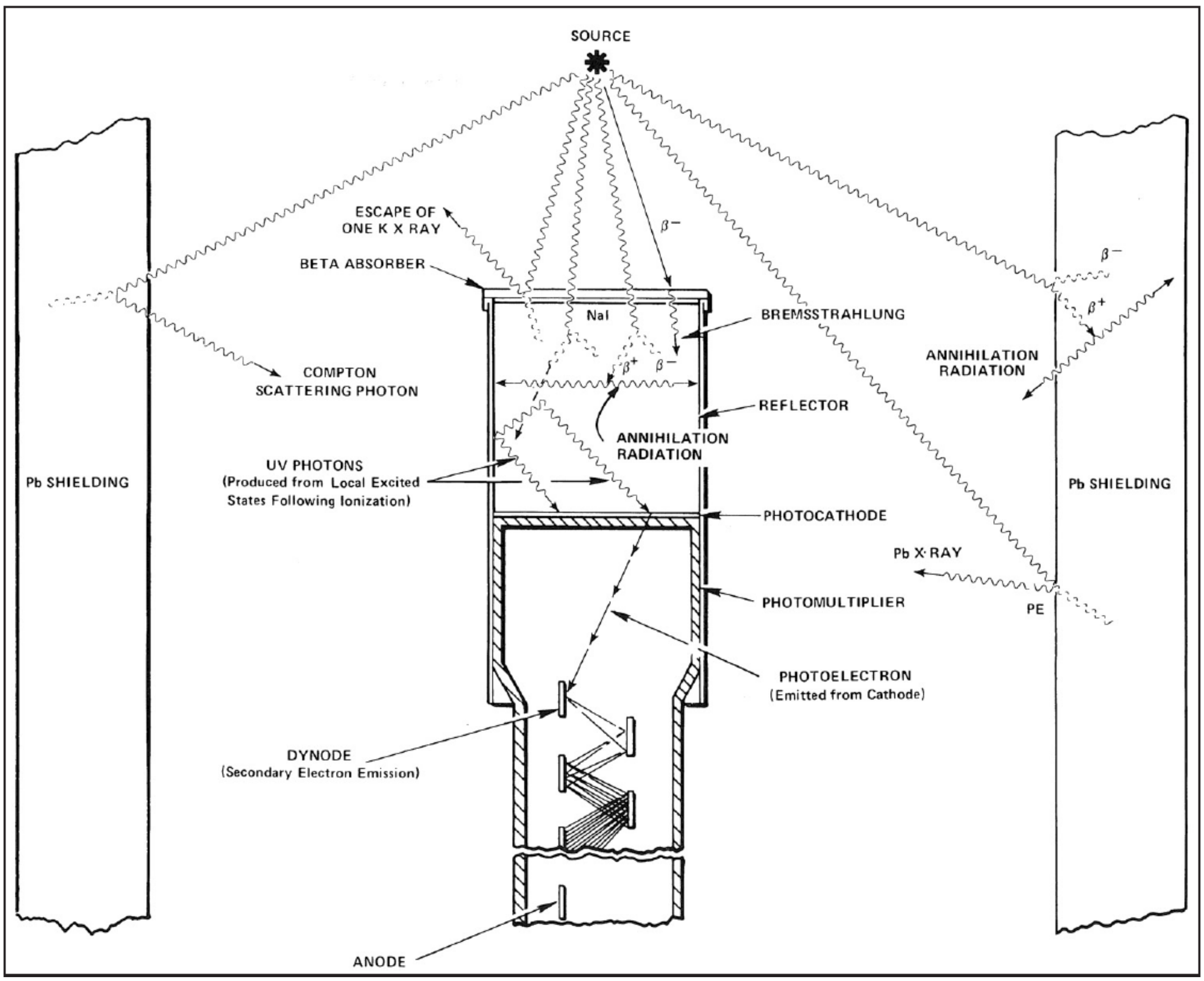
Gamma Ray Spectroscopy Pre-Lab

Your generalized experimental setup is shown below, including all possible gamma ray interactions. There are multiple conversions: gamma photon to scattered electron, electron excited doped state, decay to visible photon, visible photon to electron inside PMT (then electron multiplication), charge pulse to voltage pulse, filtered voltage pulse to threshold detector and square stretched pulse, and then to counts in amplitude bins.



Read the Guide and then answer the following questions:

[also helpful reference: Melissinos (2003) chapters 3.3.2, 8.2.5, 8.4, 9.1, 9.2]

1. From the graph near the end of the Guide, calculate the mean free path of a 1 MeV gamma ray in sodium iodide (specific gravity 3.67).

2. What is the probability that a 600 keV gamma ray undergoes photoelectric absorption in 1 cm of NaI? What is this approximately for your NaI detector?

3. The dark adapted human eye may be able to detect as few as 10 visible photons as a single flash. Will an observer with pupil diameter of 3mm be able to see individual scintillation events caused by a 1 MeV gamma ray in NaI(Tl) while viewing the surface of the scintillator at a distance of 10 cm in a dark room? Show calculations.

4. Various factors affect the energy resolution in your setup. For example, if for every incident gamma all its energy was converted into a pulse of optical photons (light pulse), and there was a 1:1 relation between the corresponding number of photoelectrons at the output of the photomultiplier tube and the intensity of the light pulse, then the energy resolution of the gamma ray spectrum would be limited only by fundamental physics. Unfortunately the actual resolution of your system is much poorer than that, i.e. there is a smearing of that 1:1 relation (in addition to other effects). Name some effects which can degrade energy resolution. What role does the Poisson statistics of the 1^{st} dynode electron multiplication play? Estimate the magnitude of that effect. [You did this earlier in your nuclear counting lab]. Show calculation.

5. Your Multi Channel Analyzer has a dead time. How does that affect the maximum radiation level you can accept in order to accurately produce a spectrum.

6. A radioactive source is placed near a particle detector. The detector counts at a rate of 10KHz, completely dominated by the radioactive source. A 2cm thick slab of aluminum (density 2.7 g/cm^3) is then placed between the source and the detector. The radiation must pass through the slab to be detected. Assuming the source emits only 1 MeV photons, estimate the count rate after the slab is inserted.