K223

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1 Introduction

When a nucleus relaxes to the ground state by emitting a γ-photon, the probability of emitting in a given direction depends on its angle with the nuclear spin axis. If the relaxation happens by emitting two simultaneous photons, these show an angular correlation. This correlation can be measured, which is the goal of the experiment. To that end, first the γ-ray spectrum of the sample ($^{60}_{27}$Co) was measured, then a FAST-SLOW coincidence circuit was set up (see Figure 2).

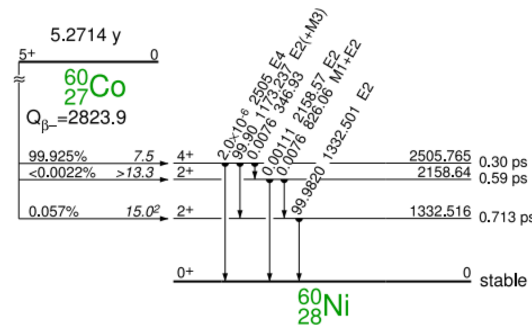

Figure 1: Cobalt decay scheme [2]

2 Theory

Figure 1 shows the decay scheme of the sample used. The $^{60}_{27}$Co (half-life $\approx$ 5.3 years) decays via β^--radiation into $^{60}_{28}$Ni; with highest probability to the 4+ angular momentum state. The lifetime of these excited Ni states are on the order of 1 ps. Decaying to the ground state follows via emitting one or more γ photons. The relaxing process with the largest branching ratio is the 4+ $\rightarrow$ 2+ $\rightarrow$ 0+ decay, produces two γ photons. The corresponding lifetimes are short enough for the emissions to be considered coincidental (from the detecting electronics point of view), and for the assumption that extranuclear forces do not cause perturbation in the correlation between the photons.

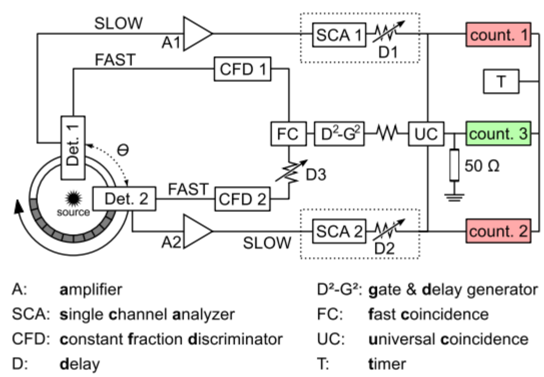

Figure 2: Experimental setup [1]

3 Experimental setup

The design of the apparatus is shown in Figure 2. A short description of the purpose and the functioning of the components follows.

3.1 Detector

The detectors consist of a crystal scintillator and a photomultiplier. The scintillator absorbs the γ-ray and re-emits visible light in form of scintillation, which induces electron emission in the photomultiplier via the photoelectric effect. The high voltage provided between the (photo-)cathode and the anode accelerate the electron, which induces an avalanche of electrons by colliding with each of the dynodes, as depicted in Figure 3. As this procedure distorts signal shape, which is required for the measurement of the energy absorbed by the scintillator, the signal on one of the first dynodes is also used as the input for the Single Channel Analyzers **SCA1** and **SCA2**.

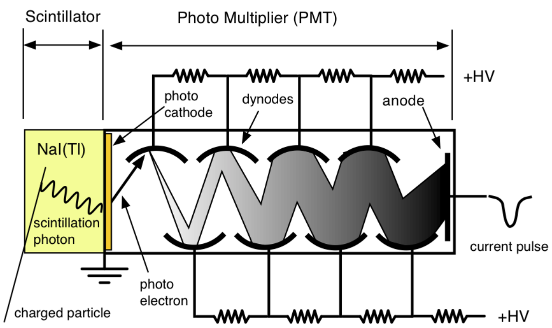

Figure 3: Scintillation detector with photomultiplier [3]

3.2 The fast coincidence circuit: Constant Fraction Discriminators

The fast coincidence circuit checks whether the two detected photons come from the same decay process. The constant fraction discriminators modify the signals as seen in Figure 4: an attenuated inverted copy of the input is added to the delayed input signal. The resulting shape crosses the 0 V line ("zero crossing point"). This point may serve as a time stamp for further processing because the result does not depend on the amplitude.

The discriminators have two outputs: while the "fast" output is a negative pulse, the "slow" output is a positive one, hence the latter is used by the fast coincidence unit **FC**, which does the actual coincidence checking. The output is fed to a gate & delay generator $\mathbf{D^2}$-$\mathbf{G^2}$, which delays the gate signal ("trigger" signal): this is required to match the output of the slow coincidence circuit, described in the next section.

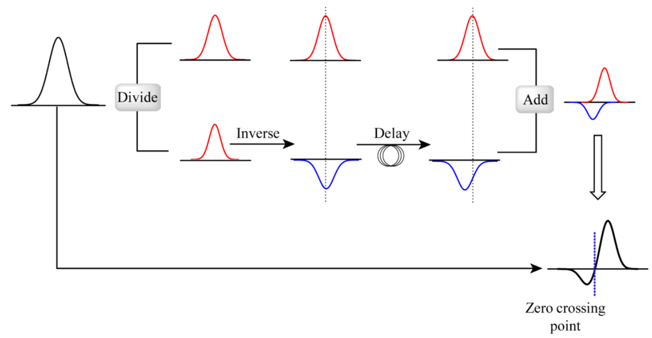

Figure 4: Scintillation detector with photomultiplier [4]

3.3 The slow coincidence circuit: Single-Channel Analyzers

The weak detector signal coming from the earlier dynode is fed through the amplifiers **A1** and **A2** first. The analyzers **SCA1**, **SCA2** determine whether the amplitudes of the signals — which are proportional to the energy of the γ-rays — fall into an interval with adjustable upper and lower limits.

4 Procedure

4.1 Amplifiers, constant-fraction discriminators

First the amplifiers $\mathbf{A}_1$, $\mathbf{A}_2$ were adjusted. We changed the gain using an oscilloscope such that the peaks corresponding to different detected photon energy levels don't hit the 9 V output ceiling of the amplifiers. The result of the adjustment is shown on Figure 5. Next we set the threshold of constant-fraction discriminators above the noise level by using the output of the CFD as the trigger for the amplifier signal of the same detector, increasing the threshold until the bright line at 0 V showing no photon detection (e.g. noise) disappeared.

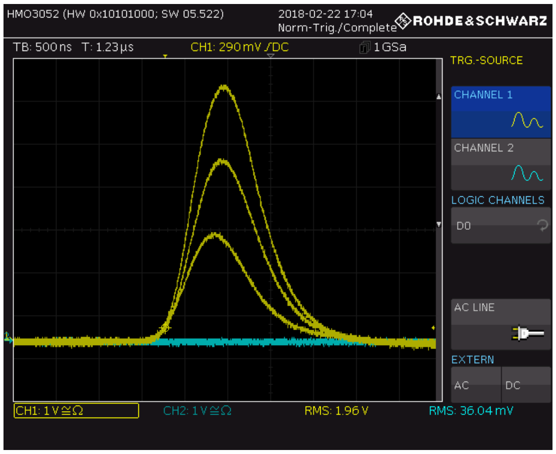

Figure 5: Well-adjusted signal of the amplifiers on channel 1. A too high gain would cause the highest peaks to flatten as saturation happens before reaching the maximum.

4.2 Fast coincidence circuit, prompt curve

We connected the CFDs' positive outputs to the fast coincidence unit **FC**, one of them through a delay unit **D3**. Keeping the resolution time of **FC** at 15 ns, we used one of the counter units and changing the delay of **D3**

References

[1] Booklet.

[2] R. B. Firestone, Table of Isotopes 8th edition (Wiley, New York, 1996)

[3] http://wanda.fiu.edu/teaching/courses/Modern_lab_manual/scintillator.html

[4] https://en.wikipedia.org/wiki/Constant_fraction_discriminator#/media/File:Operation_of_a_CFD.png