

Range of Alpha's in Gasses

(Advanced)

Goal: To study the interaction between alpha particles and various gases at various pressures.

Introduction:

As an energetic alpha particle passes through matter it loses energy. This loss of energy can be the result of collisions with the nucleus or the electrons. An example of a collision with the nucleus would be Rutherford scattering. The interaction of an alpha with an electron can result in either excitation or ionization. Below energies of several hundred MEV, alphas' lose energy primarily through interactions with the electrons.

For a detailed introduction see most introductory or intermediate level nuclear / particle physics text and look for a chapter with a title like "The Passage of Radiation Through Matter" For example:

Experiments in Modern Physics, by A.C.Melissinos, p. 150-164,
Nuclei and Particles, 2nd ed. by Emilio Segrè, (Benjamin /Cumming 1977, (QC 776.S4) Chapter 2

W.R.Leo, *Techniques for Nuclear and Particle Physics Experiments, A How-to Approach*, 2nd, Springer-Verlag, Berlin, 1994 (QC793.46.L46)

Experiments in Nuclear Science AN34 Laboratory Manual 3rd, published by EG&G Ortec
An EG&G Ortec catalog for nuclear physics. An EG&G Ortec catalog is also a good starting point for a description of the electronics used.

Wall Chart of the Nuclei

Another useful source of information is the "Particle Properties Data Booklet" From Review of Particle Properties Physics Letter, North Holland Press. (See: <http://pdg.lbl.gov/rpp/booklet/contents.html>)

The Basic Experiment

A source of alpha particle (Am241) and detector are mounted in a metal case that can be evacuated. The separation between source and the detector can be varied. The detector is a surface barrier detector that produces an output signal

proportional to the energy of the incident alpha particle. One measures the number of alphas that reach the detector and the distribution of energies of these alphas while varying separation distance, the gas pressure and maybe the type of gas. See *Experiments in Modern Physics*, by A.C.Melissinos, p. 214-217, or EG&G Ortec's *Experiments in Nuclear Science 3rd AN34*, Experiments 4 and 5. This latter reference gives an excellent introduction to the general procedure associated with this experiment.

These measurements are most easily made using an amplifier to increase the size and improve the shape of the pulse from the detector and a multichannel analyzer (MCA) to record the data.

A discussion of the basic principles of operation for a surface barrier detector can be found in *Experiments in Modern Physics*, by A.C.Melissinos, p. 208-214

Warnings:

- Do NOT open the case containing the detector and alpha source!
- When applying bias voltage to the detector, watch the signal on the scope and see the noise decrease This implies that one must first be seeing the noise on the scope with no bias voltage.
- Anytime one changes detector bias, the pressure in the vacuum chamber, or the source to detector distance, always watch the signal on the scope for any dramatic change in the signal due to some failure.
- Do not overvoltage the surface barrier detector. (45 volts max.)
- There are several different types of connectors on the coaxial cables. Do NOT mismatch male to female connectors

Hints

Consider the advantages and disadvantages of using AC coupling of the inputs to the scope.

In cables to the oscilloscope should be as short as possible. **WHY?** In practice the "Tee's" in the coaxial cable should be connected directly on the

BNC connectors on the scope.

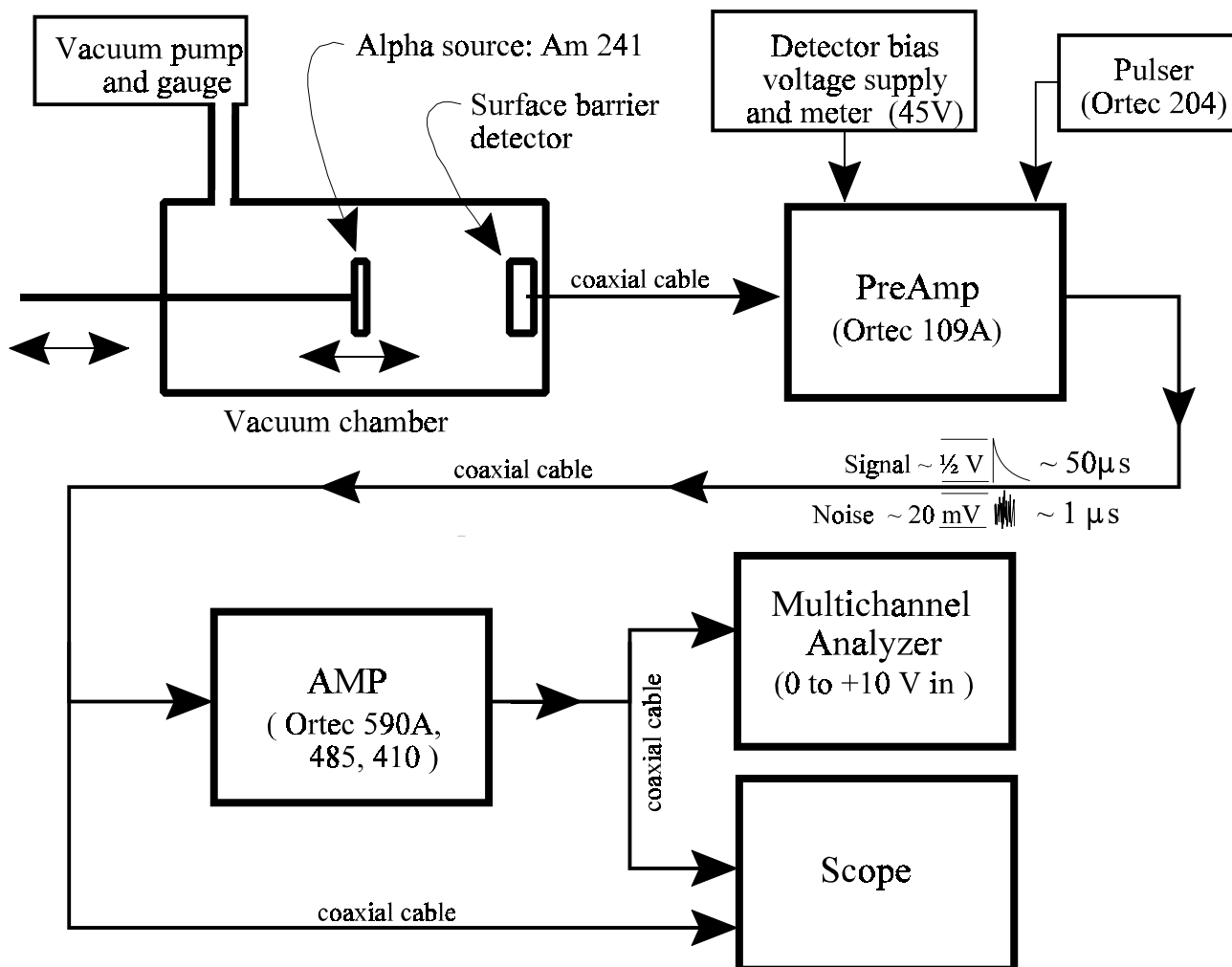


Figure 1 Basic equipment setup for measuring the range of alpha particle in a gas.

Getting Started

Below are some workable but NOT optimal setting for some of the electronics:
 (Before starting, pump down the vacuum chamber, set the source to detector distance to 1 cm, and check that the detector bias supply is OFF and turn to minimum.)

PREAMP 10X

Detector bias voltage: 45 volts

Pulser setting

- Use attenuated output.
- POWER and RELAY ON
- Normalization 0.0
- Pulse Height 2.0

- Precision Attenuation factors Off=DOWN

AMP settings:

- The AMP settings can be estimated from the size of the signal from the PREAMP (about + ½ volt) and the input range of the MCA (0 to +10 volts).

MCA settings for ORTEC 7100

- DIR (Rather than AMP) This results in an Input range of 0 to +10 volts. Use the 3 key sequence:

AMP /DIR AMP /DIR TERM

- Conversion Gain: 1024 (the default)
- Offset: 0 (the default)
- Use PHA mode to collect data. Use the 2 key sequence:

RUN PHA

- To erase data use the 3 key sequence:
0 GOES INTO ALL

Calibrating the pulser

The height of the pulses can be calibrated to read in MeV and used as a standard to determine the energy of the α 's detected by the surface barrier detector.

1. Using the MCA gather the α spectrum for Am 241 (good vacuum, minimum range).
2. On the pulser, first set the Pulse Height to the numerical value of the energy (in MeV) of the dominant α branch. Set the Precision Attenuation toggle switches in the off position. Finally adjust the Normalization knob in such a way that the position of the pulser pulses is recorded in the peak channel of the dominant α 's.
3. Lock the Normalization knob!
4. Now the pulse height dial reads in MeV This will remain true even if the gain of the amplifier is changed or the Conversion Gain or the Digital Offset on the MCA is changed (unless the Normalization or Precision Attenuation on the pulser are changed).

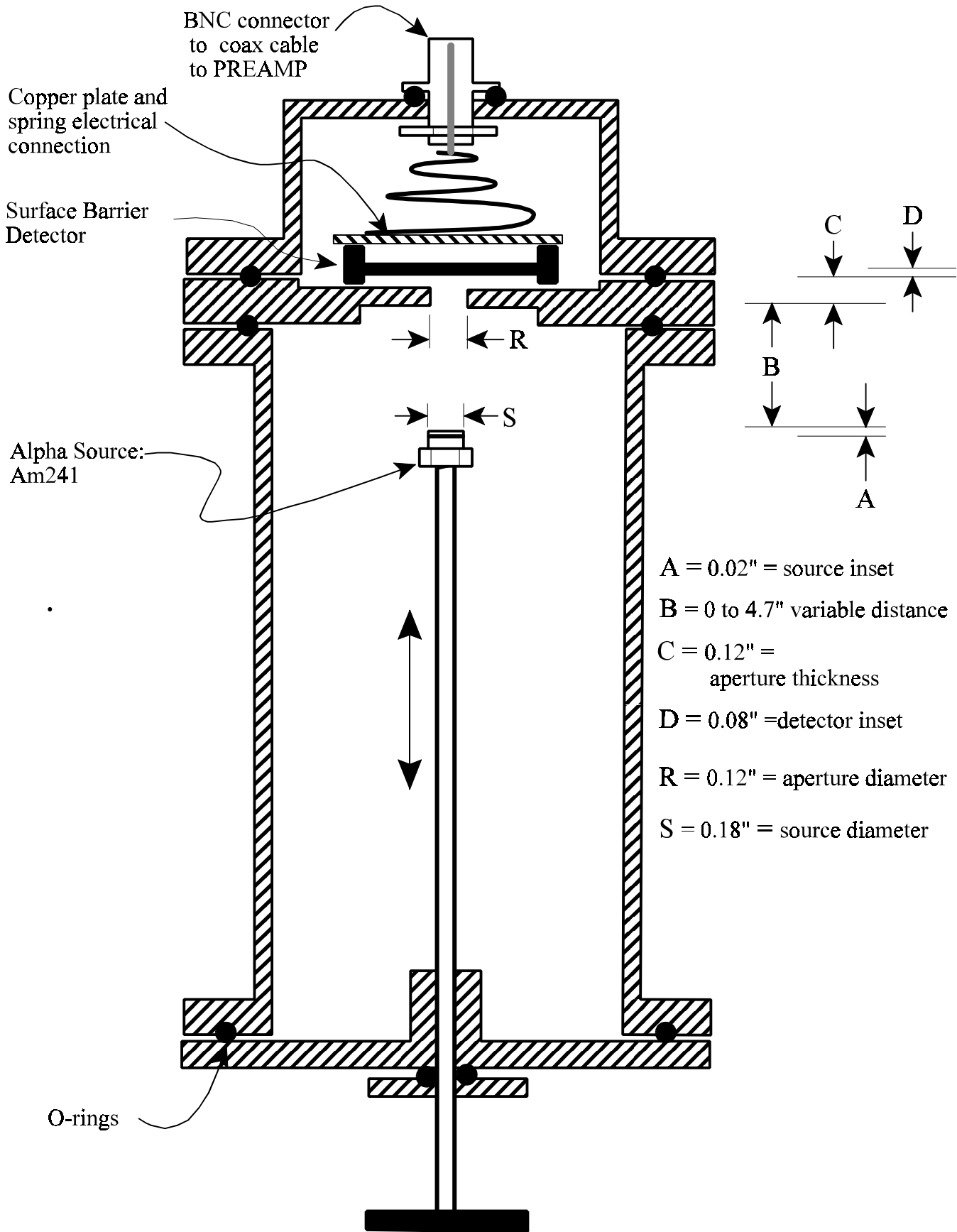
Experimental Task

1. Measure the number and energy distribution of α 's as a function of distance (at a low pressure). Compare this to the expected naive $1/r^2$ variation. Consider this problem in terms of the information in given in Fig (3).
2. What is the absolute activity of the α source?
3. Determine the energy loss per unit distance at a given energy, $\frac{dE}{dx}(E)$, for a fixed pressure (choose this pressure carefully). Determine this from the distribution of the final energy of the α 's as a function of distance, and noting that the average energy decreases with distance
4. Repeat part 3 for different pressures and try to determine a "LAW" that governs the energy loss in terms of: the current energy

of the α , and electron density in the gas.

Questions:

1. How does a surface barrier detector work? Why is the size of the pulse produced by a surface barrier detector proportional to the energy of the detected α ?
2. Why use coaxial cables?
3. What does a charge sensitive PREAMP do?
4. How is the shape of the signal from the PREAMP changed by the AMP? What aspects of the original signal are preserved?
6. Compare the shape of the signal from the surface barrier detector and the pulser.
5. How does the dead time of the MCA affect this measurement?
6. On the MCA, how can one use the conversion gain and the digital offset to increase resolution (Channel / MeV)?
7. How is the number of ions produced in the gas related to the energy lost by the passing α ?
8. If an alpha is stopped in a length L of gas, where along that path is the most energy deposited per unit distance? How could this be applied to medical radiotherapy?
9. As an α passes through a gas is the dominate interaction for energy loss with the electrons or with the nuclei?
10. Fig (3) illustrates the problem of determining the flux of α 's at the detector based on geometry of the combination of the source, detector and aperture. (Assuming a good vacuum, so that there are no losses in the gas.) Attempt to solve this problem. (analytically or simulation)



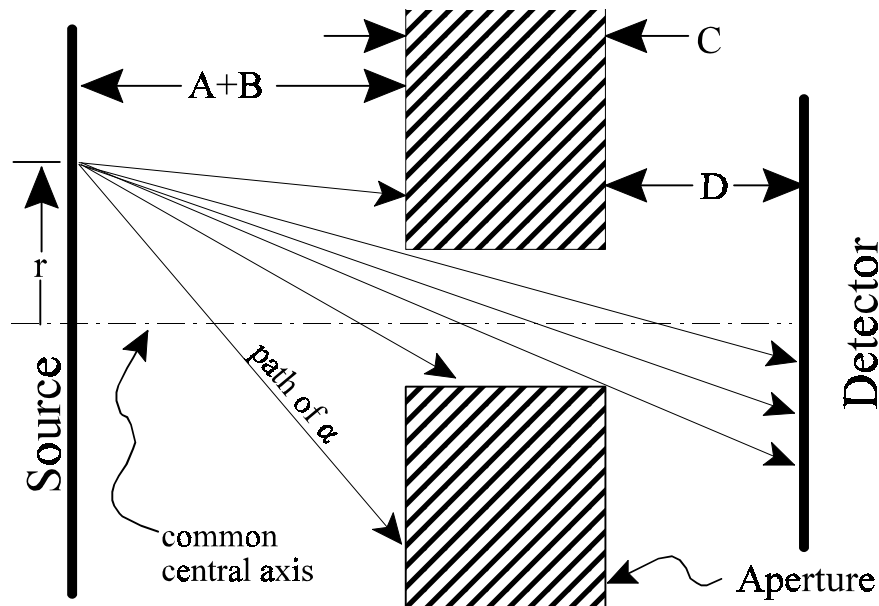


Figure 3 Geometrical factor An exaggerated view of the geometry illustrating the breakdown of the $1/r^2$ intensity law when the source is NOT a point source and the presents of finite thickness aperture. Note the distances A, B, C, and D are given in Fig (2). The source can be considered an infinite collection of point sources, and then one can integrate over the surface of the source. As r increases, the percentage of α 's emitted at a point that reach the detector decreases until all emitted α 's are blocked from reaching the detector. See Sullivan, J.D., "Geometrical Factors and Directional Response of Single and Multi-Element Particle Telescopes" Nuclear Instruments and Methods 95 (1971) 5-11 North-Holland Publishing Company.

Americium 241

Half life 458 years

Decays to Np 237 by emitting an α with the following energies and branching percentages:

5.378 MeV	1.4%
5.433 MeV	13.6%
5.476 MeV	84.4 %
5.503 MeV	0.21%
5.546 MeV	0.34%