Electron-Positron Annihilation

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Overview

In this experiment we will try to prove that the gamma rays created from the annihilation of positrons with electrons resulting from the decay of Na^{22} into Ne^{22} conserve both energy and momentum.

Questions

1) Explain what the SCA does for you in this experiment.

In this experiment the single channel analyser will determine if the pulse coming from the amplifier is in the specified range necessary to have come from an electron-positron annihilation event. This is necessary as the decay products of our sample also include a higher energy gamma ray that is produced when the an excited electron on the Ne^{22} product falls back to its rest energy.

2) Explain how the NaI detector works.

The NaI detector works by advantage of the photo-electric effect. When a photon goes into the crystal an electron is often ejected in the same direction as the motion of the photon. This electron then heads toward our photo-multiplier tube which uses successive dynodes held at a potential relative to each other to further eject electrons. The end result should be a cascade of electrons large enough that we can take a reading of voltage from the capacitor at the end of photo-multiplier tube.

3) Explain why the coincidence detector is so important.

The coincidence detector is important to maintain that any two pulse coming from detector A and B are coming from the same event and not from two random events occurring at the same time.

4) Explain how you will count your pulses

For this experiment we were able to count pulses by two methods. First, by a slightly more difficult method, we were able to count gamma rays collected at either detector with a labview program set to count a pulse when the single channel analyser (SCA) detected a pulse within a specified amplitude. Square wave pulses generated by both SCA's were then sent to the coincidence detector in our NIM bin where counts were only made when two pulses were within $50nm$ of each other. I consider this slightly more difficult than the next method used as it was necessary to use a stop watch and the counter switch to make sure that counts were only made in the 60 second time frame that we specified for the collection of coincidence data. The start button on the labview program as well needed to be pushed when data collection began, which of course required another person and some caution in the timing of all the necessary buttons. In the second method we were able to collect all necessary data through labview with the addition of a coincidence detector and program courtesy of Dr. Professor Chair Extraordinaire Ayars. With this addition we were able to collect single counts from both detectors and coincidences all with a specified time interval and without the need of coordination by multiple people thereby reducing random error.

Set-up

This block diagram was taken directly from Positron-Electron lab handout.

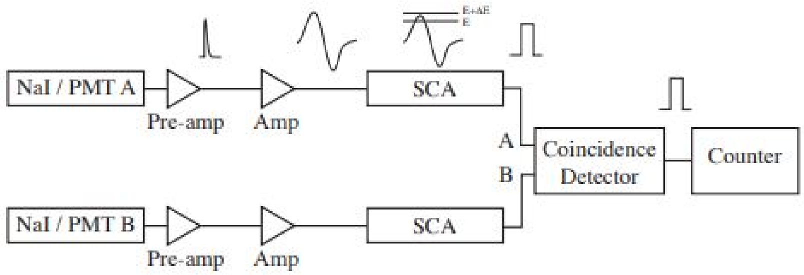

Figure 1: Coincidence measurement block diagram

To begin with the detectors will be set up 180 degrees from each other with the sample at their center as we expected the photons emitted from the decay of the produced positronium to be correlated by having opposite amounts of momentum as they initially had no momentum. We will analyse this assumption later by changing the the position of our detector on the goniometer arm while keeping the other detector fixed.

Procedure

Much of the procedural work for this experiment was already done by Young John which he thoroughly explained to me. Some of this procedure and explanation can be found in the question section at the beginning of this write up. I was however able to add a coincidence counter that was capable of taking counts from both arms A and B as well as count total number of coincidences from these arms given a specified interval. Secondary work was done in determining whether coincidence counts were coming from from random events at the same time rather then from simultaneous events correlated in time. As well spacial correlation was checked by maneuvering detector B about some fixed central position to change our angular relation.

Data

First data was taken, as shown in table 1 by adjusting the angle between the two detectors.

Channel 1	(error in 1)	Channel 2	(error in 2)	Coincidence	(coincident error)	Interval (sec)	Angular Correlation (degrees)
2743	52	3508	59	848	29.12	60	180
2772	53	3472	59	859	29.31	60	180
2744	52	3574	60	71	8.43	60	170
2758	53	3637	60	0	0	60	160
2743	52	3694	61	2	1.41	60	160
2802	53	3482	59	59	7.68	60	190

Table 1: Coincidence by spatial adjustment

Though more data will need to be taken so precise correlation to angle can be made the present data shows an outstanding correlation between coincidences and present angle as can be seen in figure 2 . Correlation between the geometry of the set up and the number of coincidences that occur at angles offset to 180 degrees can be made by looking at the size of the opening to the detector and the portion of the opening that would still accept photons related to a specific incidence, however I will leave this for a more in depth analysis of this phenomenon at a later time.

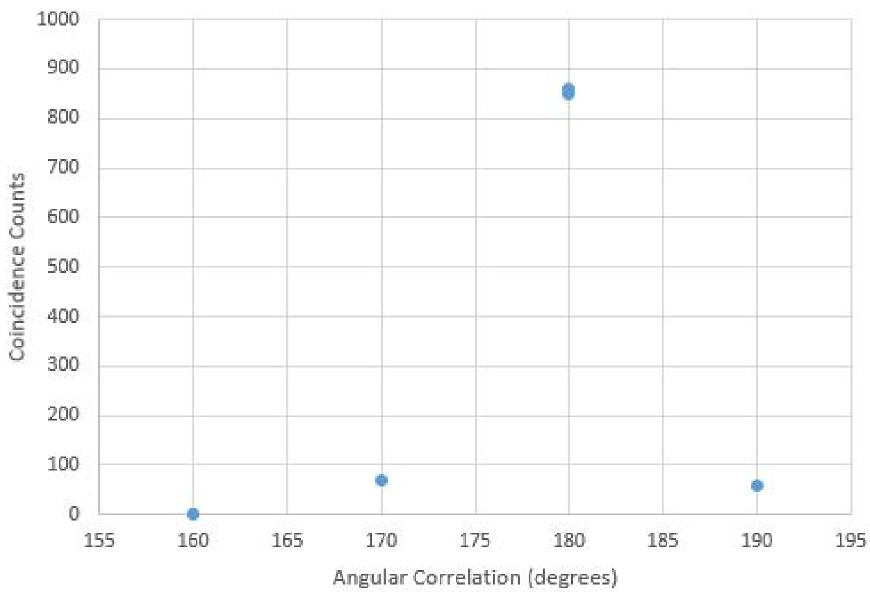

Figure 2: Coincidence by spatial adjustment

Next we checked for random coincidences by offsetting the time at which the the single channel analyser on arm B would output its pulse, though we maintained the angular correlation of 180 degrees. In doing so we made sure that a pulses arriving from the same event were offset from each other and that we were seeing only random coincidences. Small adjustments were made in this setting so that we could check as well the coincidences correlation in time.

Channel 1	(error in 1)	Channel 2	(error in 2)	Coinci-dence	(coincident error)	Interval (sec)	delay (ns)
2631	51	3405	58	823	29	60	10
2646	51	3446	59	544	23	60	30
2639	51	3434	59	82	9	60	50

Table 2: Coincidence by temporal adjustment

Here we omitted time delays of 60 ns or greater as these data points maintained no coincidences over the specified 60 second interval which data was collected over. We could expect this as the time delay on our coincidence detector would not count any pulse arriving greater than 50 ns from each other as being correlated in time. As well our sample is old and has a relatively long half life which would greatly reduce the probability of having two events be randomly correlated in time.

Conclusion

We were able to investigate the correlation of of momentum and energy between from the decay of positronium into two constituent photons and see that this event agrees with our laws of conservation. A later experiment will check to see if photons coming from electron-positron annihilation are as well quantum entangled.