FÍSICA EXPERIMENTAL I
Eng^a Física Tecnológica

8. COINCIDÊNCIAS $\gamma - \gamma$ RESULTANTES DA ANIQUILAÇÃO DO POSITRÃO PROVENIENTE DE UMA FONTE DE ^{22}Na

Neste trabalho utilizam-se as técnicas de coincidência com um espectrómetro duplo estudadas na 1^a série. Pretendemos estudar as coincidências entre os dois γs resultantes da aniquilação dum positrão oriundo duma fonte de ^{22}Na e dum electrão do material que a rodeia. As coincidências são contadas em função do ângulo entre os dois γs, de modo a verificarmos que essa distribuição é exibe um pico quando γ_1 e γ_2 são emitidos em sentidos diametralmente opostos.

Para tal usa-se uma mesa de correlações angulares, em que a fonte de ^{22}Na, emissora de β^+, é colocada no centro de um sistema de dois braços articulados suportando detectores de cintilação de iodeto de sódio e podendo rodar um em relação ao outro. Aos detectores de NaI(Tl) (cada qual acoplado ao seu fotomultiplicador) segue-se um espectrómetro duplo constituído por pré-amplificadores, amplificadores de tensão, analisadores monocanal, unidade de coincidências e três contadores.

As partes que compõem o trabalho são as seguintes:

- Verificação do *timing* do espectrómetro, isto é, que os dois braços do espectrómetro duplo estão em tempo entre si, com o auxílio de um gerador de impulsos.
- Regulação dos limiares V_1 e V_2 de cada um dos dois analisadores monocanal em valores que permitam isolar o pico de aniquilação de 511 keV, de modo a evitar-se o mais possível o fundo combinatorial.
- Obtenção da distribuição angular dos dois γs de aniquilação do processo $e^+e^- \rightarrow \gamma\gamma$. Sugerem-se aquisições de 30 s para $|\theta| = 0^o, 1^o, ..., 10^o$; e tempos crescentes ($\leq 3$ minutos) para os ângulos $|\theta| = 12^o,\ 15^o,\ 20^o$.

Nota: Em cada aquisição, o fundo de coincidências fortuitas deve ser subtraído.

Segue-se o Guia detalhado do Trabalho.

EXPERIMENT 12

Annihilation Radiation Coincidence Studies with ^{22}Na

Scope

The annihilation radiation from a ^{22}Na source will be studied with an angular correlation apparatus. The β^+ particles from the source will be converted in a foil and the resultant .511 MeV annihilation quanta will be measured with two NaI(Tℓ) detectors. The angular correlation table that will be used for this experiment has provisions to fix one of the NaI(Tℓ) detectors and rotate the other one. With this system, we will verify the angular correlation of the annihilation radiation. These quanta will be shown to be emitted with an angular separation of 180 degrees, which is the only correlation that can conserve linear momentum for the two photons. This angular correlation will be verified by using three different coincidence arrangements.

Discussion

Figure 12.1 shows the decay scheme of ^{22}Na and the resultant NaI(Tℓ) spectrum. **Note:** The positrons are in coincidence with γ's from the 1.274 MeV (2+) state. The mean life of the 1.274 MeV state is 3×10^{-12} sec and therefore, from our timing situation, decay is immediate. A small fraction of the positrons (0.05%) decay directly to the ground state of ^{22}Na. The Q_{EC} = 2.843 MeV shown in the figure is the excess energy that would be available if Electron Capture (EC) occurred to the ground state of ^{22}Na.

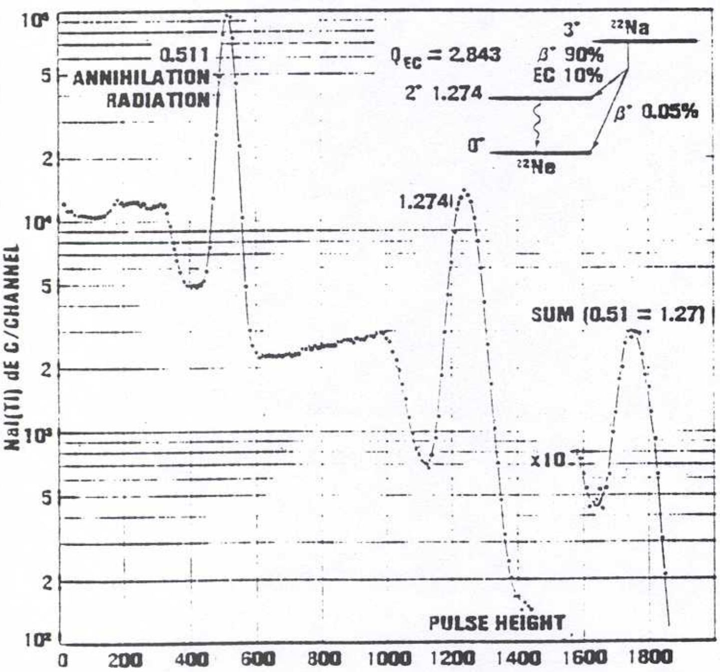

Figure 12.1. NaI(Tℓ) pulse height spectrum of ^{22}Na.

The β^+ end point energy to the ground state is 1.74 MeV. Most of the β^+ particles (90%) go to the (2^+) level at 1.274 MeV. The positron continuum to this level would have an end point energy of 0.466 MeV. Figure 12.2 shows what the distribution of β^+ particles would look like if we counted them with a β^+ pulse height analyzer.

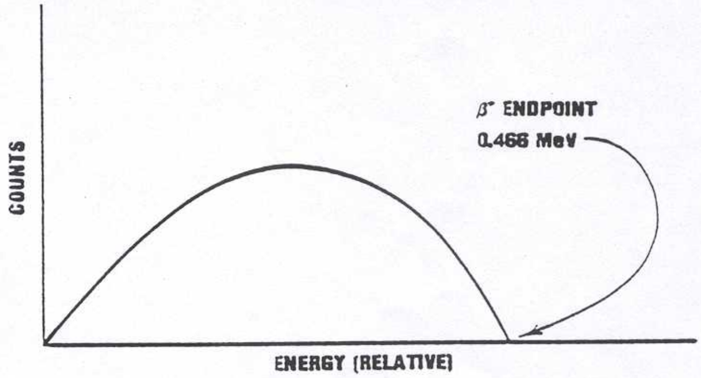

Figure 12.2. β^+ distribution from a ^{22}Na source.

In our experiment, we will encapsulate the ^{22}Na source with two converter foils to insure that most of the β^+ particles annihilate at the source. Basically the β^+ particles leave the source in an isotropic manner. When they enter the converter foil, they quickly (1×10^{-9} sec) lose energy by dE/dx in the foil. When a β^+ has essentially lost all of its energy, it finds an electron and captures that electron to form positronium which decays by the annihilation of the e^+ and e^- into two gammas. Conservation of momentum tells us that these gammas have to go off in opposite directions. This gives an angular separation of the gammas of 180 degrees. In this experiment, we will verify these conservation principles.

EXPERIMENT 12.1

Annihilation Measurements with a Multipurpose Coincidence Circuit

Discussion

From an electronic point of view, this experiment is quite similar to experiment 11. The student is urged to do experiment 11 before attempting this experiment. In the experimental procedure, we will assume that you are familiar with all of the techniques discussed in experiment 11. The only real difference is that we will use two NaI(Tℓ) detectors for the two input channels instead of the pulse generator used in experiment 11.

Figure 12.3 shows a plan view of the angular correlation table that will be used for this experiment. After the timing has been set for the electronics that will be used (fig. 12.4), it is a simple matter to fix one of the detectors and then record coincidence events as a function of $\pm\theta$. Since the annihilation radiation $\gamma_1 + \gamma_2$ leave the source with an angular separation of 180 degrees, our maximum counting rate will be observed at $\theta = 0$ in fig. 12.3. For the experiment, we will record coincidence events for the angles listed in Table 12.1. We will also make a similar table for angles on the other side of zero ($-\theta$). When we have finished with the experimental data, a plot of the data similar to fig. 12.5 will be made for the data.

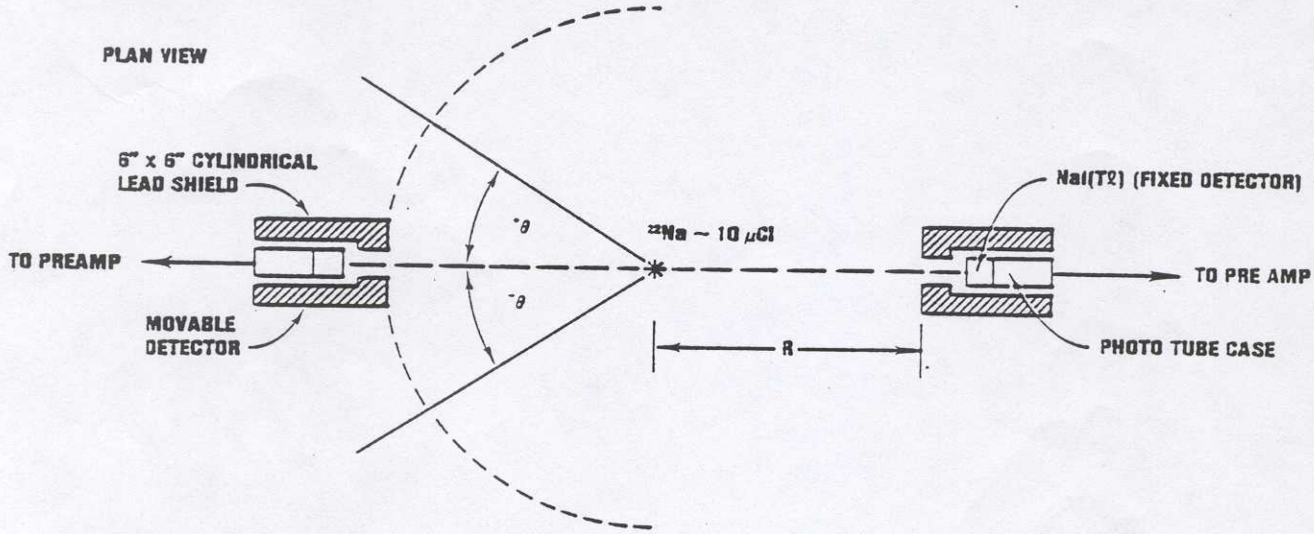

Figure 12.3. Angular correlation table with heavy rotating lead shields for the NaI(Tℓ) detectors.

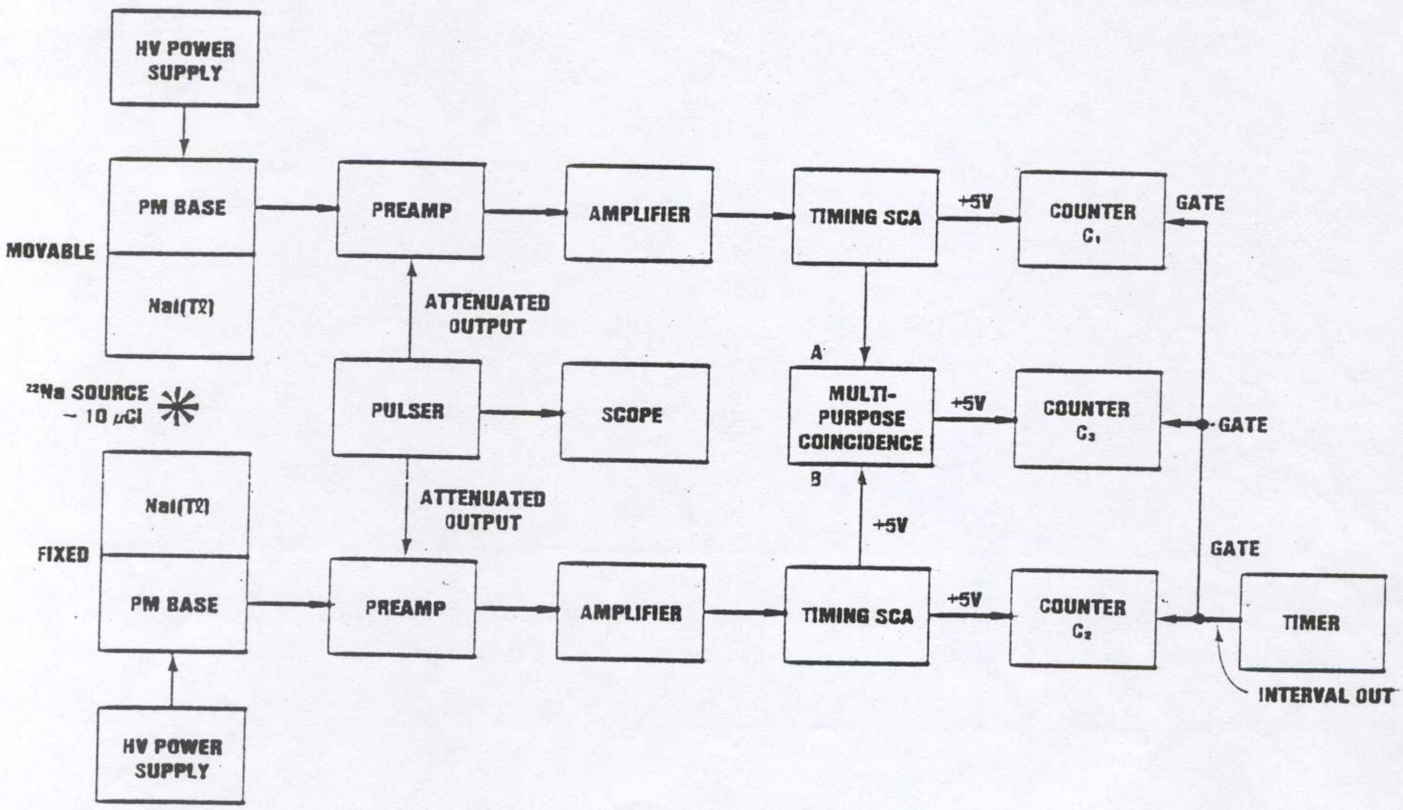

Figure 12.4. Electronics for annihilation measurements with a multipurpose coincidence circuit.

Table 12.1 Coincidence Data for the Annihilation Experiment

Run No.	+ degrees	C_1 counts/s	C_2 counts/sec	C_3 counts/sec
1	0			
2	1			
3	2			
4	3			
5	4			
6	5			
7	6			
8	7			
9	8			
10	9			
11	10			
12	12			
13	15			
14	20			

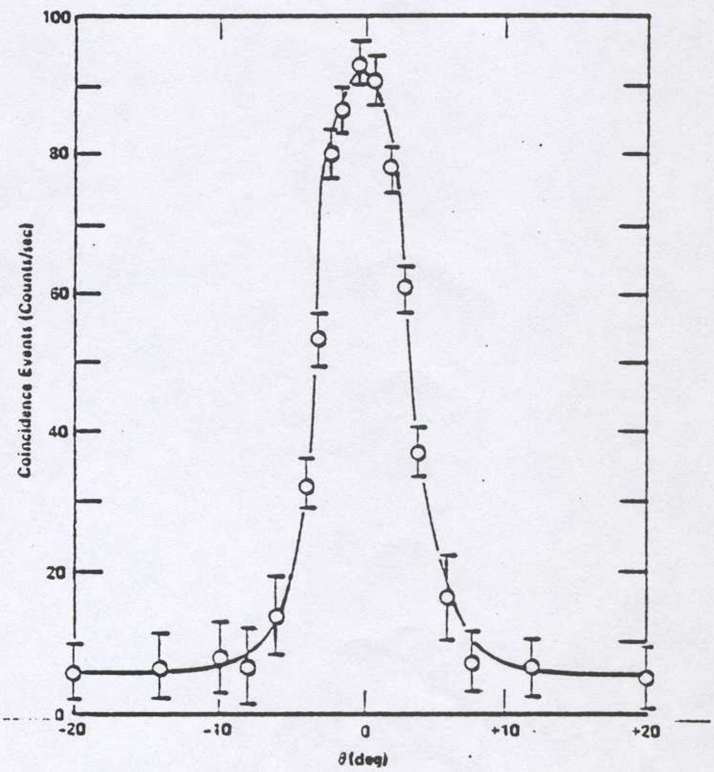

Fig. 12.5. Coincidence Data.

Experimental Procedure

1. Place the copper converter foils on either side of the 10 μCi ^{22}Na source and secure the foils with tape. Place the source in the center pivot of the angular correlation table. Adjust the high voltage on each NaI(Tℓ) detector to its recommended value. Set each amplifier on 1 μsec peaking time. Use the bipolar output of each amplifier into the SCAs. Adjust the gain of each amplifier so that the 1.274 MeV gammas are about 5 volts in amplitude.

2. Remove the source and turn on the pulse generator. Adjust the pulser so that the output pulses from each amplifier are about 3.5 volts. Set each timing SCA in the integral mode with the lower level set at 50/1000. Set the delays at minimum. Use a BNC Tee on the +5 volt logic pulse from each SCA. For each SCA, one output logic pulse goes into the multipurpose coincidence input and the other goes into the counter as shown in fig. 12.4.

3. For the coincidence circuit, set the resolving time at 250 nsec, 2 coincidence requirements, use A and B inputs, and route the F output into counter C_3.

4. Set the timer for 300 sec and start all counters. If the timing is correct, C_1, C_2, and C_3 should all give Σ/t = 0 Hz. If this is not the case, adjust the delays on the SCAs until the timing is correct.

5. Turn off the pulse generator and place the ^{22}Na source in its position on the angular correlation table. Set the SCAs LL and UL discriminators in order to isolate the 511 keV annihilation peak. Set the angle at 0 degrees and the timer at 300 sec. For each counter, determine Σ/t in counts/sec and fill in the first entry in Table 12.1. Continue for the other angular settings in the table. Repeat this whole data table for negative angles ($-\theta$) with the same absolute values as the positive angles in Table 12.1. Of course, the counting time will have to be increased for the larger angles to get reasonable statistics. If the system is lined up properly, the counting rates in counters C_1 and C_2 should remain about the same because, without the coincident requirement, we are simply looking at an isotropic source of gammas.

Exercise Plot the number of coincidence counts/sec vs θ from your data. Your angular distribution should be similar to fig. 12.5.