Gamma-Gamma Coincidence

EQUIPMENT NEEDED FROM EG&G ORTEC
Two 113 Scintillation Preamplifiers
Two 266 Photomultiplier Tube Bases
Two Bins and Power Supplies
Two 551 Timing Single-Channel Analyzers
426 Linear Gate
567 Time-to-Amplitude Converter and SCA
Two 556 High Voltage Power Supplies
480 Pulser
418A Universal Coincidence
875 Counter
Two 575A Amplifiers
427A Delay Amplifier
719 Timer
Two 905-3 NaI(Tl) 2- x 2-in. Scintillation Detectors and PM Tubes
ACE-2K MCA System including suitable IBM PC (other EG&G ORTEC MCAs may be used)
Oscilloscope
10-μCi ^{22}Na source
Source Kit SK-1G
306 Gamma-Gamma Angular Correlation Table with rotating detector and shields
ORC-13 Cable Set

Purpose

Two annihilation quanta are radiated from a ^{22}Na source in coincidence with each other for each radiation event that will be measured in this experiment. The purpose of the experiment is to verify that these quanta emanate from the source with an angular separation of 180°.

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 decay occurs by positron emission and electron capture through the 1.274-MeV state of ^{22}Ne. 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.

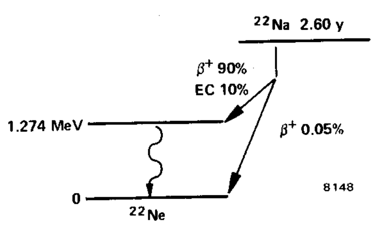


Fig. 13.1. Decay Scheme for ^{22}Na.

Figure 13.2 shows a typical gamma spectrum for ^{22}Na that was obtained with an 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 (see Experiment 3) and the annihilation process.

Figure 13.3 shows a typical instrument configuration for measuring a gamma-gamma coincidence. The ^{22}Na source is usually covered with a thin absorber such as a thin 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°.

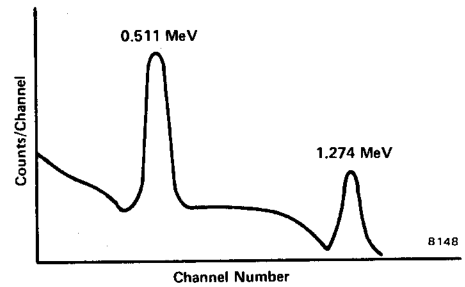


Fig. 13.2. NaI(Tl) Spectrum of ^{22}Na.

Experimentally this pair of gamma rays is detected and measured with one detector that is fixed and another detector that can rotate about the source. Figure 13.4 shows some of the details of a rotating assembly that is used for the experiment.

The ^{22}Na coincidence experiment will use three different electronic system configurations. In the first, the events that enter the two detectors will have to produce pulses that overlap each other to indicate that a coincidence exists, and the counter will then count the number of coincidences that are sensed during its timed counting interval. In the second, a pulse from the movable detector will enable the gate of the 426 Linear Gate, and any corresponding pulse from the fixed detector that arrives within the adjusted gate width interval will be considered coincident and will be counted in the counter. In the third setup, the 567 Time-to-Amplitude Converter, (TAC), and SCA will be used to measure the variations in time at which the coincident events are sensed by the two detectors; a counter can count all of the coincidences that occur within about a 500-ns range, and then an MCA can be used to obtain a spectrum of the precise timing variations.

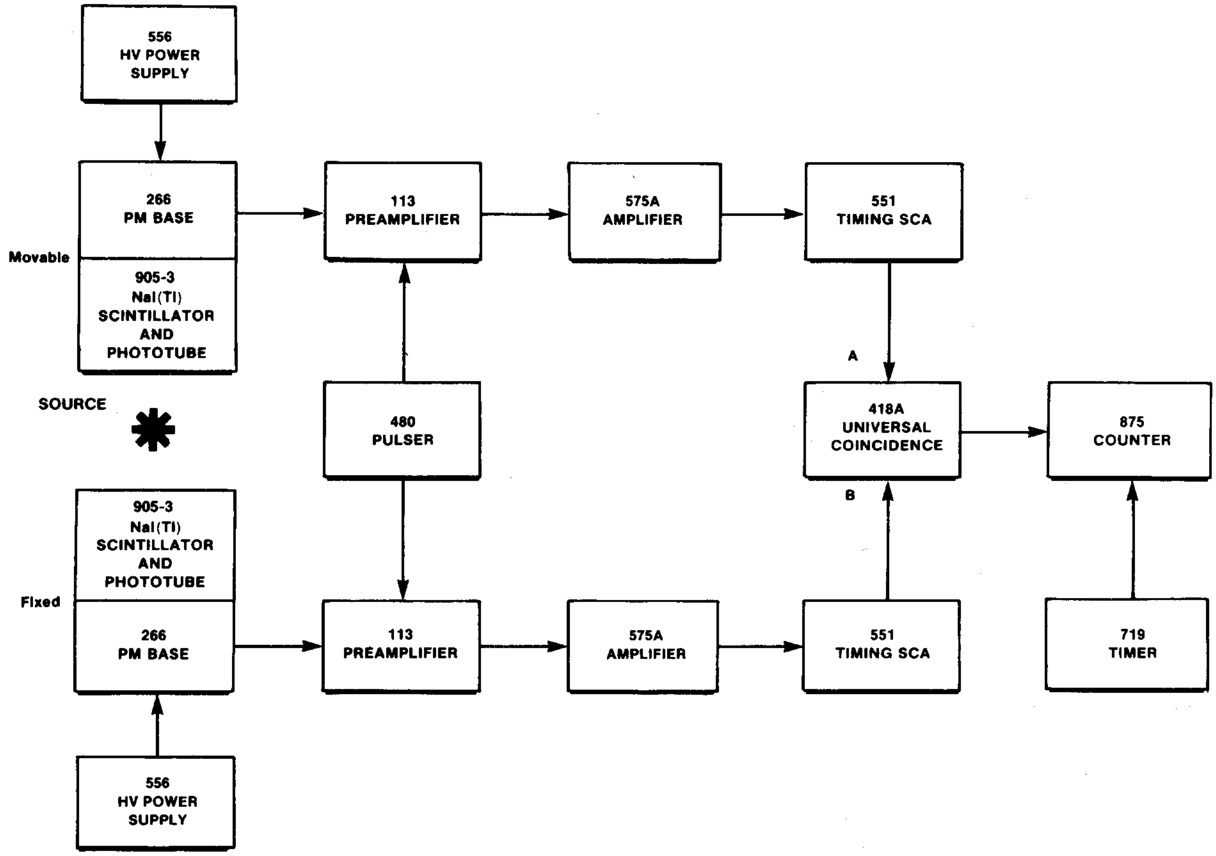


Fig. 13.3. Electronics for Experiment 13.1.

The student should complete Experiment 9 before starting this experiment and should be somewhat familiar with the principles of coincidence measurements.

EXPERIMENT 13.1

Overlap Coincidence Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.3. Use Fig. 13.4 as a guide to arranging the two detectors.

2. Set the 575A Amplifiers for negative input and unipolar output. Adjust the gain of both amplifiers so that the 1.274-MeV line of ^{22}Na results in ~6 V pulses at the outputs.

3. Set the 551 Timing SCAs for Integral mode. Set the Delay controls at minimum and the Lower-Level dials at 40/1000. Use the SCA outputs.

4. Connect the SCA Out from one of the 551 Timing SCAs to the A input of the 418A and connect the output from the other 551 to the B input of the 418A. Set the 418A Coincidence Requirements switch at 2 and the Resolving Time at maximum (2 μs). Set the A and B toggle switches at Coinc and set the C, D, and E toggle switches at Off. With the source removed and the 480 Pulser turned on, the 418A output will indicate coincidence for the two signal paths. Turn off the 480 and return the source.

5. Set the 719 Timer for a long timing period, such as 8 min, and permit the 875 Counter to operate while the movable detector is rotated slowly to both sides of 0°. The counting rate should be maximum at $\theta = 0°$.

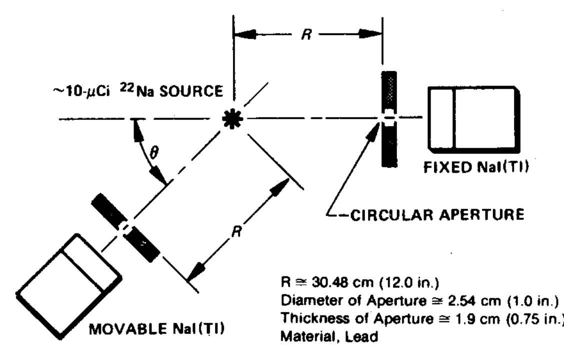


Fig. 13.4. Mechanical Arrangement of Detectors on EG&G ORTEC 306 Angular Correlation Table.

6. Set the 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

Plot the data in Table 13.1 on linear graph paper. For each counting rate, (N), the statistical variation $\pm\sqrt{N}$ should be included on the graph. Figure 13.5 shows a typical set of data for this experiment.

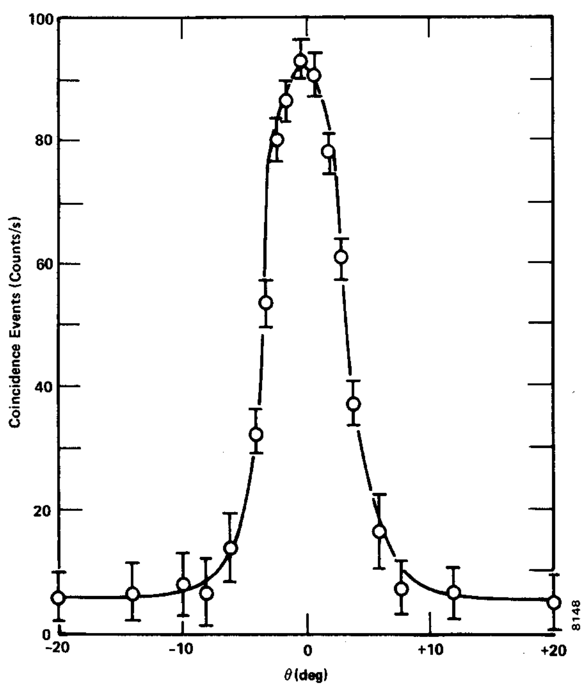


Fig. 13.5. Coincidence Data.

EXPERIMENT 13.2

Linear Gate Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.6. Use the same mechanical detector placement as in Experiment 13.1.

2. Using the ^{22}Na source, adjust the gain of each 575A Amplifier for an output of ~6 V for the 1.274-MeV gamma line.

3. Remove the source. Turn on the pulse generator and adjust the Pulse-Height dial, the Cal control, and the attenuators so that the amplifier output pulses are the same as in step **2**.

Table 13.1

θ (deg) Positive	Counts/s	θ (deg) Negative	Counts/s
0		0	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
10		10	
14		14	
20		20	
25		25	

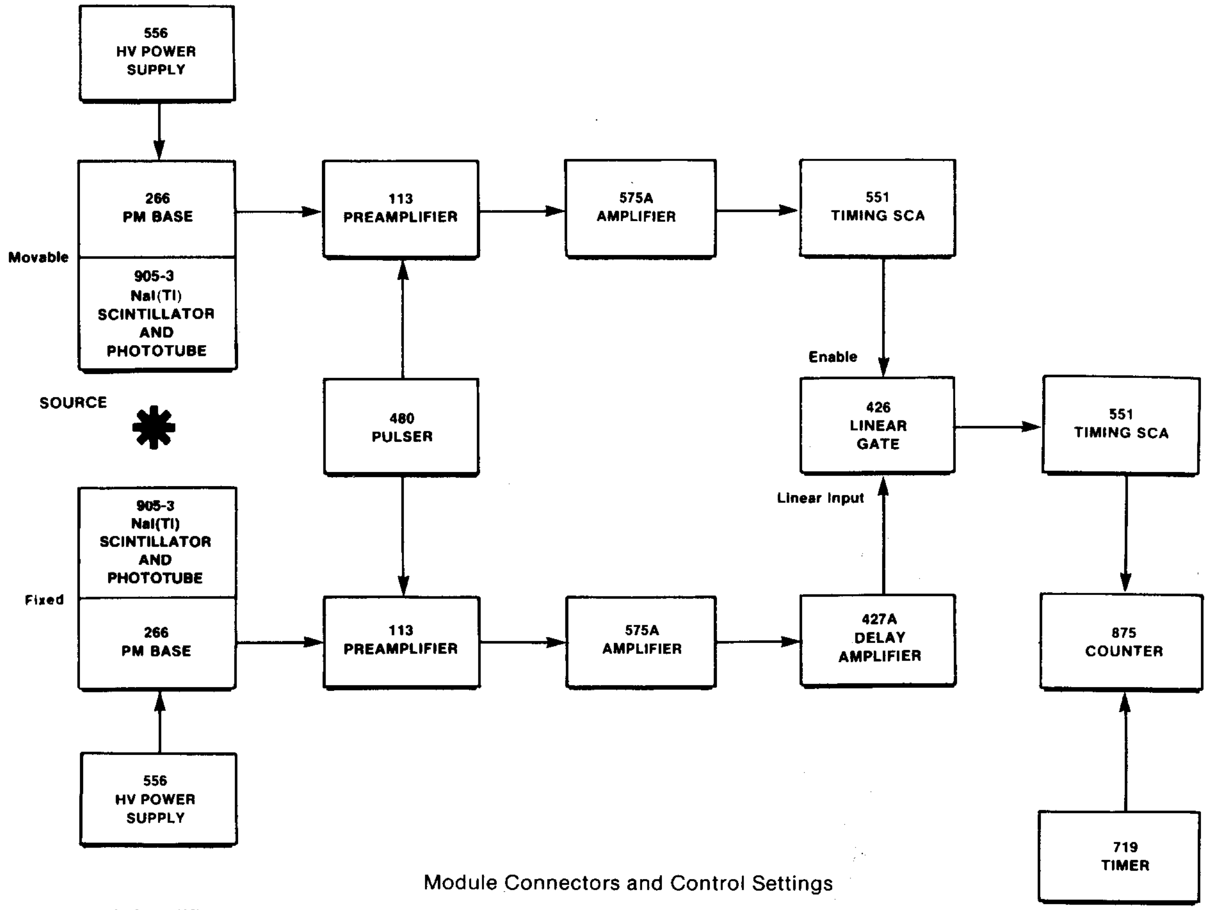
4. Look at the output of the 426 Linear Gate with the oscilloscope. If the timing is correct, a unipolar pulse should be observed whose amplitude is proportional to the pulse-height dial setting on the 480. Vary the pulse height and see that there is a linear response. If no output pulses are seen from the 426, adjust the Delay time of the 551 on the movable detector side and recheck the Gate Width control on the 426 until output pulses are seen normally.

5. Turn off the pulser and return the ^{22}Na source to its proper position as shown in Fig. 13.4. Measure the angular distribution of pulse rates from the system as in Experiment 13.1, using the angles in Table 13.1.

6. (Alternate) The output of the Linear Gate can be fed into an MCA. The spectrum should resemble Fig. 13.2 except that the 1.274-MeV peak will not be present. The coincidence requirement has virtually eliminated this peak from the spectrum.

EXERCISE

Plot the data on linear graph paper as in Experiment 13.1. Compare the count rates at $\theta = 0°$.



Module Connectors and Control Settings

575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel Analyzer on movable detector side: Lower Level = 40/1000, Integral mode, SCA Output, Delay minimum.
551 Timing Single-Channel Analyzer following the Linear Gate: same settings.
426 Linear Gate: Normal mode, Gate Width maximum (4 μs).
480 Pulser: Attenuated output, negative polarity, power switch Off.
875 Counter: Input from the 551, Gate from the 719 Interval Out.

Fig. 13.6. Arrangement of Electronics for Experiment 13.2.

EXPERIMENT 13.3

Time-to-Amplitude Converter Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.7. Use the same mechanical detector placement as in Experiment 13.1.

2. Using the ^{22}Na source, adjust the gain of each 575A Amplifier for an output of ~6 V for the 1.274-MeV gamma line.

3. Remove the source. Turn on the pulser and adjust the Pulse-Height dial, the Cal control, and the attenuators so that the amplifier output pulses are the same as in step **2.**

4. Observe the output pulses of the 567 with the oscilloscope. They should be ~6 V in amplitude. Change the delay on either 551 SCA while observing these output pulses (they can also be observed with the MCA).

5. Determine a delay vs pulse-height curve for the 567 TAC. This procedure is outlined in Experiment 9.2.

EXERCISE

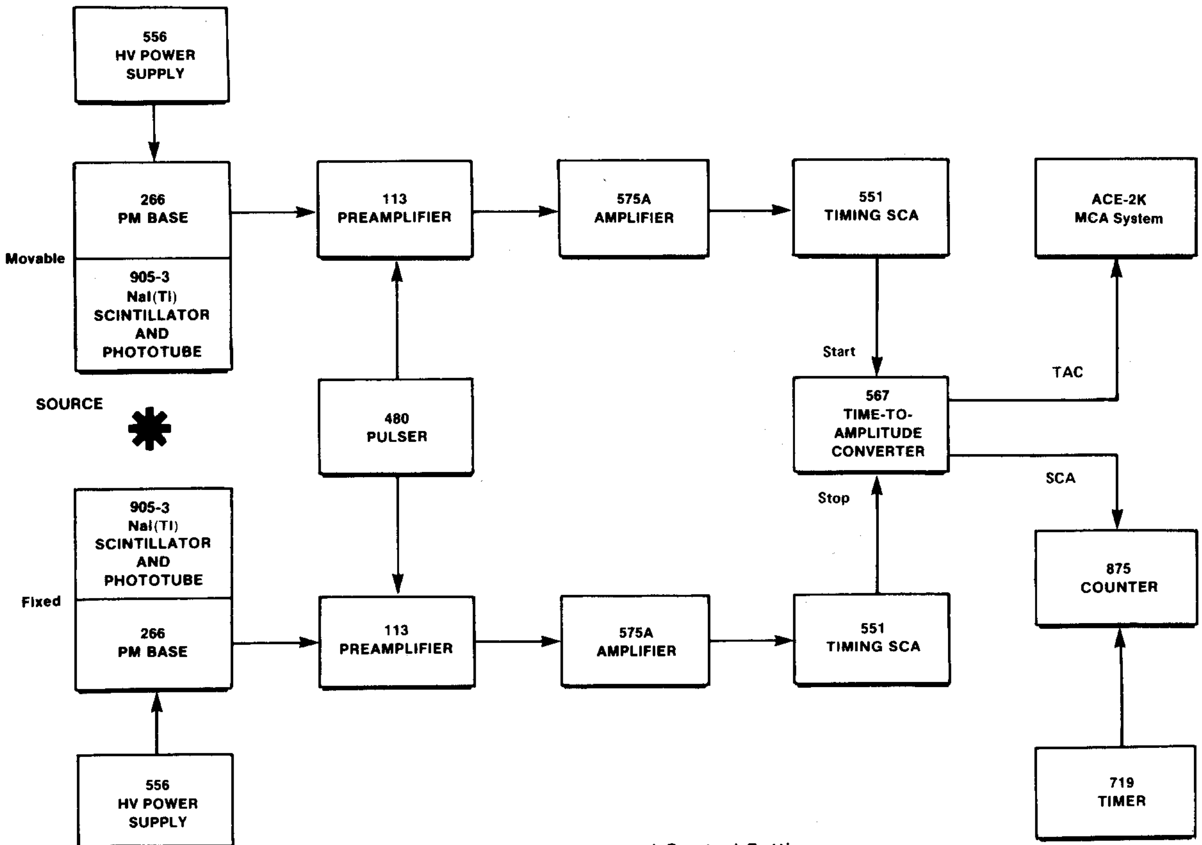
a. Determine the time resolution of the pulses from the 480 Pulser.

6. Turn off the pulser when the delays of the 551 SCAs are set for a 5- to 6-V output from the 567. Return the ^{22}Na source to its proper position as shown in Fig. 13.4. Measure the angular distribution of pulse rates from the system using the FWTM levels of the time spectrum and integrating the counts in the channels between these levels.

EXERCISES

b. Plot your data on linear graph paper as in Experiment 13.1. Compare the count rates at $\theta = 0°$.

c. Determine the time resolution for the coincidence measurements from the MCA readout.



Module Connectors and Control Settings

575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel Analyzer on movable detector side: Integral mode, Lower Level = 40/1000, Delay = 0.1 μs, Neg Out to Start Input on 567.
551 Timing Single-Channel Analyzer on fixed detector side: Integral mode, Lower Level = 40/1000, Delay = 5 μs, Neg Out to Stop Input on 567.
567 TAC and SCA: Range 400 ns, TAC Out to MCA, SCA Out to 875.
480 Pulser: Attenuated output, negative polarity, power switch Off.

Fig. 13.7. Arrangement of Electronics for Experiment 13.3.

References

1. A. C. Melissinos, *Experiments in Modern Physics,* Academic Press, New York (1966).

2. H. A. Enge, *Introduction to Nuclear Physics,* Addison-Wesley (1966).

3. K. Seigbahn, *Alpha, Beta, and Gamma Spectroscopy,* North Holland Publishing Co., Amsterdam.

4. L. C. Biedenharn and M. E. Rose, *Rev. Mod. Phys.* **25,** 729 (1953).

5. R. D. Evans, *The Atomic Nucleus,* McGraw-Hill, New York (1955).

6. B. L. Cohen, *Concepts of Nuclear Physics,* McGraw-Hill, New York (1971).

7. C. E. Crouthamel, *Applied Gamma-Ray Spectrometry,* Pergammon, New York (1960).

8. C. M. Lederer and V. S. Shirley, Eds., Table of Isotopes, 7th Edition, John Wiley and Sons, Inc., New York (1978).

9. P. Quittner, *Gamma Ray Spectroscopy,* Halsted Press, New York (1972).

10. W. Mann and S. Garfinkel, *Radioactivity and Its Measurement,* Van Nostrand-Reinhold, New York (1966).