will be measured in this experiment. The purpose of the experiment will be to verify that these quanta emanate from the source with an angularseparation of 180□.

1.2 INTRODUCTION

Sodium-22 is an excellent source for a simple gamma-gamma coincidence experiment. The decay scheme for this isotope is shown in Fig. 13.1. From the decay scheme it can be seen that 99.95% of the time the 22Na decay occurs by positron emission and electron capture through the 1.274 MeV state of 22Ne. Ninety percent of these decay events occur with positron emission, which then annihilate and produce a pair of 0.511- MeV gamma rays that can be seen in the gamma spectrum. Figure 1 shows a typical gamma spectrum for 22Na that was obtained with a NaI(Tl)
detector. The 0.511-MeV peak will usually be quite a bit more intense than the 1.274-MeV peak, primarily because of the detector efficiency differences at the two energy levels and the annihilation process.
The 22Na source is usually covered with a thin absorber such as a thin (-1/16-in.) piece of metal or plastic. Positrons from the source will lose energy in the absorber by de/dx and will be annihilated in the absorber. The NaI(Tl) detectors will see an approximate point source of radiation. When the positrons are annihilated, two 0.511-MeV gammas will leave the source with an angular separation of 180□. Experimentally the pair of gamma rays are detected and measured with one detector that is fixed and another detector that can rotate about the source.

A typical electronics diagram for measuring a gamma-gamma coincidence is shown below in Fig 2. The pulser and detector are alternately connected to the AMP inputs and are not connected simultaneously
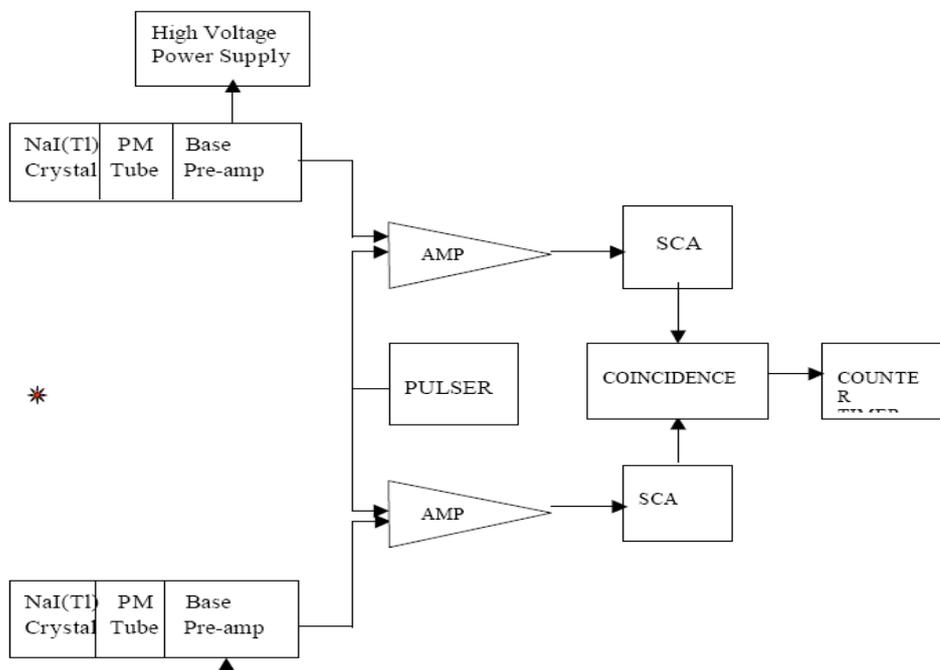
PROCEDURE

1. Set up the electronics as shown in Fig. 13.3. The instructor will assist you in arranging the two detectors on the goiniometer. The radioactive 22Na is placed in the holder at the center of the goiniometer.

2. Set the Amplifiers for positive input and Bipolar output. Adjust the gain of both amplifiers so that the 0.511- MeV line of 22Na results in approximately 3-V pulses at the outputs. Use the oscilloscope for this measurement. Ask the Lab Instructor for assistance. This is hard to observe.

3. Set the Timing Single-Channel Analyzers to CO. Set the Delay controls at minimum. Set the Lower- Level dial at 40 and the Window dial to full CW.

4. Connect the SCA Out from one of the Timing Single-Channel Analyzers to the A input of the Coincident module and connect the output from the other SCA to the B input of the Coincident module. Set the Resolving Time to 1 □s . Set the A and B switches up and C and D toggle switches down. Disconnect the NaI detector and connect the pulser into the circuit. The pulser should indicate coincidence for the two signal paths. Ask your Lab Instructor to illustrate this for you. You may use either the oscilloscope or

counter/timer. The oscilloscope is preferable. Disconnect the pulser and connect the NaI detector back into the circuit.

5. Set the Counter/Timer for a long timing period, such as 8 minutes, and permit the Counter to operate while the movable detector is rotated in steps of 0, 1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 20, and 24 degrees to both sides of 0 degrees. The counting rate should be maximum at 0 degrees.

6. Set the Counter/Timer for a long enough accumulation period to provide reasonable statistics at the points of interest and fill in the values in Table 13.1.

Exercise a. Plot the data in Table 13.1 on linear graph paper. For each counting rate (N) the statistical variation ±
□
N should be included as an error bar on the graph.
Figure 13.5 shows a typical set of experimental data for this experiment. Using the detector geometry and activity rate of 22Na, estimate the expected coincidences and compare with data. Does it make sense? Follow the inverse procedure in Exp 3.6.

Exercise b. What causes the finite width at FWHM of the peak in you data? Explain. Estimate the width of the peak from your geometry.

Exercise c. What causes the few counts or background on the far sides of the peak at very large angles? Why don't these counts go to 0 even when you can no longer connect a straight line between them? Explain.

Θ(Deg) Positive	Counts (N)	Statistical Variation	Θ(Deg) Negative	Counts (N)	Statistical Variation
0			0		
1			-1		
2			-2		
3			-3		
4			-4		
6			-6		
8			-8		
10			-10		
12			-12		
14			-14		
16			-16		
20			-20		