PHYS 4134, Fall 2016, Homework #6

Due Wednesday, October 19 2016

1. Scintillators

The Thallium-doped Sodium Iodide scintillator, NaI(Tl), is example of an inorganic scintillator. Calculate the radiation energy in eV deposited in the scintillator per photoelectron. [See problem 6.6]

A) The average photon from the de-excitation of an electron from the conduction band to the valence band in the crystal is 2.9 eV; calculate the photon energy in eV. [Hint: it should be 2.9 eV.]
B) 10% of the electron de-excitations result in the emission of a fluorescent photon, and 90% of these photons reach the photocathode of a PMT which has an efficiency of 0.15 photoelectrons per incident photon. Taking a single photon coming from an atomic de-excitation, calculate the radiation energy E (in eV) deposited in the scintillator per photoelectron. [See also problem 6.6]
C) You are using a Hamamatsu R594 PMT (you can see the characteristics, including the number of dynodes, at the product web page http://www.hamamatsu.com/us/en/R594.html). If the gain is X^N where N is the number of dynodes, calculate X, the secondary electron emission coefficient if the PMT is operated at 1500V where the gain is 7.4×10^5. [This "secondary electron emission coefficient" represents the average number of electrons knocked out of every stage by an incident electron.]
D) If the capacity C of the anode is 50 pF, calculate the output voltage pulse if a photon of energy E=200 keV is stopped in the scintillator crystal. [Again, see problem 6.6]

2. Neutron Counters

Plastic scintillators are examples of inorganic scintillators. In this case, we are looking at Bicron BC-400, a plastic consisting of carbon and hydrogen and more commonly known as polyvinyltoluene, or PVT. Although technically in the form $(C_{27}H_{30})_n$, we will model it as the simpler $(CH)_n$. Take the neutron scattering cross section for carbon and hydrogen to be equal and 2 barns in magnitude. The product sheet (available under the specifications tab at the website http://www.crystals.saint-gobain.com/Plastic_Scintillators.aspx provides the density. We will use a 5 cm thick piece. Your detector will only respond to scattering from protons, meaning you first have to scatter the neutrons from the C or H, and then detect the scattering protons. You can take the absorption cross section to be negligible compared to the scattering cross section. [See also problem 6.7]

3. Fission fragmentation

A nucleus of atomic number A decays by fission into two unequal fragments, f_1 and f_2. These fragments are detected in two detectors, each placed an equal distance on opposite sides of the fission source. If the flight time for f_1 is 30% less than that for f_2, find: a) the ratio of the masses, and b) the ratio of the kinetic energies of the two fragments. [See also problem 6.8]