# AN34 Experiment 13

## Gamma-Gamma Coincidence

### EQUIPMENT NEEDED FROM ORTEC

- 113 Scintillation Preamplifier (2 ea.)
- 427A Delay Amplifier
- 266 Photomultiplier Tube Base (2 ea.)
- 905-3 NaI(Tl) 2-in. x 2-in. Scintillation Detector Assembly (2 ea.)
- 4001A/4002D NIM Bin and Power Supply (2 ea.)
- TRUMP-PCI-2K MCA System including PC (other ORTEC MCAs may be used)
- 551 Timing Single-Channel Analyzer (2 ea.)
- 426 Linear Gate
- 567 Time-to-Amplitude Converter and SCA
- C-36-12 Cable (2 ea.)
- C-24-12 Cable (6 ea.)
- C-24-1 Cable (9 ea.)
- C-25-1 Cable (2 ea.)
- C-29 BNC Tee Connector (2 ea.)
- 556 High Voltage Power Supply (2 ea.)
- 480 Pulser
- 418A Universal Coincidence
- 996 Timer and Counter
- 855 Dual Spectroscopy Amplifier

### OTHER EQUIPMENT NEEDED

- Sealed Solid Disk Gamma Ray Sources ~1 µCi, $^{137}$Cs, $^{60}$Co, $^{22}$Na, $^{65}$Zn, $^{54}$Mn. Substitute alternate sources wth similar energies.
- Angular Correlation Table. 46-in x 46-in x 30-in high. Should contain lead shields for fixed and movable 2-in x 2-in. NaI detectors. Angular settings should be accurate to ±0.1°.
- 10-µCi $^{22}$Na source
- Oscilloscope

### Purpose

In this experiment, two annihilation quanta are radiated from a $^{22}$Na source in coincidence with each other for each radiation event that will be measured. 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.

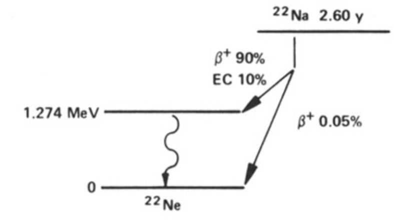


**Fig. 13.1. Decay Scheme for $^{22}$Na.**

Fig. 13.2 shows a typical gamma spectrum for $^{22}$Na obtained with a NaI(Tl) detector. The 0.511 MeV peak will usually be substantially more intense than the 1.274 MeV peak, due primarily to the detector efficiency differences at the two energy levels (see Experiment 3) and the annihilation process.

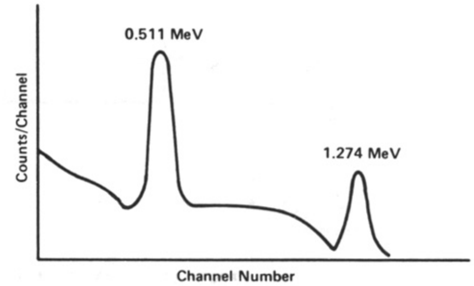


**Fig. 13.2. NaI(Tl) Spectrum of $^{22}$Na.**

Fig. 13.3 shows a typical instrument configuration for measuring 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 lose energy in the absorber by dE/dx and will be annihilated in the absorber.

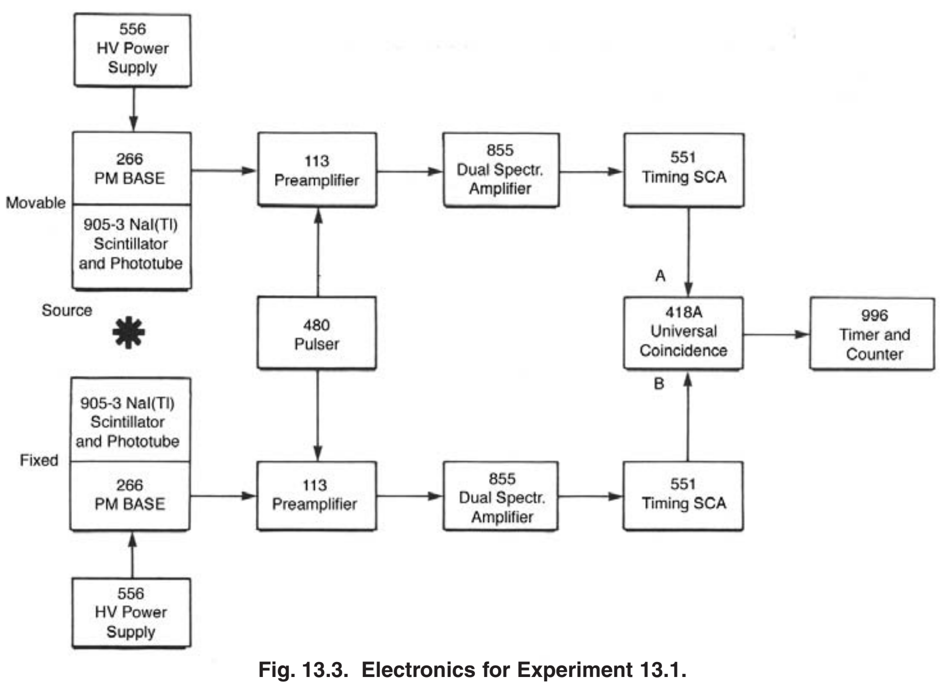


**Fig. 13.3. Electronics for Experiment 13.1.**

The NaI(Tl) detectors will see an approximate point source of radiation. When the positrons are annihilated, two 0.511 MeV gamma will leave the source with an angular separation of 180°.

Experimentally, this pair of gammas is detected and measured with one fixed-position detector and another detector that can rotate about the source. Fig. 13.4 shows some of the details of a rotating assembly used for the experiment.

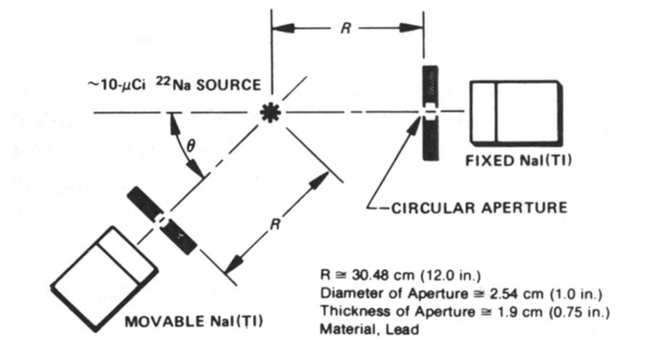


**Fig. 13.4. Mechanical Arrangement of Detectors on Angular Correlation Table..**

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. The counter will then count the number of coincidences that are sensed during its timed counting interval. In the second, a pulse from the moveable 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 configuration, 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. The counter can count all of the coincident events that occur within a 500 ns range; then a MCA can be used to acquire a spectrum of the precise timing variations.

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. 13.2. Use Fig. 13.4 as a guide in arranging the two detectors.

**2.** Set both sections of the 855 Dual Amplifier 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 551units to the A Input of the 418A ; connect the SCA Out 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 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 the 480 off and return the source.

**5.** Set the timer of the 996 Timer and Counter for a long counting period (8 to 10 minutes) and press the Count switch, allowing the counter to operate while the moveable detector is rotated slowly to both sides of 0°. The counting rate should be maximum at $\theta = 0°$.

**6.** Set the 996 timer for a long enough counting period to accumulate reasonable statistics at the points of interest and fill in the values in Table 13.1.

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 | |
| 11 | | 11 | |
| 20 | | 20 | |
| 25 | | 25 | |

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**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. Fig. 13.5 shows a typical set of data for this experiment.

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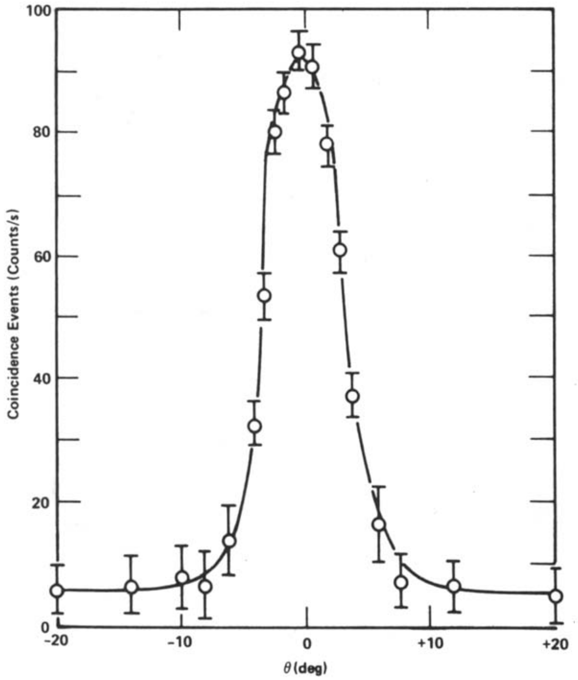


**Fig. 13.5. Coincidence Data.**

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 a 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.

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**EXERCISE**

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

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**EXPERIMENT 13.2**

## Linear Gate Method for Measuring Gamma-Gamma Coincidence of 22Na

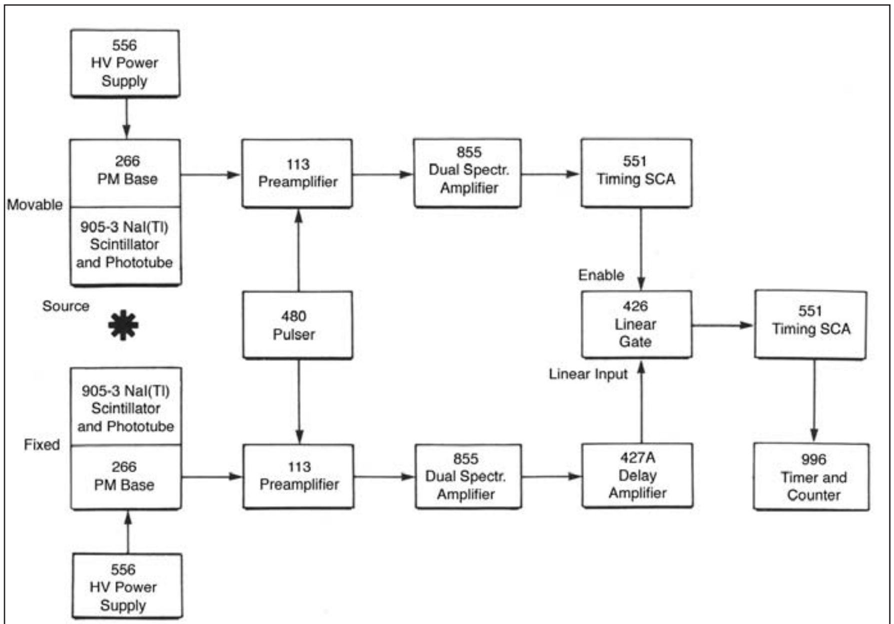
### Procedure

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 section of the 855 Dual Amplifier for an output of ~6V for the 1.274 MeV gamma line.

3. Remove the source, turn on the 480 Pulser and adjust the Pulse-Height control, the Cal control, and the attenuators so that the amplifier pulses are the same as in step 2.

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




Module Connectors and Control Settings

855 Dual Spectroscopy Amplifiers: Negative Input, Bipolar Output.
551 Timing Single Channel Analyzers: Lower level = 400/1000, Integral mode, SCA Output, Delay minimum.
426 Linear Gate: Normal mode, Gate Width maximum (4 µs).
480 Pulser: Attenuated output, negative polarity, power switch Off.
996 Timer and Counter: Input from the 551.

**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 section of the 855 Dual Amplifier for an output of ~6V for the 1.274 MeV gamma line.

3. Remove the source, turn on the 480 Pulser and adjust the Pulse-Height control, the Cal control, and the attenuators so that the amplifier pulses are the same as in step 2.

4. Observe the output pulses of the 567 with the oscilloscope. They should be ~6V 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.

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EXERCISE

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

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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.

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EXERCISES

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

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

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### References


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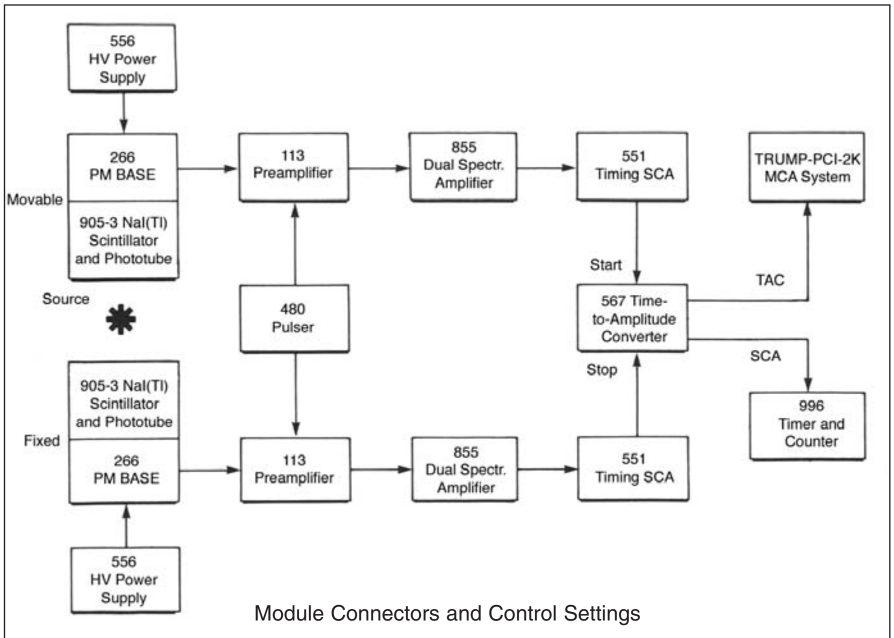


Module Connectors and Control Settings

855 Dual Spectroscopy 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. 13.6. Arrangement of Electronics for Experiment 13.3.**

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