Engineering of body scanners

Gamma camera

The principal radionuclide imaging system currently available is the gamma camera. Radionuclide imaging using a gamma camera is also referred to as scintigraphy. The principle of the gamma camera was described by Anger about 40 years ago. Anger's camera formed images using analogue circuitry. Modern gamma cameras make extensive use of digital circuitry, but the underlying principles are still close to those of the original camera. However, the intervening years have seen steady improvements in the resolution of gamma cameras and improvements in linearity and uniformity, concepts described below. The method of image formation depends on whether the radioisotope being imaged emits a single γ-ray, such as 99Tc *(Technetium-99 is an isotope of technetium)*, or two opposed photons via the emission of positrons, such as those from 11C.

Introduction: Gamma Camera Components

The **gamma camera** includes the following components:

1) **The collimator,** which focuses the gamma sources onto the NaI crystal.

2) **The crystal,** which detects incoming gamma rays.

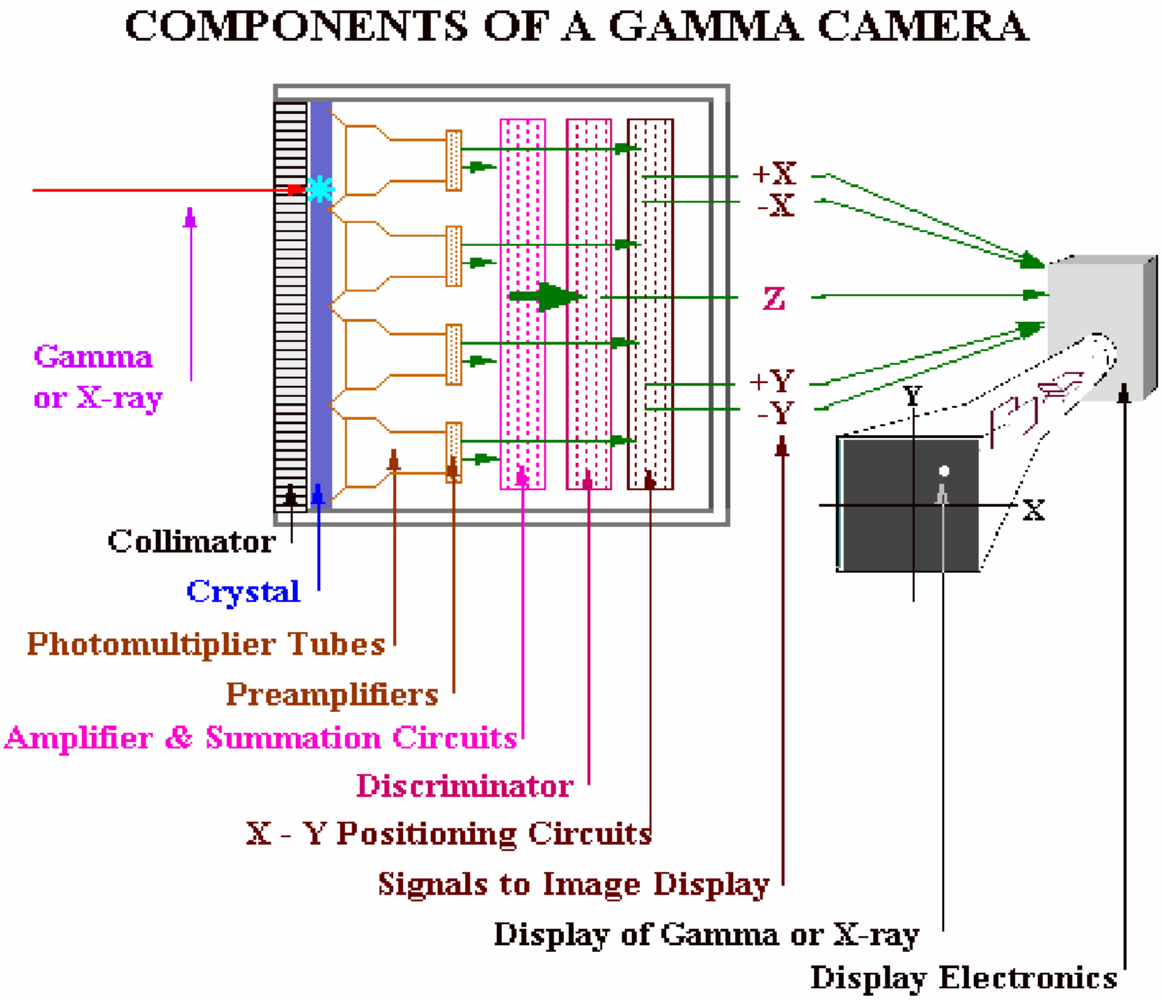
3) **Photomultiplier (PM) tubes and preamplifiers,** with convert the light produced by the interaction of the gamma ray and the crystal into an electronic signal.

4) **Amplifiers and summation circuits,** which combine individual signals and allow calibration of the gamma camera output.

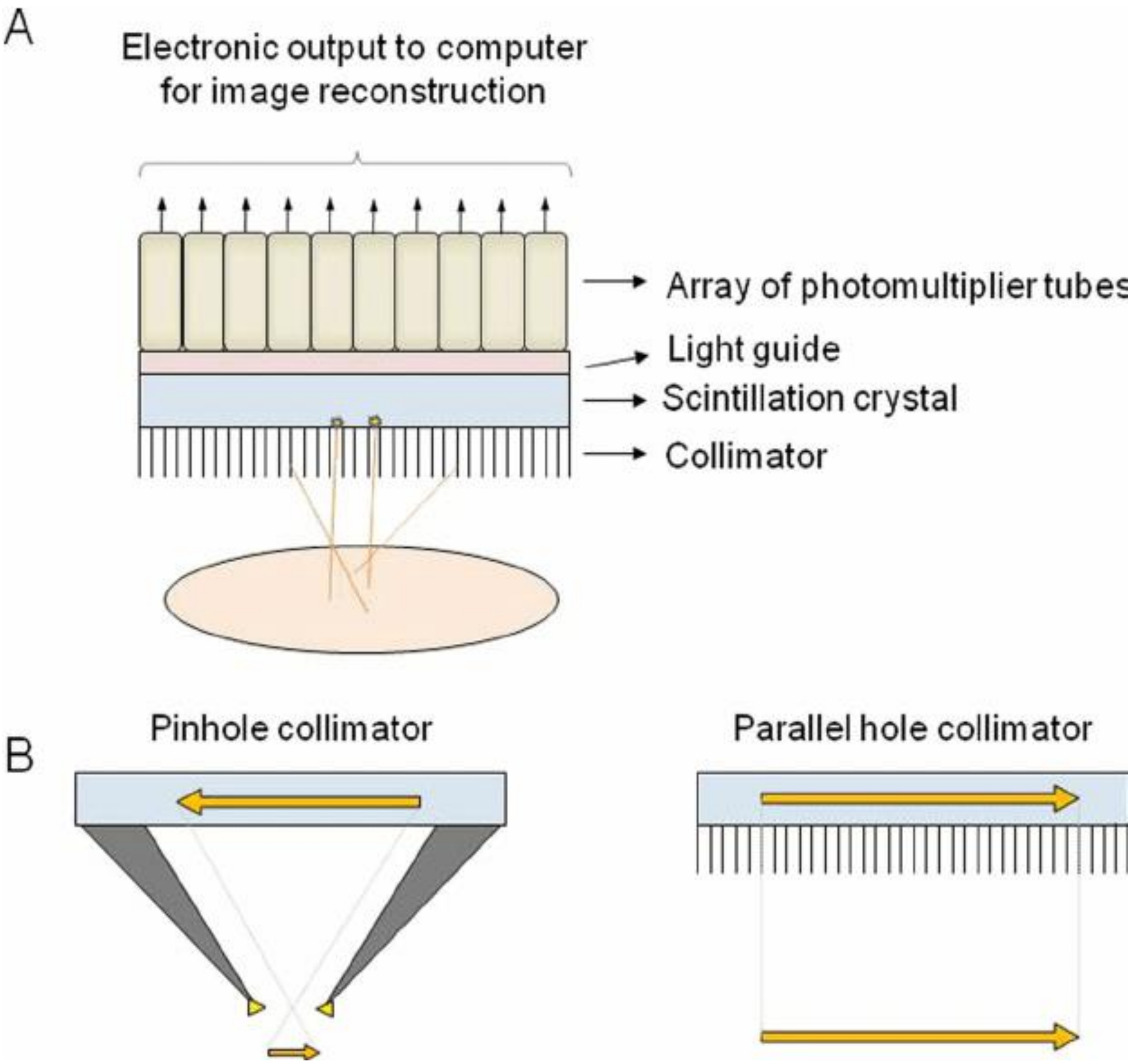
5) **A discriminator,** which ensures that only detected gammas with the appropriate energies are displayed. The discriminator emits a Z-pulse, which caries that information to the display.

6) **X and Y positioning circuits,** which examine signals from individual PM assemblies and determine the position of the gamma on the crystal. This position information is carried to the display via + X, -X, +Y, and –Y signals.

7) **A visual display with display electronics,** which depicts the corresponding position of the gamma on a screen.

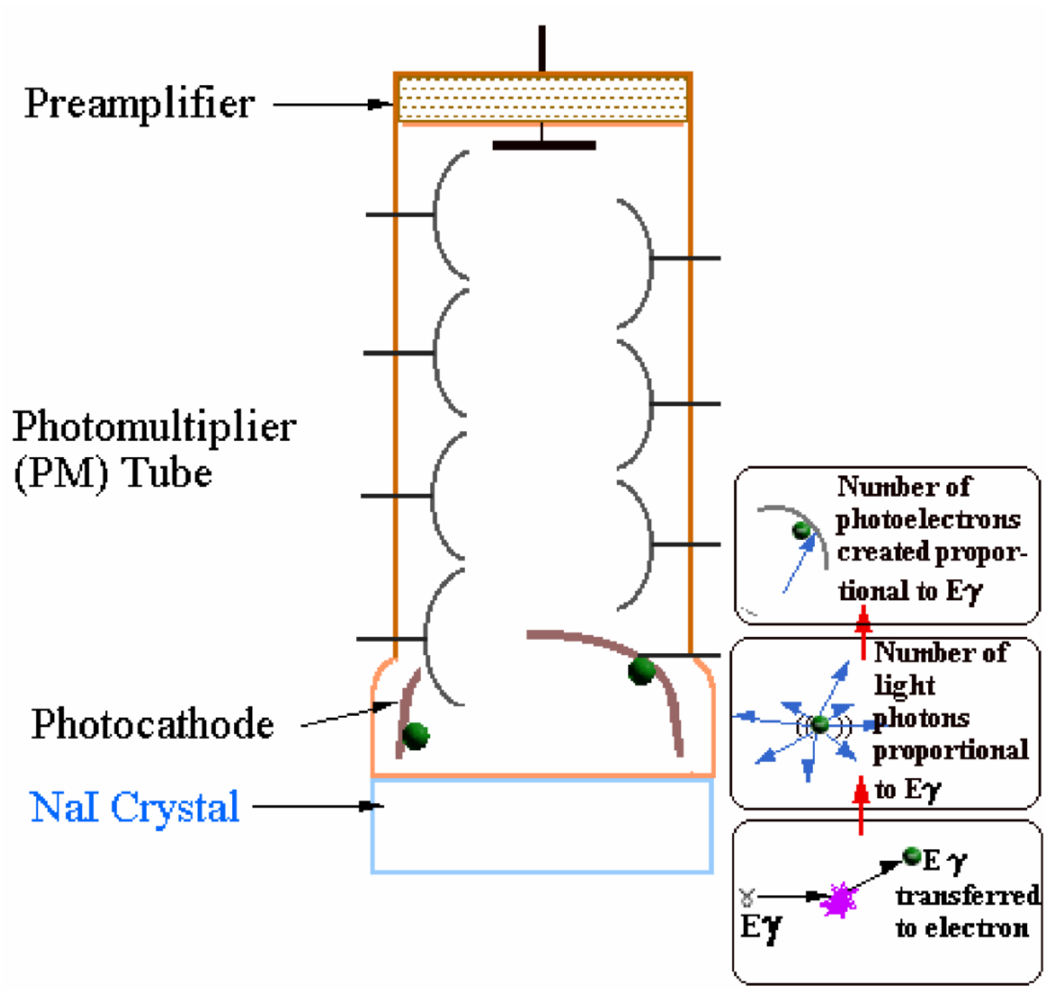


The collimator consists of a large block of absorbing material, usually lead, through which a set of parallel holes has been driven. The thickness of the collimator is typically 50 mm or so, with holes of a few mm diameter. For a 400 mm field of view there are therefore many thousands of holes. γ -rays emitted from the patient can only pass through a collimator hole if they are travelling parallel or almost parallel to the axes of the holes, otherwise they strike the side of the hole and are absorbed.



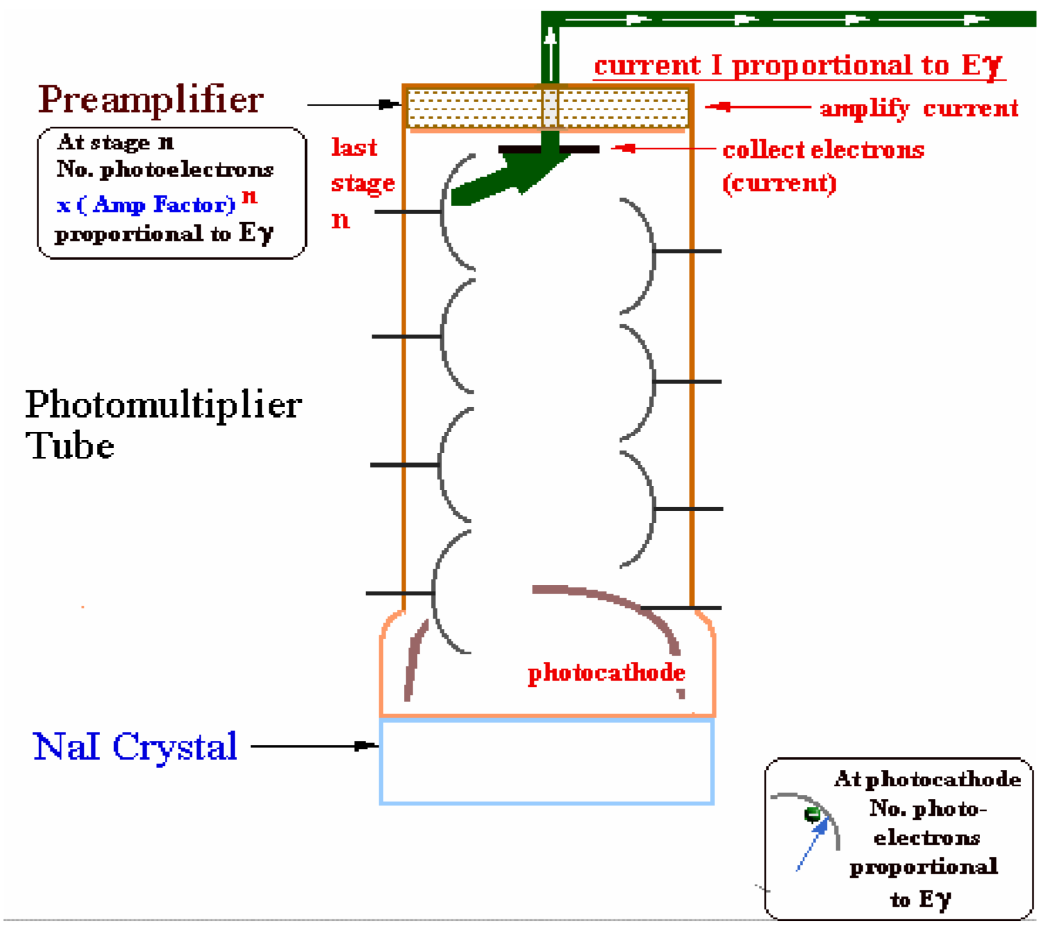
Detection by the NaI Crystal

The PM tube is the first component necessary for measuring the energy of individual incoming gammas. At diagnostic nuclear energies, the gamma or X-ray usually deposits all its energy in the Sodium Iodide (NaI) crystal via photoelectric interaction. The energy transferred to the crystal produces **excitations** that cause the emission of many lower energy light photons. The number of light photons released is proportional to the energy of the incident gamma or X-ray.



Optical-to-Electrical Signal Conversion

Some light photons fall on the light sensitive front surface of the photo multiplier (PM) tube. The number of photons that fall on this surface depends upon the size of the PM tube and its proximity to the area where the gamma ray hit the crystal. The more light photons that were produced in the crystal, the more will be detected by the PM tube. The photons that impact the surface of the PM tube knock electrons off its surface. The number of PM tube photoelectrons is therefore proportional to the energy of the incident gamma or X-ray.



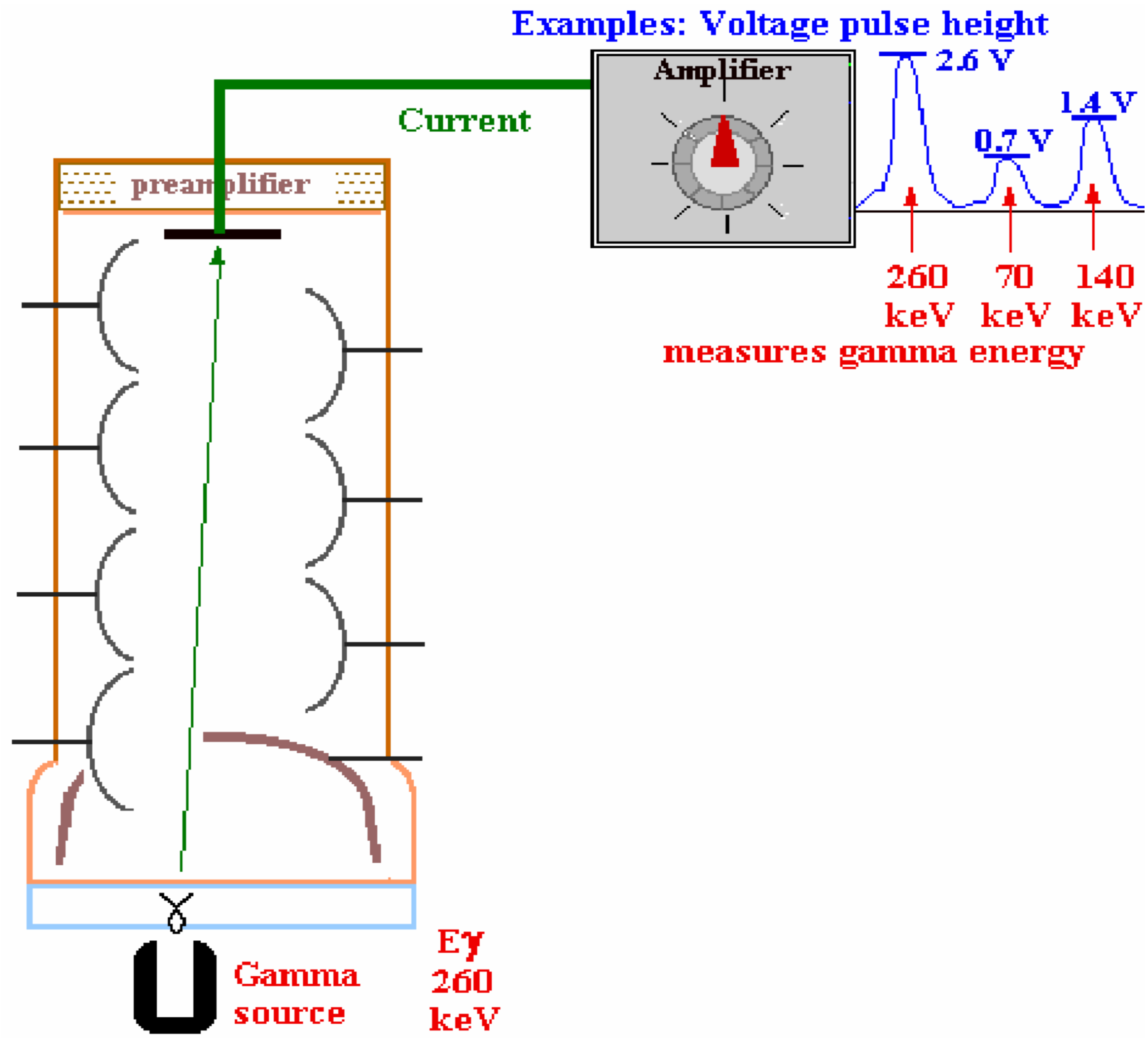
Gamma Energy Determination

- **PM Tube Signal Amplification**

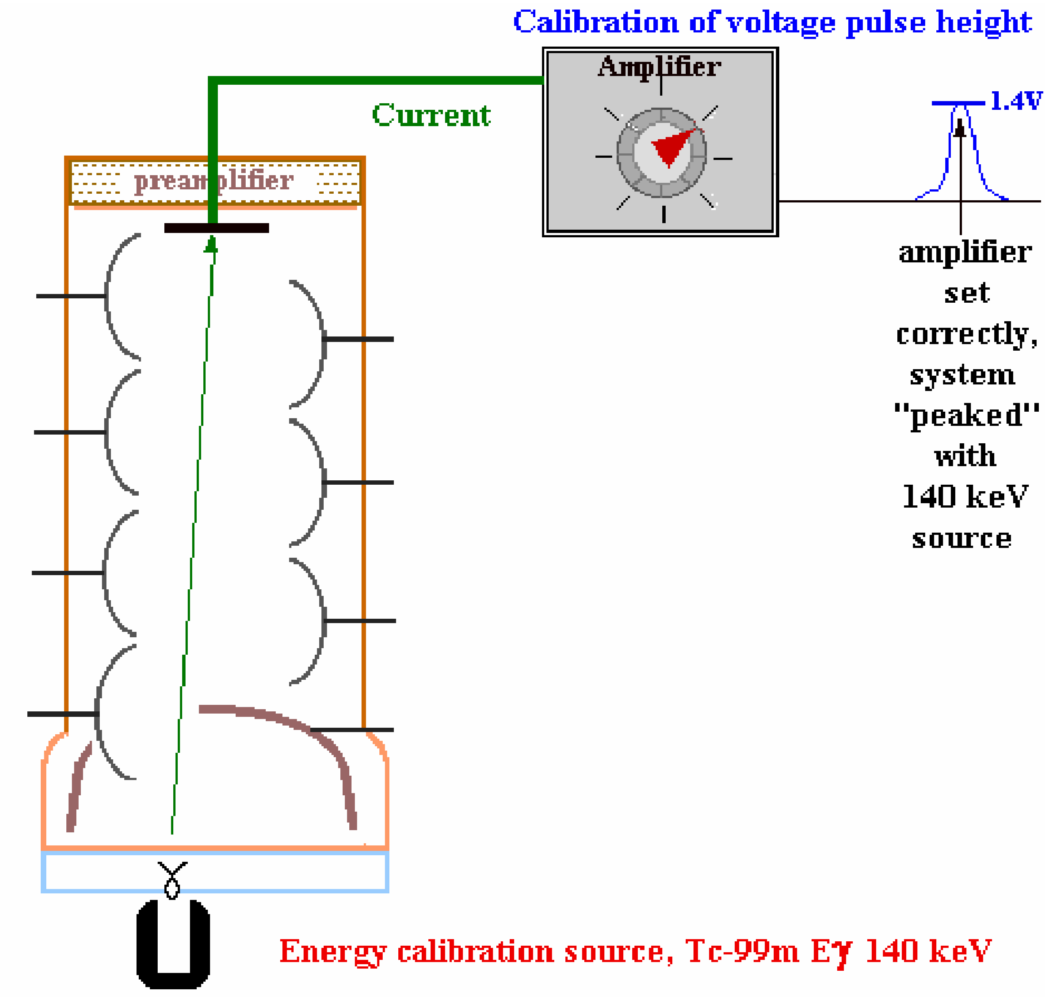
The photomultiplier tube has several stages, the first of which is the photocathode. Each stage is at a positive voltage relative to the stage before it. Electrons are ejected from one stage surface and are accelerated to the next higher stage. The energy each electron gathers during acceleration allows it to knock out additional electrons from the next surface. This produces an electron amplification factor for each stage.

- **Signal Energy Calibration**

Gammas with known energies are used to energy calibrate the gamma detection system. The amplifier is adjusted so that detected energies have a voltage signal value that is standard for that particular energy (For example, 1.40 volts for 140 keV). If the height of the voltage pulse is too high or too low, the amplifier is adjusted to standardize the height of the pulse. This process determines the energy scale. Any other energies detected will be proportional to this calibration energy (For example, 3.61 volts for 361 keV).



Examples: Voltage pulse height
Amplifier
Current
preamplifier
2.6 V
0.7 V
1.4 V
260 keV
70 keV
140 keV
measures gamma energy
Gamma source
Eγ 260 keV


Calibration of voltage pulse height
Amplifier
Current
preamplifier
1.4V
amplifier set correctly, system "peaked" with 140 keV source
Energy calibration source, Tc-99m Eγ 140 keV