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SPS Chapter Research Award Final Report

Project Title	Neutron Radiation Around an AmBe Source at Massachusetts General Hospital
Name of School	Suffolk University
SPS Chapter Number	6917
Total Amount Awarded	$2000.00
Total Amount Expended	$2000.00
Project Leader	John Thomas

Abstract

Please enter the abstract of the accepted proposal.

There are multiple implementations in determining neutron radiation of both an AmBe source and a 15 MV medical linear accelerator (LINAC). These detection methods include: the use of high purity metal foil activation:, bubble neutron detectors, and an organic liquid scintillator. These methods will allow us to understand the neutron energy spectrum. The new organic liquid scintillator is expected to determine the ratio of the neutron and gamma production as well as the total count for each in a 200 keV to 22 MeV window using pulse shape discrimination. The neutron bubble detectors are expected to provide evidence of a 1/r^2 distribution for neutrons within the same energy range. The high purity metal foils will be layered to allow for localized energy neutron capture.

Statement of Activity

Overview of Award Activity

The purpose of the project is to determine the neutron radiation of an AmBe source with the help of BD-PND bubble neutron detectors as well as the method of blocking neutron radiation by using polyethylene sheets as the protecting material. This project is the main focus of what the team has been aiming from the start, which is finding ways to block the scattering neutron from a radiation source. With the help of the results from previous parts of the project in last semester, we can use the average values of the AmBe source's activity and compare them with the values with get after using polyethylene sheets as blocking materials. Six BD-PND bubble detectors were used to determine different effectiveness of polyethylene on blocking neutrons by placing them in different ways (one layer of sheet, two layers of sheet, a cube of sheets, ...). The obtained results are expected with different number of bubbles in different detector.

The project was more straightforward than the chapter thought it was going to be, this was because all of the preparation and practice that the team did before going. The polyethylene sheets were cut to equal thickness for shielding tests. Groups were in charge of each individual BD-PND bubble neutron detector, to make sure all were removed after the proper duration of exposure. The apparatus used had already been constructed from a previous year and was repurposed to hold BD-PND bubble neutron detectors and sheets of polyethylene equidistant to the source.

We accomplished creating a digitizer for the oscilloscope, running several experiments and presenting our preliminary results at APS April. We did not meet all of our goals simply because of time, when seniors are graduating and applying for graduate school, it is hard to find time for all of us to go and conduct research. Additionally, many of the bubble detectors we initially had expired meaning we could not use them to properly collect data. In total we had 12 people involved in the project, all members of SPS. Every student worked on different portions of the project like data analysis, design, procedure, to actual execution of the experiments.

Description of Research - Methods, Design, and Procedures

The experiments were conducted in the Proton Center of Massachusetts General Hospital (MGH), which is the place that the AmBe source is kept for the purpose of equipment calibration. Throughout this semester our main goal was to test polyethylene shielding with BD-PND bubble neutron detectors in the high and medium sensitivities. BD-PND bubble neutron detectors are used to detect neutrons at the energy level of 250 keV to 15 MeV. The goal of the experiment was testing whether or not polyethylene was a viable option for neutron shielding. The apparatus used was a quarter circle wooden arc that had equal radius to the source throughout the whole arc. Next was placing all of the BD-PND bubble neutron detectors on the apparatus on the radius of the 55 cm. This was done by using six of the bubble detectors with different levels of shielding

1 polyethylene sheet thickness = 1 inch

Bubble detectors

Position	notes
0S A	no shield, between box and 1s
0s B	no shield, between 1S and 2S
1s	1 shield
1S box	1 shield enclosed except top
2S	2 shields
3S	3 shields

The neutron detector with one layer of shielding in the box had five sheets of polyethylene around it and for shielding of neutrons bouncing off the walls, which is very unlikely but still something to test. During the experiment, superheated fluid inside the detector absorbs kinetic energy of neutrons and then causes bubbles to expand in the fluid. The number of bubbles can be counted and can be exchanged to the dosage absorbed (in mrem) by a correlation factor. The idea was to remove each bubble detector after it had an estimated 50- 100 bubble in it to not overexpose and leave analysis impossible. Then the time of removal would be noted and this would be used to determine the intensity of the neutrons.

Discussion of Results

The experiment was conducted with six positions of bubble detectors: one with one shield placed in front of the detector, one with one shield but placed inside the box of sheets, one with two shields, one with three shields, one with no shield and placed between box and one shield, and one with no shield and placed between one shield and two shield. After going through all the measurement and calculation, the final result for the average value of linear attenuation coefficient for polyethylene sheets on high speed neutrons is $\mu = 0.156 \pm 0.013646$ 1/cm. This value indicates that after passing through one centimeter thick of polyethylene sheet, the intensity of scattering neutrons from AmBe source is reduced by e to the power of 0.156, which is nearly 1.169 value of the intensity. Including the error in the result, the intensity reduction per one centimeter can reach the lowest of 1.153 unit of intensity or the highest of 1.185 unit of intensity. From this result, we can include that although the amount of intensity from AmBe source that a centimeter thick of polyethylene sheet is not that high as it is expected; however, combination of sheets of polyethylene have effect on blocking the scattering neutrons in passing through bubble detectors.

Since there is a limitation of the number of sheets of polyethylene can be placed on the stand, the maximum of layers of protection was used is only three. We will try to redesign the stand and have more cases with more polyethylene sheets placing in front of the bubble detectors. By this, we can have more measurement from the experiment leading to a more accurate result. Another point of view in this experiment is having the different thickness for the polyethylene sheet. Because this is the first time we did the experiment with polyethylene for shielding, we only prepared one kind of thickness for polyethylene sheet, which is 2.54 cm thick. It is a good idea to prepare three different sheets with three different thickness, one is smaller than 2.54 and one is larger than 2.54, then the result can be compared and evaluated more precisely. For example, we can find a sheet of polyethylene with the thickness of 1.69 cm and we can have a comparison on the difference between the linear attenuation of two sheets of 2.54 cm and three sheets of 1.69 cm, which having the same combining thickness. After analyzing the effectiveness of using polyethylene in shielding neutrons, we can move to other materials and will have some comparison with the attenuation of polyethylene, which is one of the most common plastic, on high speed neutrons.

Dissemination of Results

time = total time irradiated min, sec
R= distance from source to bubble detector in cm
C= average of bubble counts
S= sensitivity = bbls//mrem

$\sigma_C = \sqrt{N + \sigma_\varepsilon^2}$ **is total error in measurement of bubble count**

σ_ε **is stdev of counts of four views**
D= dose in mrem = C/S

$\sigma_D = \frac{\sigma_C}{S}$

Position	BD ID	S sensitivity bbls/mrem	R cm	min:sec time	C	σ_ε	σ_C	D(mrem)	σ_D	time sec
0S A	18043104	28	52	8:01	136.50	5.51	12.92	4.875	0.4613	481
0s B	19035248	17	52	8:01	110.50	3.70	11.14	6.5	0.655471	481
1s	17131134	27	55.5	12:00	148.75	4.92	13.15	5.509259	0.487146	720
1S box	18043141	27	58	12:00	155.75	7.27	14.45	5.768519	0.535011	720
2S	19039447	16	57	17:55	102.25	6.40	11.97	6.390625	0.747827	1075
3S	18229105	15	57	27:54:00	115.75	7.14	12.91	7.716667	0.860663	1674

Calculation of neutron intensity received by each bubble detector

K= conversion for mrem to n/cm^2

K= 2.43x10^4 n/cm^2 per mrem

$$\sigma_I = \frac{K}{T}\sigma_D$$

I= intensity in n/cm^2 sec

Position	BD ID	D(mrem)	σ_D	time sec	fluence F	Intensity I	σ_I
0S A	18043104	4.88	0.4613	481	118462.50	246.28	23.30476
0s B	19035248	6.50	0.655471	481	157950.00	328.38	33.11424
1s	17131134	5.51	0.487146	720	133875.00	185.94	16.44118
1S box	18043141	5.77	0.535011	720	140175.00	194.69	18.05662
2S	19039447	6.39	0.747827	1075	155292.19	144.46	16.90436
3S	18229105	7.72	0.860663	1674	187515.00	112.02	12.49349

Calculation of linear attenuation coefficient for each thickness

x cm	r cm	d=r-x	I_0	I	σ_I	μ	σ_μ
2.54	55.5	52.96	312.09	185.9375	16.44	0.20	0.0348
5.08	57	51.92	324.72	144.45785	16.90	0.16	0.023
7.62	57	49.38	358.99	112.01613	12.49	0.15	0.0146

Calculation of linear attenuation coefficient as average of 3 measurements

$$\mu_{avg} = \frac{1}{3}(\mu_1 + \mu_2 + \mu_3) \qquad \sigma_{\mu_{avg}} = \frac{1}{3}\sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2}$$

x cm	μ cm^-1	σ_μ	μ_{avg}	$\sigma_{\mu_{avg}}$
2.54	0.204	0.035	0.172	0.015
5.08	0.159	0.023		
7.62	0.153	0.015		

Final result: calculation of average of last 2 measurements for high speed neutrons

x cm	μ cm^-1	σ_μ	μ_{avg} cm^-1	$\sigma_{\mu_{avg}}$
5.08	0.159	0.023	**0.156**	**0.013646**
7.62	0.153	0.015		

Bibliography

Cite all resources referenced in the final report here.

Impact Assessment:

How the Project Influenced your Chapter

This experience was 100% worthwhile. My chapter has learned how to work together as a team and the struggles of what doing research is like. You will spend a lot of long nights in laboratories in basements trying to get machinery to work, you will spend hours panicking and preparing your poster to get it printed on time for your presentation. Most importantly, academic research is not easy and it takes a lot of time and a lot of perseverance, most of the time, experiments will not go your way. Most of the surprises we encountered were strange data outputs, and machinery not working the way we expected it to. This experience continues to influence further research as this project has been going on for years and the department plans to continue it for many years.

Our SPS chapter and physics department has become immensely stronger through this project. We are able to recruit students to join SPS and join our research project simultaneously, it has been a great help with retention and getting freshman into research early on.

We would advise that students apply for the chapter research grant, but start early. Even a "small" grant like this one can change a research project immensely. It is an amazing opportunity to get your project funded, especially if you are at a smaller institution that lacks funding.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	In total we had 12 people involved in the project, all members of SPS. Every student worked on different portions of the project like data analysis, design, procedure, to actual execution of the experiments.
Was the amount of money you received from SPS sufficient to carry out the activities outlined in your proposal? Could you have used additional funding? If yes, how much would you have liked? How would the additional funding have augmented your activity?	The amount was definitely sufficient, although with the nature of research, more money is always better. With additional funding, we would eventually like to extend to using bonner spheres to measure different energy levels and we are currently applying for this years SPS grant to fund an external compression system (rather than the screw type system on each detector). It makes use of different types of detectors made to have different neutron energy thresholds so that they do not respond to neutrons below the threshold. Such a system of multiple energy dependent bubble detectors and the recompression system will allow a variety of experiments for energy determination of the neutron spectrum.
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	Yes, this project has been going on at Suffolk for many years and as seniors graduate we continue to pass it down to first and second year students to continue the research.
If you were to do your project again, what would you do differently?	If we were to do this project again, I think we would find time to do more experiments, gather more data, and expand our knowledge. With research in undergrad, time is always an issue.

Press Coverage (if applicable)

If your project received press coverage, please include references or URLs to the coverage. When possible, attach copies of articles to this report.

Expenditures

Expenditure Table

Item	Please explain how this expense relates to your project as outlined in your proposal.	Cost
Bubble detectors	Used to provide evidence of a 1/r^2 distribution for neutrons	$480
Single metal foil set of 4 foils	Irradiated and used in conjunction with the new scintillator to determine the ratio of the neutron and gamma production as well as the total count for each in a 200 keV to 22 MeV	$500
Shielding	Used to examine the difference in absorption of neutrons for layers of polyethylene	$975
	Total of Expenses Covered by SPS Funding	$1955

Activity Photos

Please include captions and credits for each photo. By including photos below, you are giving SPS and the American Institute of Physics permission to use these photos in their online and printed publications.

Note that you will be encouraged to upload high resolution copies of your best photos directly to SPS via the FluidReview site when you submit your report.

Students setting up experiment with polyethylene shielding of different thicknesses and students taking notes.

Students examining the radiation source

Students with the bubble detector and shielding set up