SOCIETY OF PHYSICS STUDENTS

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SPS Chapter Research Award Interim 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	$2,000.00
Project Leader	John Thomas

Abstract

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

The entire Statement of Activity should be no more than three pages, and organized as follows. Note that some of the information requested may be taken directly from your proposal, but it is anticipated that the research questions, goals, and methods/designs/procedures have evolved for most projects since work has started. The information provided in this interim report should reflect those changes.

Interim Assessment

The Interim Assessment should be a detailed description of the completed portions of the proposed project. Provide sufficient background information for a non-specialist to understand why the completed components are significant for the advancement of the project.

This section should include:

- Research question – What question does the research aim to address?
- Brief description of project – What has the research project entailed, and have new elements influenced the overall aim of the research?
- Progress on research goals – What has been accomplished so far?
- Any changes in the scope of project – Indicate whether the project is turning out to be a more complicated or more straightforward research project than expected and why; influencing factors may include personnel size, research scope, materials and equipment availability…
- Personnel – Who has been involved in the research activities and in what ways? How many participants are SPS members?
- SPS connection – How is the activity strengthening the objectives of the SPS program, both at the proposing school and nationally?

The aim of the research project is to characterize the neutron energy spectrum of an AmBe neutron source and a 15MV Medical Linear Accelerator (LINAC). Recent experiments have been centered about the AmBe source, since it is of known activity, and investigating the accuracy of our BD-PND detectors. These detectors have a short working life, and only three were still operational at the beginning of this year. Funds from this SPS grant have been used to purchase six new BD-PNDs, but they were not acquired until the end of April. In the absence of these detectors, we have been evaluating the radial symmetry of our AmBe source using an organic liquid scintillator (EJ-301). Based on preliminary experiments, the source seems to be radially symmetric. Subsequent experiments with the new BD-PND's will be used to provide more information about the possible symmetry of the source. The scope of the project has remained on target, however roadblocks arose causing a setback in the execution of a few phases of the experiment. These delayed phases were; using the BD-PND to determine a 1/r^2 relationship of neutron flux, due to manufacturing backlog of the detectors and experimental issues in our software package for the manipulation of the oscilloscope. The new BD-PND bubble detectors will be used in our next experiment along with the updated software package for the oscilloscope.

The entirety of the SPS chapter takes part in the research project, about a dozen students. In addition to the SPS members, Tara Medich, the Director of Radiation Safety at MGH, Joe McCormac, cyclotron operator at MGH, Jacqueline Nyamwanda, Educational Coordinator for Medical Dosimetry at Suffolk University, Dr. Walter Johnson, Physics Program Director at Suffolk University and project leader, also participate in the research.

This project allows students to get experience working as part of a research team. The team is structured so that the upperclassmen are well versed with all experimental components, with a specific area of expertise. They are responsible for educating and training the underclassmen in all aspects of the project, so that the information is passed down and research will perpetuate after students graduate. Students beginning on the project will attend project meeting and experiments, primarily as documentors, and as they learn more about the project, new students participate more in the experimental planning and design as they learn more about the particulars of the project.

Updated Background for Proposed Project

This section should be a supplemental update to the background given in the project proposal. Indicate any new literary sources being used and include a brief summary of relevant research that has been newly published or that has been newly uncovered or applied by the researchers. If appropriate, provide an updated explanation of how the research project will contribute to the scientific discussion.

The broader context of this research endeavor is to answer NASA's challenge to find materials to shield mars astronaut from the neutrons in cosmic rays. Through collaboration with Mass General Hospital (MGH) and their Proton Center the team gained access to multiple neutron sources but before shielding experiments can be performed a broad array of neutron detectors need to be amassed and have their procedure perfected. Currently high purity metal foils, BD-PND bubble neutron detectors, and an organic liquid scintillator are being tested. Recently, focus has shifted from the LINAC to the AmBe source and with this the scope of supplemental research has shifted as well. An AmBr source is a mixture of americium 241 and beryllium 9 that generates neutrons and gammas through radioactive decay. The americium emits alpha particles as it decays, these strike the beryllium nuclei a creating carbon 12, a neutron, and a gamma. When this specific source was created it's activity and other characteristics were precisely measured. This allows for the accurate calculation of a current activity

Description of Research - Methods, Design, and Procedures

This section should provide an updated synopsis of your research experiment, simulation, or study. It should include a description of the set-up, procedures, and methods of data collection and analysis currently being used. This section may be bulleted, but must include enough detail that it is clear to others who are not familiar with the topic.

During this semester, the main focus of the research are using high purity metal foil activation with bubble neutron detectors and organic liquid scintillation as the methods of detecting the neutrons and gammas from the AmBe source. BD-PND bubble neutron detectors are used to detect neutrons at the energy level of 250 keV to 15 MeV. Eljen EJ-301 organic liquid scintillator for neutron/gamma discrimination from the AmBe source in the energy range of 250 keV to 15 MeV. High purity metal foils are used to isolate localized energy regions based on the resonance cross sectional peaks of each foil. High purity metal foils are used to allow for the targeting of localized energy regions based on the resonance cross sectional peaks of each foil. Having multiple foils help us build a neutron energy spectrum distribution with greater accuracy, and having enough foils allows us to project the total thermal and epithermal neutron distribution.

Neutron bubble detectors are used under the effective energy range 250 keV to 15 MeV. The neutron bubble detectors were placed in an array 75 cm away from the AmBe source. During the experiment, superheated fluid inside the detectors absorbs kinetic energy of neutrons and then causes bubbles to expand in the fluid. The number of bubbles can be counted and can be converted to the dosage absorbed (in mrem) by a correlation factor.

High purity metal foils are used in the energy range of 0.025 eV to 250 keV. Indium (In), Gold (Au), Dysprosium (Dy) and Tungsten (W) are the metals that can be used as the foils with Cadmium (Cd) covers. These metals are used for thermal neutrons (0.025 eV) and epithermal neutrons (>0.025 eV - 250 keV) capture. Cadmium is used as the cover for the foils since it has an extremelylarge thermal cross section, which makes it able to capture all the thermal neutrons. With this cover, the interior foil (which made by In, Au, Dy, W) only captures the neutrons with energy of their resonance cross section. The number of thermal neutrons can be determined by subtracting the number of neutrons captured by covered foil from that of uncovered foil. These foils are placed in the radius of 9.5 cm to the source and once irradiated undergo beta decay, which can be measured by using a liquid beta scintillator.

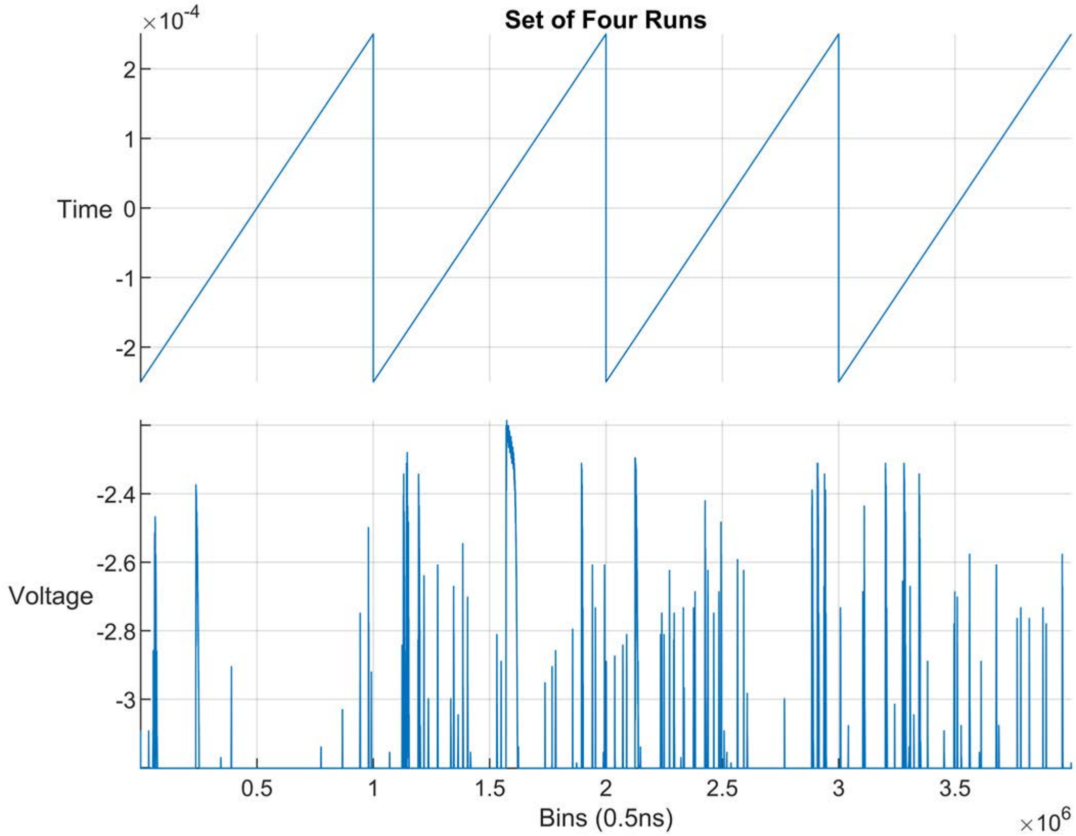
The organic liquid scintillator detector is used at 200 keV to 15 MeV effective energy range. This scintillator detector is placed 45 cm away from the source and is rotated radially about the source in 60° intervals. The scintillator is connected to an oscilloscope, which digitizes the analog detector output. The oscilloscope control code catalogues the detector outputs, which are subsequently processed using Python and MATLAB modules.

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. The first step was placing a source holder in the middle of the table in the radiation room. A quarter circle wooden arc, prepared by Brian, Jack, and Jackson, was used to hold the scintillator in place. The arc is repositioned around the source to obtain measurements at different angel designations. On the stand, there are marks of 0, 30 and 60 degrees, where the scintillator should be, so the data can be collected in a full circle around the center AmBe source. The cables were set up from the scintillator to the oscilloscope as well as the computer running the Python code to collect data. After everything was ready, the oscilloscope was set at 50 microsec per cm, which means one sweep has a length of 500 microsec, and the trigger level of -3 volts. For each position, a data set was collected consisting the data of 50 runs each set. The data were collected three times for one position of the stand (0, 30 and 60 degrees), and the stand was moved four times in the whole experiment so the scintillator was placed at different places in a full circle.The data were collected for each run through the process of neutrons radiating from the AmBe source, going through the liquid of the scintillator, and creating the equivalent signals on the oscilloscope. There are two packages of code that Jack and Jackson used during the experiment, one is for transferring the analog signal from the oscilloscope to the computer, and one is for reconstruction and processing of the data of collected neutrons.

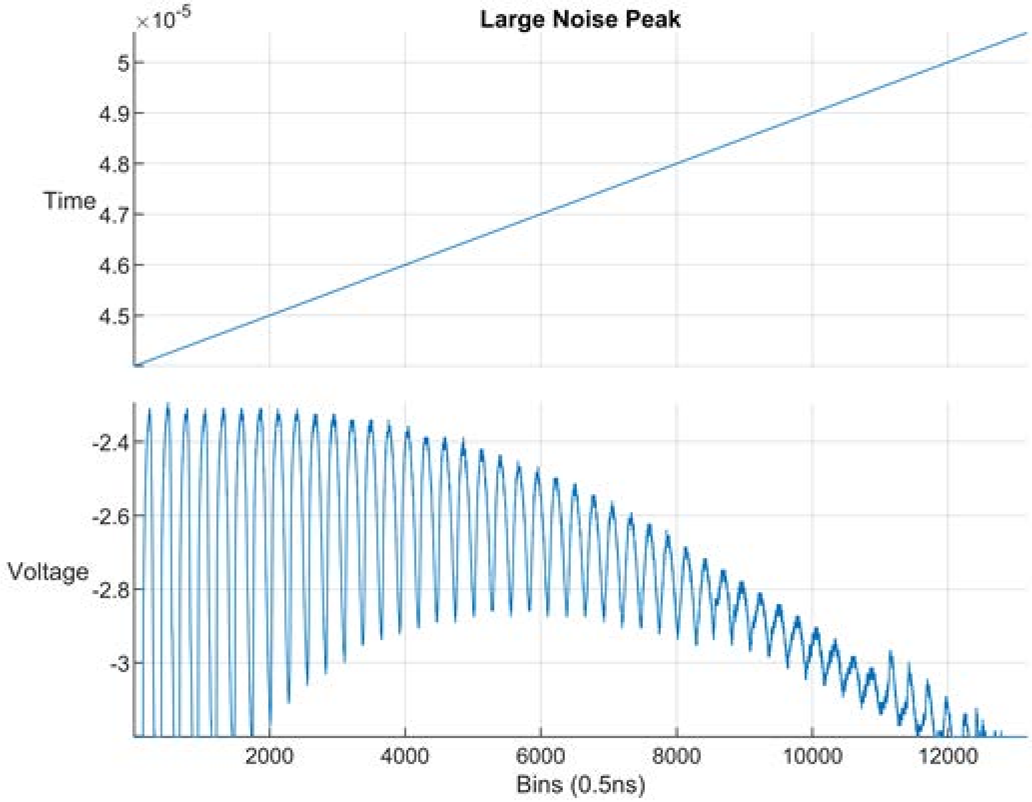
Initial Results

This section should be a brief explanation of any initial results. Examples of results to discuss may include, but are not limited to, the effects of constraining a parameter, characterizing a material, or testing an apparatus. The idea with this section is to describe what you have observed at this time.

Successful acquisition of oscilloscope signals has allowed for neutron/gamma discrimination as well as noise rejection. The graph below shows the signal output of four consecutive runs for a total measurement time of 200 microseconds.
The peaks shown are all in the noise rejection region as they have pulse widths on the 100-6,000ns scale. A closer look at these peaks reveal a unique shape as shown in the Large Noise Peak graph. The peak shown is the same peak in Figure 1 located at 1.5x10^6. The peak itself is a width of 6,000 ns, 300 times the size of our expected neutron pulse. The top graph with “Time” on the y-axis shows the elapsed time in window of the oscilloscope. The vertical drop offs denote where files were concatenated. The negative time value is a result of



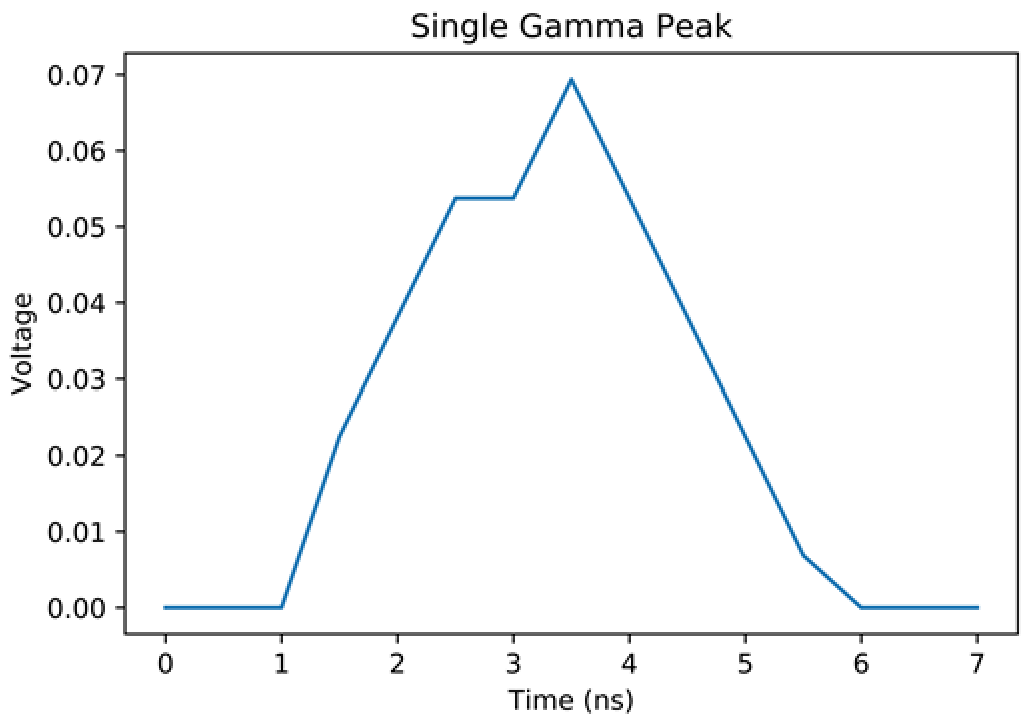
a time offset in the oscilloscope, the complete measure time is 50 micro seconds, 25 before the 0 point and 25 after.



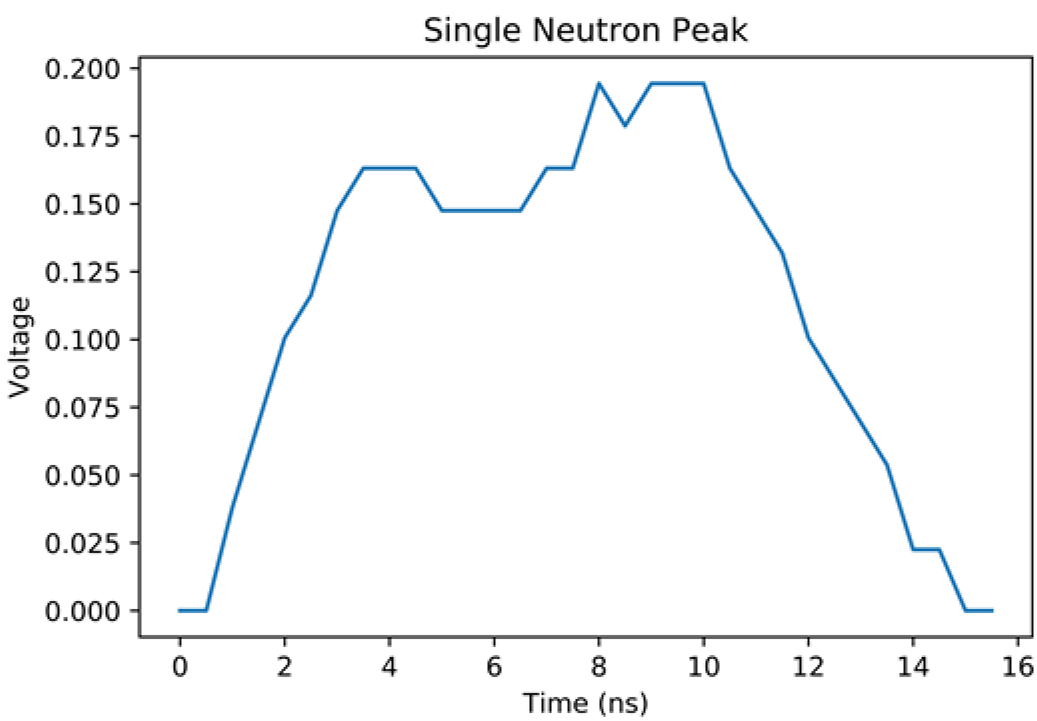
Large Noise Peak $\sim 6000\, ns$

The noise peak shows a flat signal from 0 to approximately 1 ns (2000 bins) which is modulated by a high frequency of approximately 7 Mhz. After that there is a quarter cycle sinusoidal envelope extending from 2000 to 12000 nsec – corresponding to a 500 KHz signal modulated by the higher frequency of about 7 MHz. This is not currently understood.

A single neutron and gamma peaks are shown below which were taken from the same set of four runs displayed above. The immediate difference in these two peaks as compared to the noise are the peak voltage above background, the width of the peak, and the non symmetric shape. The gamma peak has a pulse width of about 5ns and the neutron peak has a width of about 15 ns.

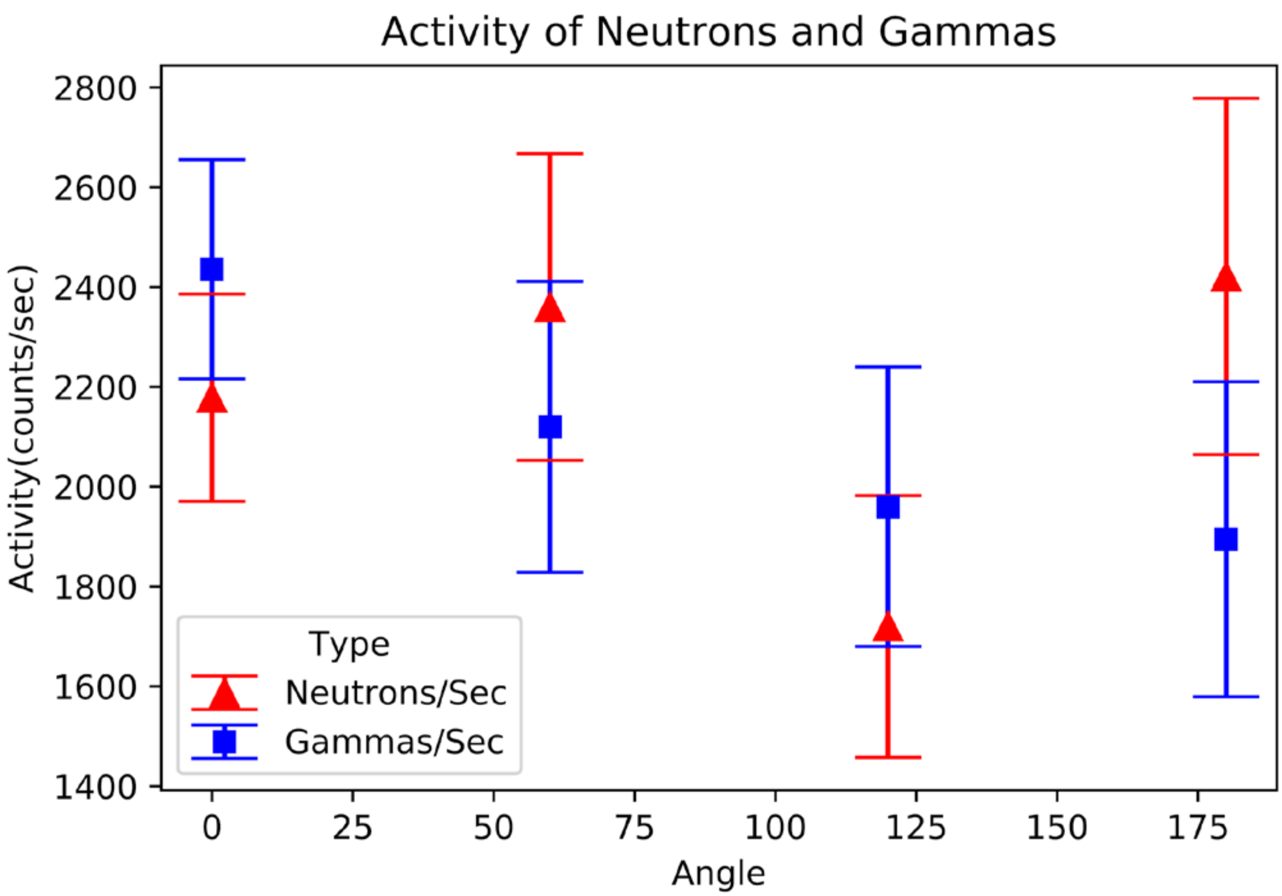


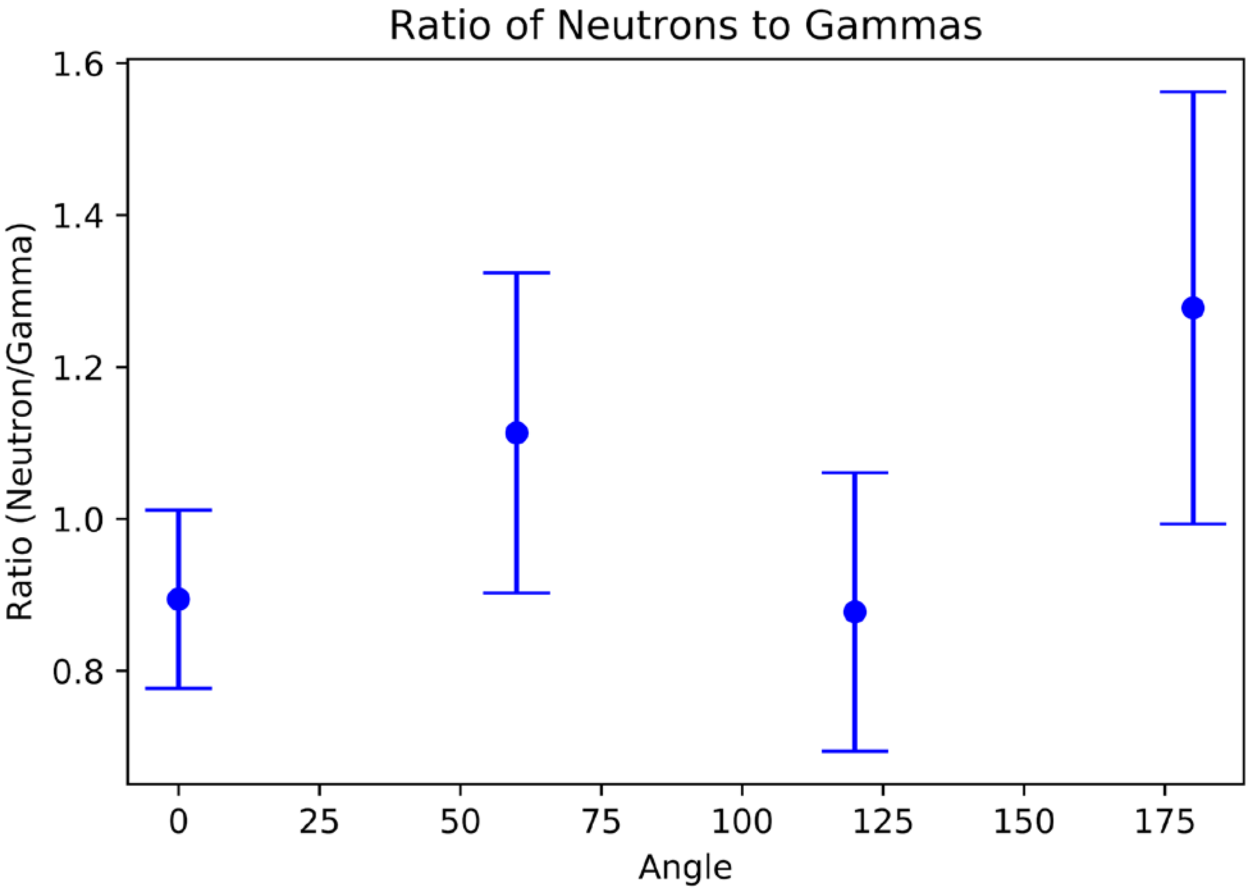
Single Gamma Peak $\sim 5\, ns$



Single Neutron Peak $\sim 15\, ns$

After neutron/gamma discrimination of each file we were able to show radial symmetry and a one to one ratio of neutron and gamma production as shown by the following two graphs.





The relative activity for each angle averaged around 2,200 (neutrons or gammas)/sec for all four angles along a 180 degree arch. The neutrons and gammas also showed a one to one ratio of production from the AmBe source which is expected as the alpha emission from the americium decay, reacts with the beryllium producing a single neutron, gamma, and carbon-12. The gamma emission is expected to have a consistent energy of 4.44 MeV while the neutron emitted ranges in energy from 0.025 eV to about 8 MeV. This is why the ratio is not exactly one as some of the gammas pass directly through the scintillator undetected and not all neutrons are detected as they may have an energy below 250 keV, the lowest detection level of the detector.

Project Timeline

This section should provide a timeline of completed events and milestones.
The projects focal point in the spring 2019 semester was to figure out a way to correctly analyze the data from the liquid scintillator and test the AmBe source for radial symmetry. After about 5 months of coding, the data from the scintillator could be obtained and analyzed using matlab and other programing tools. Using the wooden arc apparatus, which gave measurements at intervals of 30 degrees around the source, the radial symmetry of the source was tested form 0 degrees to 180 degrees obtaining 50 runs per interval from 0 - 60 - 120 - 180 degrees. After analyzing the data of the intervals in between 0 and 180 the source appears to be radially symmetric. To know for sure the second half of the interval, 180 - 360 will also have to be tested against the data we obtained for the first interval. The two experiments on March 5th and March 27th respectively. On the 5th was the first test of obtaining data directly from the scintillator and the 27th was when radial symmetry was tested. In the future to help the case for radial symmetry bubble detectors will be used at

the same intervals around the source. The April conference was a success and the presentation of the research collected generated some interest from other companies that were in attendance who were also using neutron detectors.

Statement of Next Steps

The entire Statement of Next Steps should be no more than one page, and organized as follows.

Plan for Carrying Out Remainder of Project (including Timeline)

This section should detail an updated plan for carrying out the remaining components of the project, in bullet or paragraph form. Include, at minimum:

- The key milestones and the dates by which important steps need to be completed in order to finish the project on time you prosed (by December 31).
- Personnel - Who will be involved in the research activities and in what way? How many participants are likely to be SPS members? Are there SPS members or others with special expertise that will help to ensure success?

Over summer 2019- plan projects for upcoming year
September 2019- introduce freshman students to SPS and recruit new students to work on our team
Late september 2019 and early october 2019- conduct 2-4 more experiments and begin working on publication and presentation for PhysCon 2019
November 2019- present at PhysCon
December- submit final report

Personnel

- All students in SPS will likely be involved in the activities, with the new year of incoming freshman, our team will be about 10 people
- Our advisor Dr. Walter Johnson and the team in the proton center who have special expertise will help ensure our success

Bibliography

Cite all resources referenced in the interim report here.