Manual for Coincidence Box

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Used for detection of simultaneous events in a GM tube. The coincidence box is used in nuclear physics and in the study of cosmic radiation.

The output of the box sends a pulse to an external counter when two (or optionally three) of the inputs receives a pulse simultaneously (meaning: within 1 microsecond).

The coincidence box can use both conventional GM tubes with BNC connectors and GM sensors with 6 mm Jack, provided that the detectors are identical. Each of the three inputs can be enabled or disabled by means of a switch.

The device is powered by the provided mains adapter.

Operation

The pulses from a GM tube are too long to be used directly for determining coincidence. Each input therefore contains a circuit that detects the leading edge of the pulse from the detector, outputting a 1 μs long pulse. (This 1 μs interval we will call the gate time τ.)

The short pulses from each channel are fed to an AND gate, and if the pulses overlap, a pulse is sent on to the output circuit where it is stretched to enable common counters and datalogging equipment to respond.

Disabling a channel simply sets the corresponding input of the AND gate high.

In most applications, in addition to the coincidence count rate you will need to know the count rate of the individual detectors. *It is very important that these are measured with the coincidence box in the signal chain* (with the other two channels disabled), rather than for example connecting the detector directly to a counter. Various input circuits will have different criteria for rejecting pulses close to the limit of detection, making their count rates incomparable.

Random coincidence

Neglecting dead time in the detection system, it can be shown that with completely uncorrelated pulses from two detectors, there will be a random coincidence rate

$$r_R = 2 \cdot r_A \cdot r_B \cdot \tau,$$

where r_A and r_B are the count rates of the two individual detectors, and τ is the previously mentioned gate time. For example: A count rate of single events of 500 s^{-1} in both channels will result in a random coincidence every two seconds.

This formula is used to correct the experimental results for random coincidences.

For a system with three detector channels in coincidence, r_R like before will be proportional to the three separate count rate, but this time multiplied by τ^2 rather than τ.

In a muon observatory, r_A, r_B and r_c will all be about 0.5 s^{-1}, causing random coincidences to occur once per 10^5 years in average.

Applications

The instrument can be used for observing muons from the cosmic radiation, which is discussed in detail in the manual for the 5142.00 Muon Observatory.

If you have access to the three isotopes Cs-137, Co-60 and Na-22, a number of interesting differences between these nuclides can be demonstrated. It is strongly recommended to create a stable setup using rails, joint link and source holder, as described below.

Cs -137

Cs-137 beta decays into Ba-137. Most of the beta radiation is stopped within the source. 94% of the decays go to an excited level, which decays with the emission of gamma radiation. (The rest of the decays go to the ground state.)

The gamma quanta are emitted completely uncorrelated; therefore this source gives coincidence count rates consistent with the formula for random coincidences.

Co-60

Co-60 beta decays almost 100 % to an excited level in Ni-60, which then decays in two steps to the ground state with the emission of gamma radiation. This source is also designed to absorb most of the beta radiation internally.

The time difference between the two gamma quanta can be neglected completely compared with the gate time. Therefore, a coincidence count rate higher than the random count rate will be observed.

Na-22

Na-22 decays by beta plus decay (89.8%) or electron capture (10.1%) to an excited level in Ne-22, which then decays with the emission of gamma radiation. The range of the positrons is so short that if they escape from the source, they are stopped by the material in the source holder (5141.95).

When positrons annihilate, two gamma quanta with exactly opposite directions are emitted.

All these processes take place on a time scale that is orders of magnitude smaller than the gate time. As was the case for Co-60, an increase in the coincidence count rate is observed, but this increase will further have a strong angular dependence: When the angle between the detector directions is, for example 90°, only coincidence between one of annihilation quanta and the gamma radiation from the nucleus can be recorded. When the source and the two GM tubes are placed in a straight line with a source in the center (180°), coincidences between the two annihilation quanta are also registered.

RECOMMENDED PRODUCTS

Observation of cosmic radiation

5142.00 Muon Observatory
Also needed: 3 large area GM tubes 5125.25 *or* 3 large area GM sensors 5135.65.
Use *identical* detectors.

Nuclear physics

5141.02 Rail for Mounting Bench (2 pcs.)
2946.10 Sliding Saddle, 1 Hole (2 pcs.)
2946.50 Joint Link
5141.95 or 5141.97 Holder for radioactive source.
Note: 5141.95 is for the radioactive sources provided by Frederiksen (threaded mount) – 5141.97 is for 12 mm cylindrical sources provided by for instance Phywe.

Also needed: 2 GM tubes 5125.15 or 2 GM sensors 5135.70. Use identical detectors. (Investing in the large area tubes offers no advantage for this application.)

Specifications

Nominal GM voltage (BNC inputs): 525 V

Supply voltage to GM sensors (Jack inputs): 5.0 V

Gate time: 1 µs + / - 3%

Output Level: 5 V

Output Pulse Width: 45 µs

Supply voltage: 12 V, 200 mA DC from the provided adapter