Tutorial Questions:

1. The figure to follow shows a typical spectrum with a Ge detector, measuring the gamma spectrum of an "AmBe" source. This produces neutrons from the (α,n) reaction, but along the way produces gamma radiation. The process is:

$$ {}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + \alpha $$

The alpha is then captured on Be as follows:

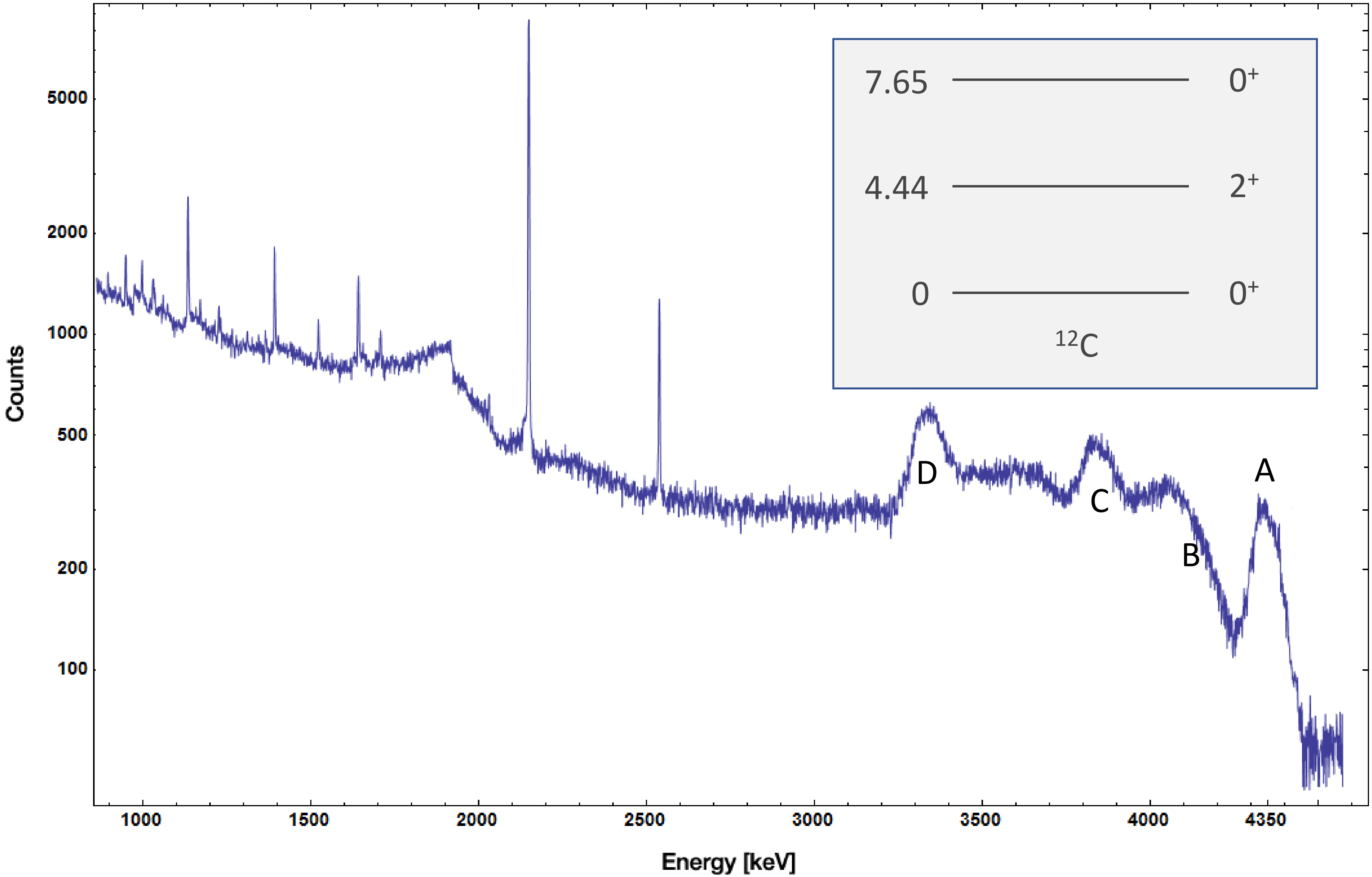
$$ \alpha + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C^{*} + n $$

This reaction has a Q-value of 5.7 MeV

The radiative de-excitation of the carbon gives off photons. ${}^{12}_{6}C^{*} \rightarrow {}^{12}_{6}C \ + \gamma$ A level diagram for ^{12}C has been included.

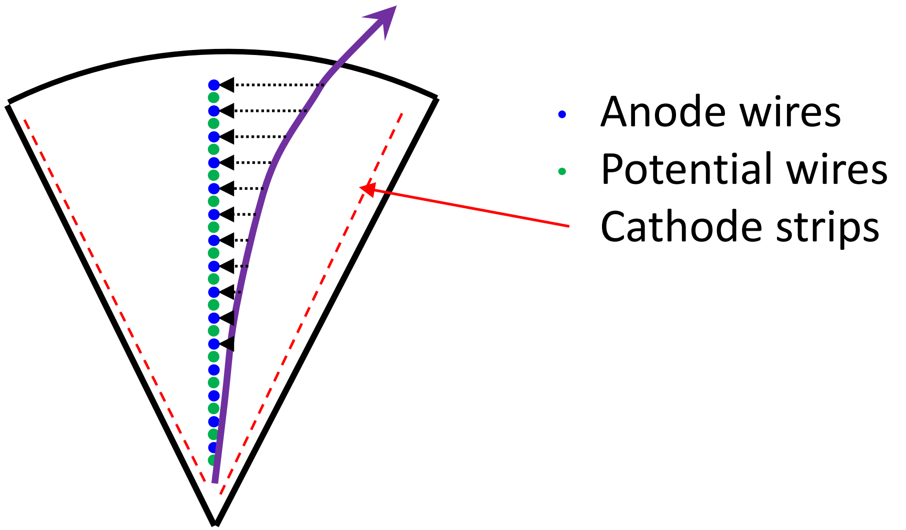
a. Considering that the Ge crystal is likely rather small and the various ways that gammas interact with matter. Can you explain the structures A through D?
b. If the spectrum were to extend further, should you expect to see other peaks? Why or why not?
c. If a different source, say ^{137}Cs were used, how would the spectrum differ?

Gamma spectrum for AmBe source measured with Ge counter



Tutorial Questions:

2. In the discussion for Jet Drift Chambers, it was stated that in a magnetic field you could measure momentum and charge.



a. How do you measure momentum?
b. What does one need to do to measure charge?

Tutorial Questions:

3. One of the open challenges for the standard model is the non-observation of glueballs. The glueball is the only particle currently predicted by the standard model that has not been observed.

Aside: Mesons are quark-anti quark pairs and they are characterized by their quantum numbers J^{PC} .

The overall angular momentum is $\vec{J} = \vec{L} + \vec{S}$

The parity depends on the orbital angular momentum $P = (-1)^{L+1}$

Charge conjugation depends on orbital angular momentum and spin $C = (-1)^{L+S}$

Glueballs, are a feature of the strong interaction that allows gluons to couple to gluons, and hence form meson like states. The lowest energy states are predicted to range in mass from 1 GeV to 2 GeV, and will have J^{PC} of 0^{++} or 2^{++}. Hybrids of quarks with physical gluons or non quark-antiquark states could exist with exotic quantum numbers.

Tutorial Questions:

a. If you found a state with J^{PC} of 0^{+-} could you claim this was not a standard meson?

b. A group has claimed the observation of a glueball, the $f_0(1500)$ 0^{++} with a mass of 1505 +- 6 MeV. **Your job is to design a detector to verify this.** Note: They claim to have seen this in the channel

$$p\overline{p} \rightarrow \pi^0 f_0(1500), \text{ and } f_0(1500) \rightarrow \eta\eta'$$

Assume you have access to a beam of low energy antiprotons you can bring to rest in a hydrogenous target. How will you build a detector to detect this?

Hint: the η and η' can decay in a variety of ways. Use the Particle Data Group tables to decide which decay channels you will focus on for your detector. What is the rational for your decisions? Would $\eta' \rightarrow \rho\gamma$ be a good choice? Why or why not?

d. Given the measured masses and their uncertainties, is $f_0(1500) \rightarrow \eta\eta'$ even possible? Likely?