

Experiment 6 Information sheet

Geiger-Müller Tube

The Geiger-Müller tube (or GM tube for short) measures the incident number of energy-rich particles: α and β particles, but also X-ray and γ photons. This detector consists of a metal tube with a thin wall, with a metal wire on its axis (see Figure 1). The β particles as well as the X-ray and γ photons can enter the tube through the wall. For α particles, the tube's wall is too thick: incident α radiation is fully absorbed by the wall. For detecting α particles, the tube is therefore on one side fitted with a very thin (and thus fragile) window of aluminium or mica. The tube is filled with a gas mixture under low pressure. A power supply provides a voltage of about 500 V over the tube's wall and the central wire.

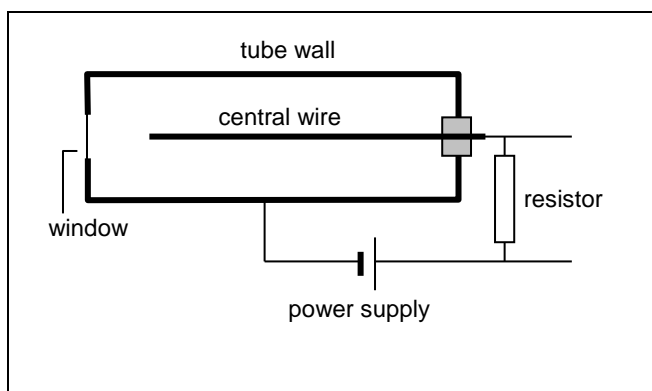


Figure 1 – The GM tube.

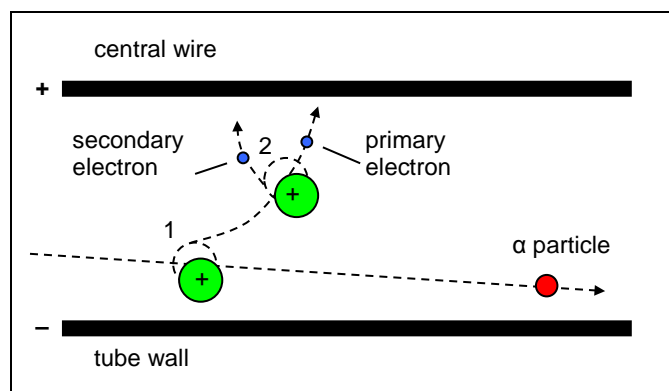


Figure 2 – The avalanche or snowball effect in the GM tube.

Operation

If an energy-rich charged particle or photon enters the tube, it will *ionise* a small number of atoms of the gas mixture. Thus, some positively charged gas ions and negatively charged free electrons are created in the tube. The positively charged gas ions are attracted by the negatively charged tube wall, and move towards the tube wall under the influence of this electric force. The negatively charged free electrons are attracted by, and thus move towards, the positively charged central wire. This process is shown in Figure 2: an α particle (red) ionises a gas atom (1), which creates a gas ion (green) and a free electron (blue). This electron is called the *primary electron*. The motion of the primary electron towards the central wire under the influence of the electric force is accelerated. Therefore, during this motion the speed, and thus the kinetic energy of the primary electron, increases. The increase of the kinetic energy depends on the voltage over the tube: the larger this voltage is, the larger is the increase of the primary electron's kinetic energy. If the voltage over the tube is large enough, also the primary electron can, on its way to the central wire, ionise gas atoms. Also this process is shown in Figure 2: the primary electron ionises a gas atom (2), which creates a gas ion and a free electron. This electron is called a *secondary electron*. In this way a so-called avalanche or snowball effect originates: one incoming energy-rich particle creates a number of primary electrons, and each of these primary electrons in its turn creates a number of secondary electrons. This results in a current of millions of electrons towards the central wire. After arriving at the central wire, they move on through a resistor and the power supply towards the tube wall. There the electrons and gas ions recombine, so that the gas mixture again fully consists of gas atoms. All of this happens in a very short period of time: about 10^{-4} s.

During this very short period of time there is a current in the resistor. This causes a voltage pulse over the resistor. This voltage pulse is amplified and detected by an electronic pulse counter. If the amplified voltage pulse is fed to a loudspeaker, it can be heard as a click.

Dead Time

During the avalanche or snowball effect in the tube, the detector is insensitive to a new incoming energy-rich particle for a specific period of time. Such a new incoming particle will ionise a number of gas atoms and thus create an avalanche of electrons and an corresponding voltage pulse. This new voltage pulse,

however, cannot be discerned from the voltage pulse caused by the particle that entered the tube somewhat earlier. The GM tube thus only detects part of the incident radiation. The period of time in which the GM tube is insensitive to a new incoming particle is called the tube's *dead time*. The order of magnitude of this dead time is the time taken by the avalanche or snowball effect: about 10^{-4} s.

Leave this information sheet at the equipment set-up