

Gamma-Gamma Coincidence Measurement

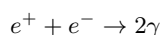
Nuclear physics lab add-on

In this add-on, you will build a more complex circuit using both the germanium and sodium iodide detectors to measure coincident gamma rays from a source. When building a complicated circuit, it is important to make sure at every step along the way, the circuit behaves as you would expect. Ensuring this will save you time in the long run.

The first source you will use is ^{22}Na , which decays by positron emission (β^+).



The positron then annihilates with an electron, producing two photons, each with energy 511 keV.



Due to momentum conservation, these photons must be emitted back to back in their rest frame. By detecting photons in coincidence at various angles, we can confirm that this is the case. To do this, we construct a coincidence circuit as shown in Figure 1.

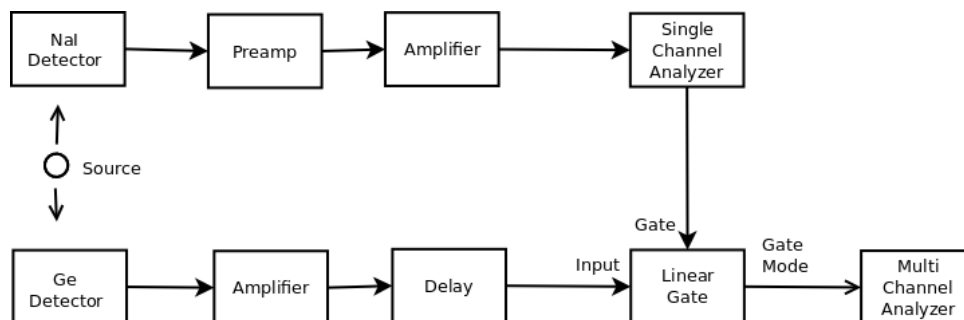


Figure 1: Gamma Gamma Coincidence Circuit

The coincidence circuit uses three new modules:

- **Delay Generator** Delays a signal for a given amount of time. An analog delay is essentially a bunch of wire in a box. Digital delays can be more complicated. We need a delay because without one, by the time we decided that we had a good signal from the Ge detector it would be too late to read the signal from the NaI detector. By delaying the signal from the NaI detector, we can read both while still ensuring that the two photons were detected at the same time.
- **Single Channel Analyzer (SCA)** Takes in an amplified signal and emits a logic pulse if the energy lies between its lower and upper thresholds. This is used to select only events where the germanium detector measures a 511 keV photon.
- **Linear Gate** Passes the signal from its input socket when a logic pulse is sent into the gate socket. The time duration during which the signal is passed can be adjusted on the module.

Setting the SCA

The first thing we have to do is to find the setting on the SCA which selects only the 511 keV peak in the NaI detector, so we can use this as a coincidence gate for the Ge detector.

- To begin: Set up a circuit as shown in Figure 2, using the ^{22}Na source. Set the oscilloscope to trigger on the logic signal from the SCA. Notice that the logic pulse comes after the start of the signal from the NaI detector. This means that we need to delay the NaI signal or else we won't be able to capture the whole signal.
- Setting the Delay: Take the NaI signal, plug it into the delay amplifier and look at the output on the oscilloscope (still trigger on the SCA output). To start, put all the switches on the delay amplifier to the left. Flip each switch, noting how this changes the signals you see on the oscilloscope. Now adjust the switches so that the NaI pulse begins at least $1 \mu\text{s}$ after the start of the SCA pulse.

- Setting the Linear Gate: Take the outputs of the SCA and delay and send them into the linear gate. Look at the output of the linear gate on the oscilloscope. With the "Gate Mode" switch set to off, you should just see the NaI signal that you put in, unchanged. When you turn on gate mode, only the part of the NaI signal that is inside the gate should show up. You can adjust the width and offset of the gate with the knobs on the module. Make the gate big enough so that the whole signal is passed, but don't make it any bigger, as this will increase the chance of random coincidences.
- Adjusting the SCA: Plug the output of the linear gate module into the PCI card in the computer (terminate with 50Ω). With gate mode off on the linear gate, you should see a regular NaI spectrum coming in. Now turn on gate mode and start taking a new spectrum. You should now see an upper and lower cutoff in the spectrum. Adjust the settings on the SCA so that only the 511 keV photopeak shows up. You now have a coincidence gate set up for the NaI.

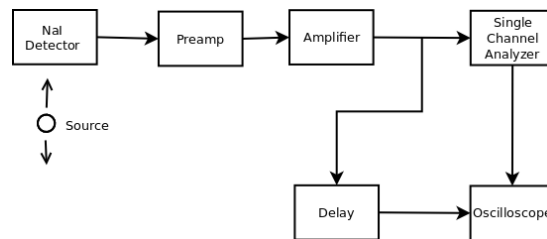


Figure 2: Circuit to set the delay

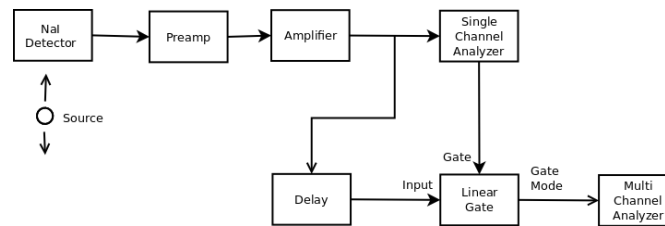


Figure 3: Circuit to set the SCA

The Coincidence Circuit

Plug the output of the Germanium detector into the other amplifier (remember to turn on the high voltage), and send that signal into the delay instead of the NaI signal (see Figure 1). Place the ^{22}Na source directly between the two detectors. Look at the signal coming out of the linear gate on the oscilloscope to make sure the signal is still within the gate. The signals you see on the scope are γ rays from the Ge detector which are in coincidence with a 511 keV γ in the NaI detector. You can confirm this by moving the NaI detector so that the source and two detectors make a right angle. You shouldn't see any more signals coming out of the linear gate. Move the NaI detector back to 180° and plug the linear gate output back into the PCI card.

The Coincidence Measurement

You are now ready to measure coincidences as a function of angle. Make sure to keep the NaI detector the same distance from the source for each measurement. As you wait for counts to come in, you can try to estimate the expected N vs. θ curve, where N is the number of coincidence counts in the photopeak. Of course, the theoretical curve is a delta function at $\theta = \pi$, but both detectors have finite solid angles, and you must account for this in order to compare with your measurement. You may also try to estimate your random coincidence rate in order to see how many counts would be consistent with zero coincidences.