Gamma Ray Spectroscopy

In Lab 2, Radioactivity, we explored how an excited nucleus could spontaneously decay, emitting an alpha particle, a positron or electron or a gamma ray. In this lab, we will explore the nucleus decaying to a lower energy state by emitting a gamma ray. A gamma ray is a high energy electromagnetic wave. Gamma ray photons have energies in the 1 MeV to 1 GeV range, compared to photons on the order of 1eV emitted when an atom decays to a lower energy state.

Answer the following questions before continuing:

1) Why might high energy gamma rays be harder to detect than other radiation? What might be the problems? Explain.

2) Can you think of a way to detect gamma rays? Explain.

Gamma ray detection is fairly complicated. The method you will use involves scintillator crystals. When a high energy gamma photon passes through the crystal, it can produce a high energy, fast electron by one of three processes: photoelectric effect, Compton scattering or pair production. For the lower energy gamma rays, photoelectric effect dominates. As the energy increases, the Compton effect and then pair production become more dominant.

The fast electron passes through the crystal exciting ions in its path. When the excited ions decay to lower energy states they emit visible light. So the passing of a single high energy gamma photon produces a flash of light in the crystal. (This is called fluorescence.) The scintillator crystal is attached to a photomultiplier tube so that the light from the crystal goes into the photomultiplier tube.

In the photomultiplier tube, the photons eject electrons via the photoelectric effect. Instead of just collecting the few electrons ejected, the electrons are accelerated through a series of electrodes called dynodes. At each dynode, more electrons are ejected, amplifying the signal, so that a cascade of electrons is finally detected at the anode, as in the Figure below. This yields a current pulse, which is converted to a voltage pulse whose height is proportional to the number of photoelectrons and is thus proportional to the number of photons reaching the tube. This, in turn, is proportional to the initial energy of the fast electron, which is proportional to the energy of the initial gamma ray.

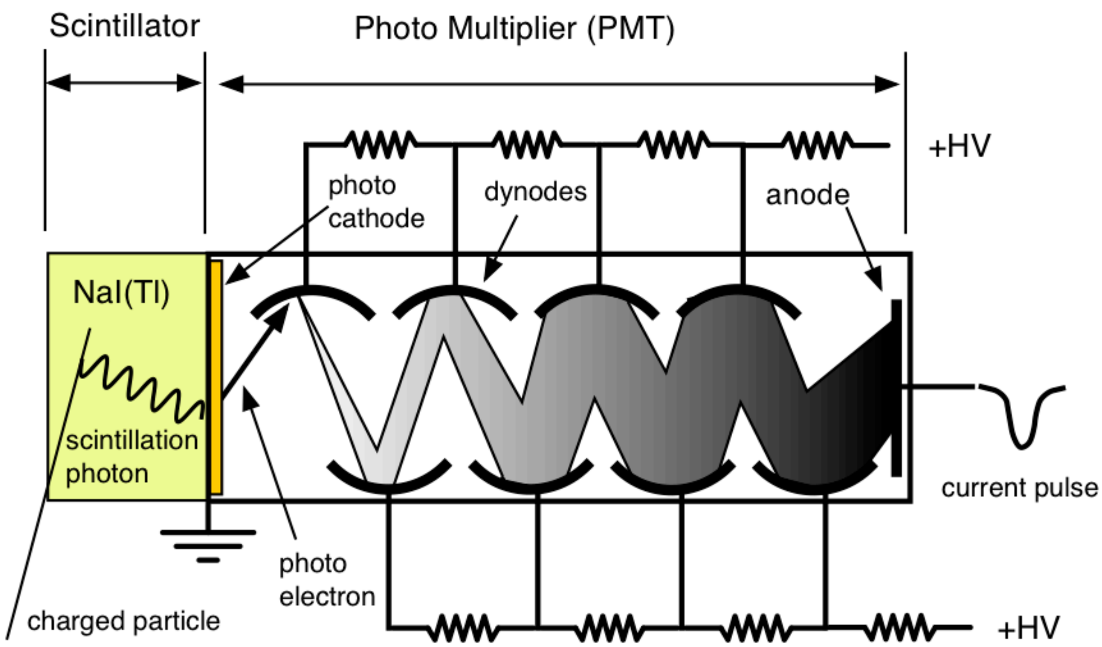

Figure from
http://wanda.fiu.edu/teaching/courses/Modern_lab_manual/_images/PMT.png

The voltage pulses are analyzed using either a single or multi-channel analyzer in order to determine the energy of the fast electrons, which is essentially equal to the energy of the incoming gamma ray.

Explain your understanding of gamma rays and how the scintillator detection process works to a TA before proceeding.