Research Paper

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Gamma-Gamma Coincidences Final Draft

Abstract:

In this lab we measured how angles affect the intensity in coincidence counting of simultaneously emitted gamma rays for both Sodium-22 and Cobalt-60. We also calculated the anisotropy for our data using Cobalt-60, with the anisotropy A=1.1, which was high when compared to the expected anisotropy of 0.17.

Introduction:

Coincidence is when two events occur within a very short time frame of each other, in this case we are referring to two gamma rays hitting different detectors within a time frame of 10-110 nano-seconds of each other. Coincidence is one of the most important concepts in any physics dealing with radiation, because there is a big difference between 1000 random hits per minute and 1000 coincidences per minute. If there are 1000 random hits per minute and no coincidences, then either the radioactive substance is absorbing part of the radiation, something else is absorbing the radiation, or the other radiation is not being detected. If there are 1000 coincidences, then it is possible to find out more data about that particular reaction, such as the energy of both of the particles. In this experiment we use coincidence counting: the count of coincidences that fall within that time frame, rather than anti-coincidence counting where we take everything but the counts which fall within the time frame. We are preforming this experiment to verify the principles of coincidence between gamma rays from the same decay, as well as the principles of accidental coincidences.

Diagram of the detectors and source

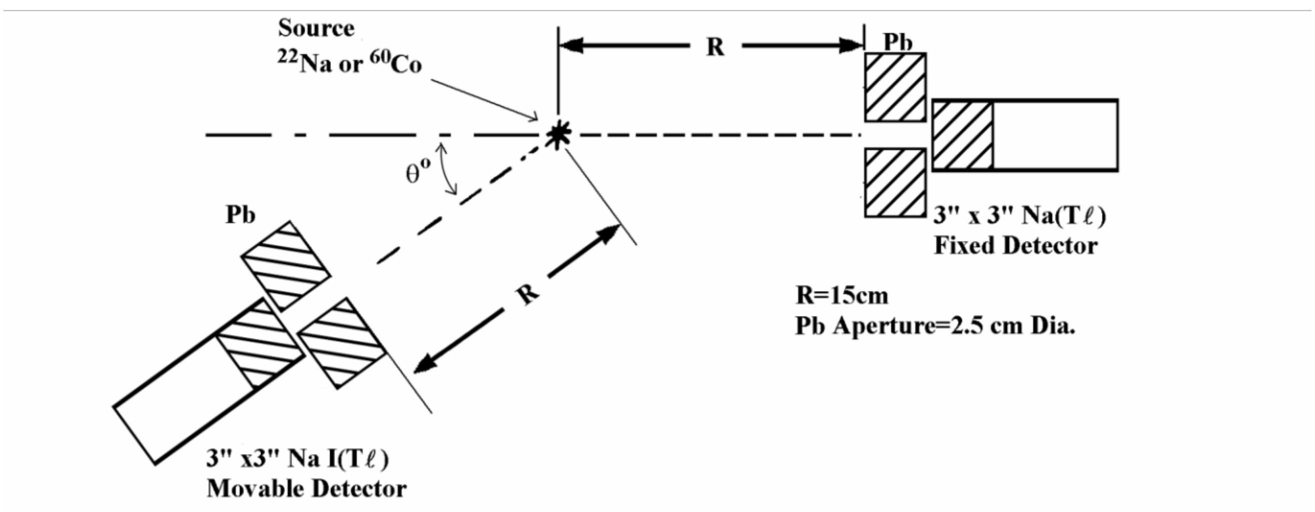
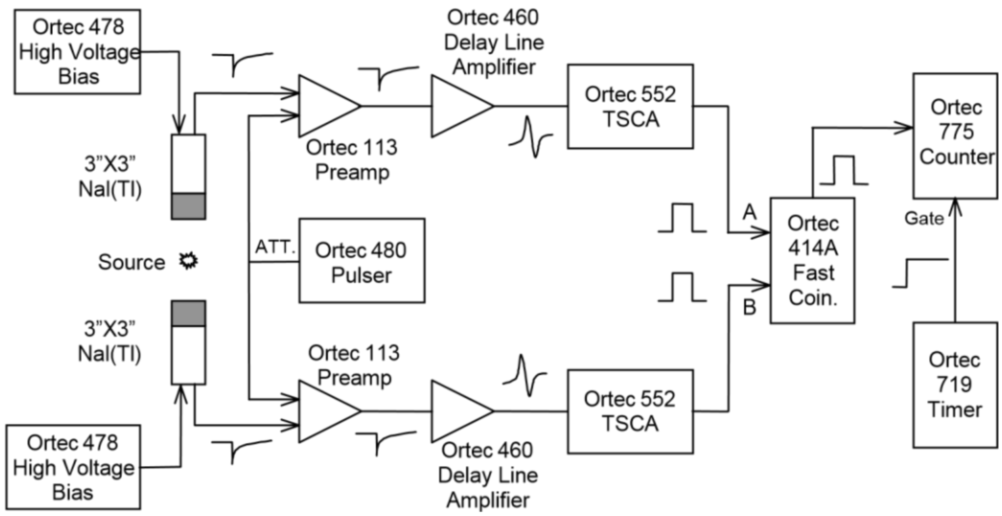


Diagram of the machinery used in experiment



Experimental Procedure:

For this experiment, we used a fixed detector attached to a swinging detector and a fixed source (see first digram), 2 Ortec 113 Preamps, 2 Ortec 460 Delay Line Amplifiers, 2 Ortec 552 TSCA, 1 Ortec 553 , 1 Ortec 414A Fast Coincidence hit 1 Ortec 775 Counter 1 Ortec 719 Timer, 1 T-connector and 10 wires. The two detectors were then attached to an Ortec 113 Preamp which we then connected to an oscilloscope to adjust the voltage to 100 mV. After that we disconnected the preamp from the oscilloscope before connecting it to two Ortec 460 Delay Line Amplifiers using their negative inputs and bipolar outputs before adjusting the gain to allow the 1.274 MeV line of the Na-22 to produce a 6 V pulse height. At this point we connected each of the Delay line amplifier to an Ortec 552 TSCA which we then used to remove the unwanted noise from our signal by adjusting the lower and upper level discriminators. Then it was connected to an Ortec 414A Fast Coincidence and from there a counter and a timer to collect the number of coincidences that occurred within a specific resolving time for the duration of each trial. After a few mistakes that required us to re-do the set-up procedures, one of the Ortec 552 TSCAs broke requiring it to be replaced with a Ortec 553 which did the same job. Once the set-up was finished, we then began collecting the data, starting with the Na-22 before readjusting the system for the Co-60, which used the same process as the Na-22 except it required an ND-62 Multichannel Analyzer in order to adjust the discriminators correctly.

$\sigma = \pm \sqrt{N}$ $\quad\quad$ $error = \pm \sqrt{N}$[1]

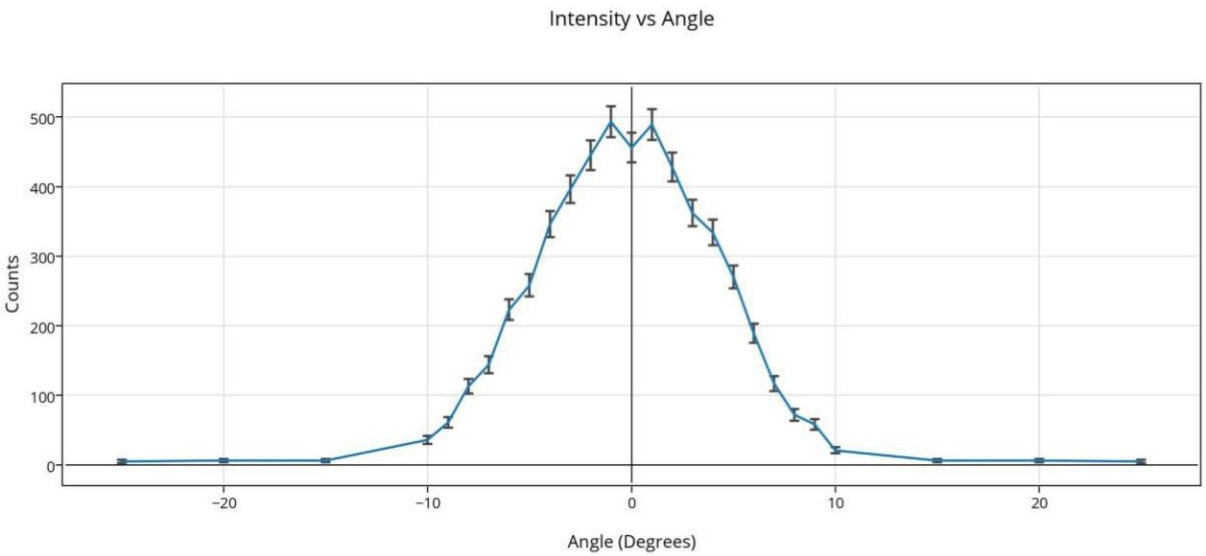
Results and Analysis:

Where N = the number of counts

The data we gathered from Sodium-22 was all done with a resolution time of 15 nano-seconds (with an error of 0.3 nano-seconds)

Sodium-22	Angle (Degrees)	Time (Minutes)	Counts	Statistical Variation (+ or -)	% Error (+ or -)
	0	20	456	21.4	4.68
	1	20	489	22.1	4.52
	-1	20	493	22.2	4.50
	2	20	428	20.7	4.83
	-2	20	445	21.1	4.74
	3	20	362	19.0	5.26
	-3	20	396	19.9	5.03
	4	20	334	18.3	5.47
	-4	20	346	18.6	5.38
	5	20	270	16.4	6.09
	-5	20	258	16.1	6.23
	6	20	189	13.7	7.27
	-6	20	223	14.9	6.70
	7	20	117	10.8	9.25
	-7	20	144	12	8.33
	8	20	72	8.5	11.8
	-8	20	113	10.6	9.41
	9	20	58	7.6	13.1
	-9	20	61	7.8	12.8
	10	20	21	4.6	21.8

	-10	20	36	6	16.7
	15	20	6	2.4	40.8
	-15	20	6	2.4	40.8
	20	20	6	2.4	40.8
	-20	20	6	2.4	40.8
	25	20	5	2.2	44.7
	-25	20	5	2.2	44.7



Sodium-22 Intensity vs Angle with Error Bars Graph

The angular width of our data was 30 degrees, a reasonable width given the experiment and the source used. The reason the peak had an angular width was because while the swinging detector slowly increases the angle from 0 degrees fewer and fewer of the gamma rays hit both detectors at the same time because as the angle from 0 increased, the amount of the source directly between the two detectors decreased.

The data for Cobalt-60 was gathered using a resolution time of 110 nano-seconds (with an error of 0.4 nano-seconds), we got 21 counts in 80 minutes where the second detector was at a 180 degree angle from the first detector, and 10 counts in 80 minutes when the second detector was at a 90 degree angle from the first detector.

When we took the number of counts that hit each detector individually for our accidental coincidence analysis, we did it with the same resolving time as was used to count the number of coincidences the detectors recorded, with a much shorter time. When we counted the number of hits Sodium-22 received, we had the stationary detector record 23250 hits in 2 minutes, about 193.75 per second; while the swinging detector recorded only 4916 hits in the same time, only 41 per second. On the other hand, Cobalt-60 received a much lower 2292 hits in 2 minutes for the stationary detector, about 19.1 per second; while the swinging detector recorded an even lower 1520 hits in the same time, only 12.67 per second.

The accidental coincidence rate is equal to the resolution time multiplied by the counts per second that are detected by each of the detectors.

$$^{22}Na \rightarrow N_{acc} = \tau N_A N_B = ((15 \pm 0.3)\times 10^{-9} s)(193.75 / s)(40.97 / s) = 1.19 \times 10^{-4} \pm 2 \times 10^{-6} / s$$

Sodium-22 had an accidental coincidence rate of 0.14 per 20 minutes, so it was only slightly important, and mostly only at the larger angles above 15 degrees where we only had single digit counts.

$$^{60}Co \rightarrow N_{acc} = \tau N_A N_B = ((110 \pm 0.4)\times 10^{-9} s)(19.1 / s)(12.67 / s) = 2.66 \times 10^{-5} \pm 1\times 10^{-7} / s$$

Cobalt-60 had an accidental coincidence rate of 0.13 per the 80 minutes we ran the experiment for, so like sodium-22, it was only slightly important.

Anisotropy is equal to the number of hits detected at 180 degrees per a set time minus the number of hits detected by a detector at 90 degrees for the same period of time, divided by the number of hits at 180 degrees (the same one that was previously mentioned).

$$A = \frac{21/t - 10/t}{10/t} = \frac{11/t}{10/t} = 1.1 \qquad t = 80\text{min}$$ Anisotropy (experimental)

A = 0.17 = Anisotropy (expected)

The anisotropy was much higher than was predicted by the equation given in the lab manual, roughly 6.5 times higher. This could be because we got outliers in both cases, with the 21 being high and the 10 being low, as just increasing the 10 to 12 drops the anisotropy to 0.75.

Conclusion:

In our experiment we measured how angle affects the coincidence rate of Sodium-22 and calculated the anisotropy of Cobalt-60. If I were to repeat the lab, I would start by taking much longer measurements than what we took, and I would use multiple trials per angle and use the mean of those trials to lower the error of the data. I would also take the data for angles 11, -11, 12, -12 13, -13, 14, and -14 in order to see how the data levels out at the edges, whether it was a sharp point on the graph or a curved point that appears sharp because of the gap in angles we used. I would also retake the data for the angle at 0 degrees, to try and see if ours was accurate or if it was an outlier.