Laboratory 3: BF_3 Proportional Counter

Objectives

- Be able to connect and place a BF_3 proportional counter in operation
- Understand the physical processes that occur within a BF_3 detector for detection of thermal neutrons
- Be able to describe the features in a theoretical BF_3 spectrum for an infinitely large detector, medium-sized detector, and small detector
- Understand how BF_3 proportional counters can be used in conjunction with moderating material to measure a neutron spectrum

Equipment

- BF_3 proportional counter
- 1 Ci ^{239}PuBe source with moderator
- Lynx box
- Attenuator
- Ring stands and clamps
- Lucite moderating cylinder set
- Cadmium cylinder
- Meter stick
- Ion and neutron radiation survey instruments

Precautions

- ☠ Do not connect/disconnect bias cables with the high voltage energized; this can cause damage to the detector or electrical shock
- ☠ **Do not energize detector until set up is verified by TA or instructor**
- ☠ Observe proper source handling techniques

Reading

- Knoll Chapter 7 (207-218)
- Knoll Chapter 4 (124-126)

Procedure

The following is a block diagram for the BF_3 proportional counter system.

Figure 1 Block Diagram for the BF_3 Proportional Counter System

The following is a description of the connectors used for set up of the BF_3 proportional counter system

Table 1 Description of Connectors for Components

Component 1	Connect with	Component 2
BF3	SHV	Preamplifier
Preamplifier (HV in)	SHV	Lynx Box (HV +)
Preamplifier (Signal)	BNC	Lynx Box (Energy)

1. Set up detector system as shown in Figure 1 and Table 1

☠☠☠ *Check set-up with Instructor or TA before proceeding* ☠☠☠

2. Set the coarse gain to 100 and the fine gain to 1.25

Characteristic Curve

1. Use a 1 Ci ^{239}PuBe source located in a moderator by inserting detector into the paraffin-filled barrel
2. Set count time for 30 s and count at 100 V increments up to maximum voltage listed for the detector.
3. Determine the operating voltage

Use of Moderator

A set of Lucite cylinders and the ^{239}PuBe source will be used to determine the effects of moderating material.

1. Reduce the applied voltage to zero
2. Wait at least 30 s before disconnecting the detector cable
3. Disconnect detector cable and place the detector in the wood/Lucite stand
4. Reconnect the detector and increase the high voltage to the determined operating voltage
5. The instructor will remove the ^{239}PuBe source form the moderator and place it 25 cm from the detector
6. Use the survey instruments (Ion chamber and Rem-Ball) to measure the exposure and/or dose rate from the source. Use the instrument to determine what conditions exist: “Radiation Area”, “High Radiation Area”, “Very High Radiation Area”
7. Make 1 minute counts for each Lucite thickness (omitting the smallest Lucite cylinder)

8. Make 1 minute counts with the full set of Lucite cylinders in place with the following modifications:
    a. With a small-diameter cadmium shield around the detector
    b. With a large-diameter cadmium shield around the outside of the set of the Lucite cylinders (remove the small-diameter shield around the detector)
9. Make a 5 minute background count for each of the following conditions:
    a. With all Lucite cylinders in place (remove the cadmium shield)
    b. With no Lucite cylinders (bare detector)

Spectrum

1. Reduce the detector high voltage to zero and remove the detector from the stand
2. Reconnect the cable and restore the high voltage to the operating voltage
3. Place the detector into the moderator
4. Start counting and adjust the gain so that the highest peak is in channel 231
5. Obtain a spectrum for 10 minutes
6. Save the spectrum for later analysis

For Laboratory Report include:

Results

- Provide a graph of your characteristic curve data. Label the operating voltage.
- State the value selected for the operating voltage.
- Provide a graph of count rate versus Lucite moderator thickness.
- Provide a graph of the pulse height spectrum produced by thermal neutron interactions in the small and medium sized BF_3 tube. Identify key features and energies in the spectrum.

Discussion

- Explain the results of the Lucite moderator experiment.
- Report the results of your experiments with cadmium. Explain your results. Explain how a BF_3 detector can be used as a fast neutron monitor.
- Compare the predicted pulse height spectrum for the small and medium sized tubes with the measured pulse height spectrum.

References

[1] G. F. Knoll, Radiation Detection and Measurement, Hobokem: John Wiley & Sons, Inc, 2000.

[2] H. Cember and T. Johnson, Introduction to Health Physics, McGraw-Hill Companies, Inc, 2009.

Appendix A: Data

System #: _____

1. BF_3 Detector Information .
    a. Manufacturer: _____
    b. Model: _____
    c. Serial number: _____
2. Amplifier.
    a. Coarse Gain setting: _____
    b. Fine Gain setting: _____

Characteristic curve data:

Do not exceed 1500 V!

Applied potential (V)	Counts in 30 s
0	
100	
200	
300	
400	
500	
600	
700	

Applied potential (V)	Counts in 30 s
800	
900	
1000	
1100	
1200	
1300	
1400	
1500	

Operating voltage: _____ V

Survey

1. Ion-Chamber instrument:
    a. Make & model: _____
    b. Serial #: _____
    c. Calibration date: _____
    d. Measured exposure rate: _____ mR/h at _____ cm from source.
2. Neutron instrument:
    a. Make & model: _____
    b. Serial #: _____
    c. Calibration date: _____
    d. Measured exposure rate: _____ mR/h at _____ cm from source.

☐ Radiation Area ☐ High Radiation Area ☐ Very High Radiation Area ☐ None apply

Neutron moderation (using Lucite cylinders):

Cylinder ring number	Lucite thickness (cm)	Counts in 1 min
0	0.00	
2	0.24	
3	0.87	
4	1.49	
5	2.10	
6	2.71	
7	3.32	
8	3.93	
9	4.57	
10	5.14	
11	5.73	
12	6.28	
13	6.92	
14	7.55	

1. Cadmium cylinders:

Cadmium position	Counts in 1 min
Around BF_3 detector	
Around outside of Lucite cylinders	

2. Backgrounds:

    a. Background count with moderator (all Lucite cylinders in place): _____C/5 min

    b. Background count without moderator (no Lucite): _____C/5 min