SOCIETY OF PHYSICS STUDENTS

An organization of the American Institute of Physics

SPS Chapter Research Award Proposal

Project Proposal Title	Neutron Radiation Around an AmBe Source at Massachusetts General Hospital
Name of School	Suffolk University
SPS Chapter Number	6917
Total Amount Requested	$2,000.00

Abstract

The abstract should be **no more than 50 words**. The abstract should be a standalone description of the proposed research project, appropriate for posting on the SPS website or publishing in *The SPS Observer* or *Radiations*. The abstract should be in paragraph form and should include the school name, a brief description of the proposed project, and a brief statement about the motivation for the project.

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.

Proposal Statement

The entire Proposal Statement should be no more than 4 pages, and organized as follows.

Overview of Proposed Project

The Overview should be a more detailed description of the proposed project than the abstract, and provide sufficient background information for a non-specialist to understand the proposed research question and why the question is significant.

This section should include:

- Research question – What question does the research aim to address?
- Motivation – Why is this research project important? What are some potential impacts of the research?
- Brief description – What will the research project entail?
- Research goals of the project – What will the research project accomplish?
- SPS connection – How will this activity strengthen the objectives of the SPS program, both at the proposing school and nationally?

The research question(s) behind this project are:

- What is the neutron energy spectrum for this specific 15 MV LINAC?
- What is the ratio of both 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?
- Which material works best for radiation shielding when it comes to space travel?

Our research will allow us to fully map the neutron flux around the LINAC, which will then help doctors at MGH determine dosages of secondary radiation based on the location of the patient in the room. Additionally, there may be applications in space travel as we look at a variety of metals for radiation shielding purposes.

This project will require a variety of experiments using high purity metal foils in addition to neutron bubble detectors. Bubble detectors on an array will help map the neutron flux, determine symmetry in the room and provide evidence of a 1/r^2 distribution for neutrons in the energy range (200 keV to 15 MeV). The high purity metal foils will be layered to allow for localized energy neutron capture.

The goal of this project is to determine which materials are best for radiation shielding in regards to space travel in addition to mapping the neutron flux around this 15 MV LINAC.

This project connects to SPS both as a chapter and nationally. This research is part of the primary focus of our chapter. Nearly every member of our chapter works on the project, and it helps members gain valuable research experience in preparation for graduate school and industry alike. Our primary objective of our chapter at Suffolk is to foster friendship among physics majors while gaining valuable experience through research and outreach. This project has been huge for our chapter, allowing us to receive more publicity from the university and make SPS and the Physics department more recognized on campus. As for nationally, this project helps to support the main goal of SPS, “[to] help students transform themselves into contributing members of the professional community.” (spsnational.org) Through this project, students strive towards the mission of SPS- moving physics beyond the classroom and creating a crucial experiential learning opportunity for students who might not have otherwise had the chance to work on physics research as an undergraduate.

Background for Proposed Project

This section should place the proposed research project in a broader context. It should include a summary of the current knowledge about the subject with appropriate literature references, and an explanation of how the proposed work would add to that knowledge.

After a few students decided they wanted to recreate a CubeSat mission, they were then inspired by the challenge issued by NASA in regards to how to shield radiation during space travel- our advisor reached out to MGH for their neutron sources. Through a collaboration with Mass General Hospital (MGH) and their oncology department, we found a LINAC typically used to treat cancer patients- that worked perfectly for what we needed for our project. Since the LINAC is used for cancer treatment using radiation, it gives off neutrons as a byproduct.

The next step we took in the process was using bubble detectors to determine the map of the neutron flux in neutrons per cm^2 per second, around the LINAC. From previous publications of simulations of LINACs, we know there is a dominant peak in neutron production centered at a high-energy peak of 1 MeV and a low-energy peak around 0.025 eV. From these peaks, if we determined the neutron flux at these points, we then could determine the neutron production coefficient (Q Value), in terms of neutrons emitted per Gy (Gy is the SI unit for an ionizing radiation dose). After this determination, we compared our Q value results with Q values published on other 15 MV LINAC machines.

After this, more experiments took place using both neutron bubble detectors and high purity metal foils. After positioning the detectors in an array and radiating the detectors, the relationship between the fluence and the distance from the head was determined. Then we calculated the neutrons per area for a given radius and integrated over 4πr^2 to obtain the Q value for the machine in neutrons/Gy. Bubble detectors, although powerful tools have limitations to what energy they can detect, no lower than 200 keV.

In order to examine low-energy neutron fluence, we used high purity metal foils to perform neutron activation analysis. After neutrons bombard a thin, pure metal foil, they create radioactive isotopes. By studying the radioactive emissions and decays from a foil, we were able to determine the number of incident neutrons.

This is where the funding for new detectors, new foils, and new liquids for the scintillator come in. Since we have been working on this project for a long time and due to the lifespan of the detectors, we are unable to continue our bubble detector analysis, as our current detectors are expired/ have been reused many times and will not recompress. New foils will allow us to look at different types of materials for shielding and allow us to look at different cross-sections of materials to see which work best. The liquids for scintillator would allow us to perform different types of analysis on the foils in the future, giving us more data and allowing us to more accurately represent the fluence map around this accelerator.

Expected Results

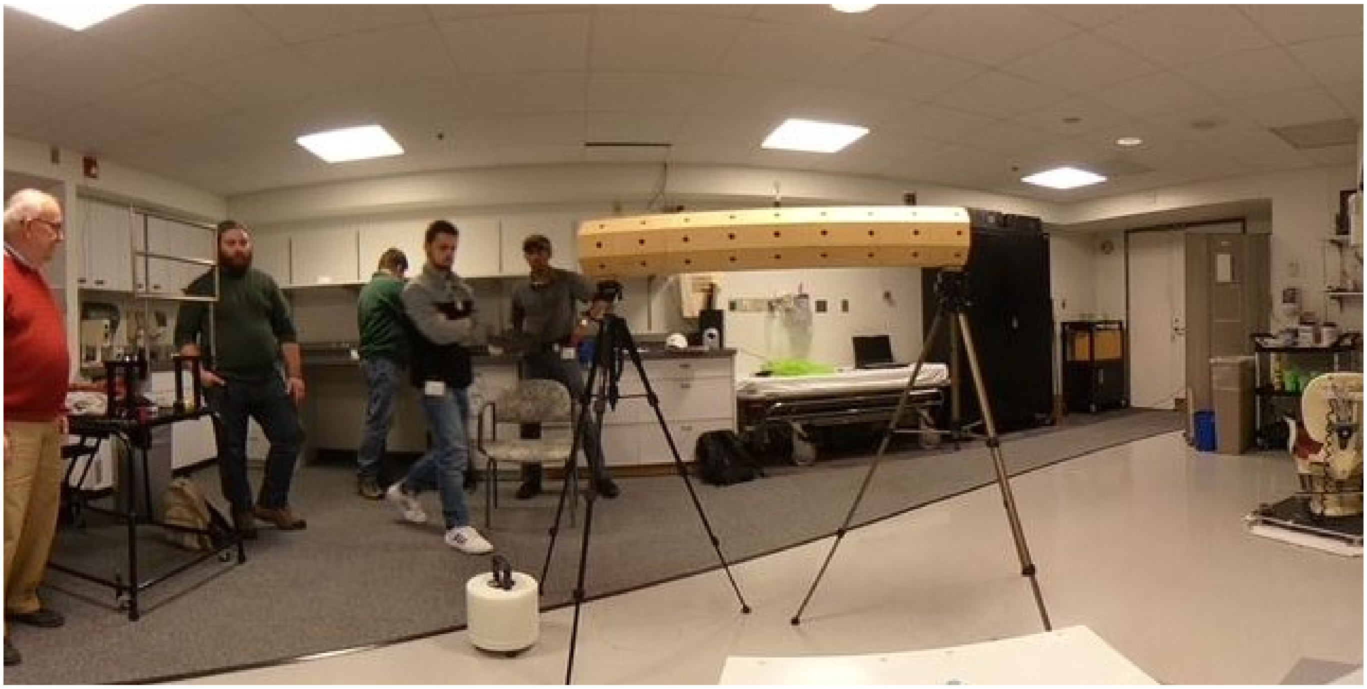
This section should be a brief explanation of the type of results expected. Examples include constraining a parameter, characterizing a material, or testing an apparatus, among others. The idea with this section is to describe what the proposed project aims to accomplish.

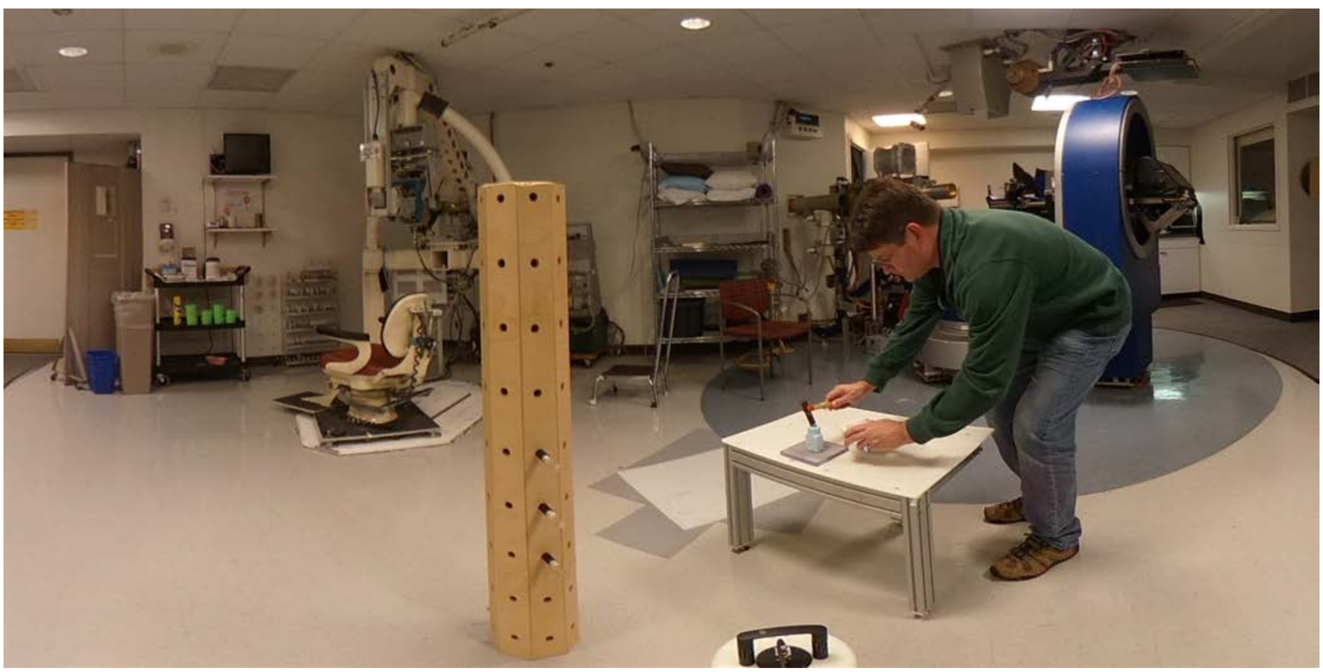
With the three detection methods, high purity metal foils, neutron bubble detection, and organic liquid scintillation we expect a wide variety of results that can then be linked together to introduce the use of radiation shielding. All three of these detection methods will be used to form a full neutron energy spectrum. The first will be the determination of the 1/r^2 neutron distribution around the AmBe source. If this distribution is uniform we will be able to accurately predict the neutron distribution down to an epithermal level. At both the epithermal and thermal level we are able to detect neutrons using the high purity metal foils based on their respective resonance peaks, for example, In^{115}absorbs a 1 eV neutron forming In^{116} which then undergoes a m1 beta decay with a half life of about 54 mins. Where as Au^{197}absorbs a 6 eV neutron forming Au^{198}which then undergoes a beta decay with a half life of about 2.7 days. With the current foils we have we can cover a small section of the epithermal and thermal neutron production, we expect that with this new layering method we will be able to target additional energy ranges. Neutrons will thermalize as they pass through the foil layers, allowing each subsequent foil to capture a different energy range of neutrons.

Our last detection method is expected to give us our most complete field of results in the 200 keV to 22 MeV range. This detector uses pulse shape discrimination allowing us to discriminate between neutrons and gammas. This will allow for the tagging of each neutron and gamma with respect to their energies. This will be analyzed in a heat map form to show the relative distribution of neutrons and gammas allowing for the clear separation between the two. The average pulse width for a gamma is about 5ns where the neutron has a average pulse width of 10ns. Once we have mapped the neutron environment of the AmBe source, the same procedure will be implemented in the LINAC treatment room.

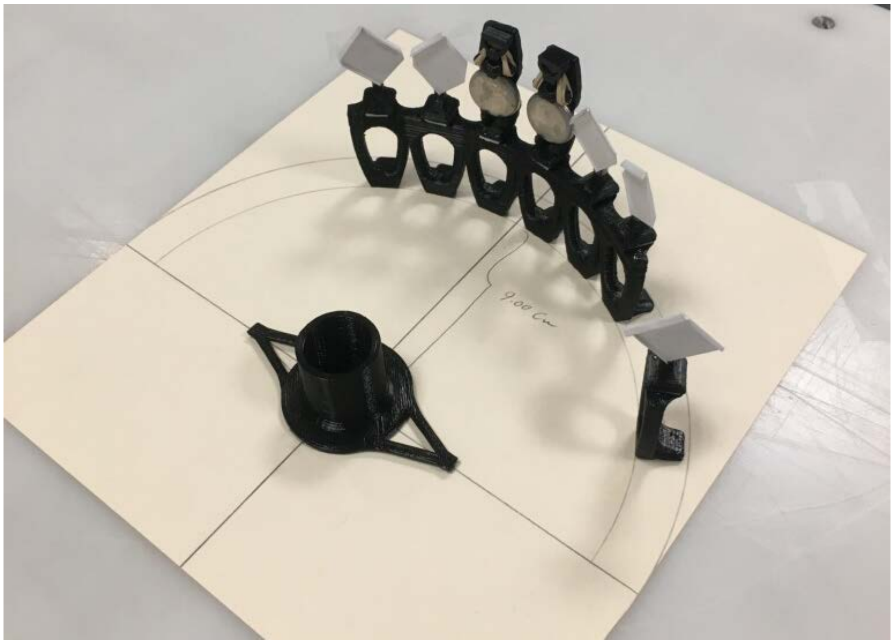
Description of Proposed Research - Methods, Design, and Procedures

This section should provide evidence of a thoughtful research experiment, simulation or study that addresses the research question. It should include a detailed description of the proposed research project and an explanation of how the experiment or study will be set-up, executed, and analyzed, and how the information will be disseminated. This section may be bulleted, but must include enough detail that it is clear to reviewers that the project has been well researched and thought-out.

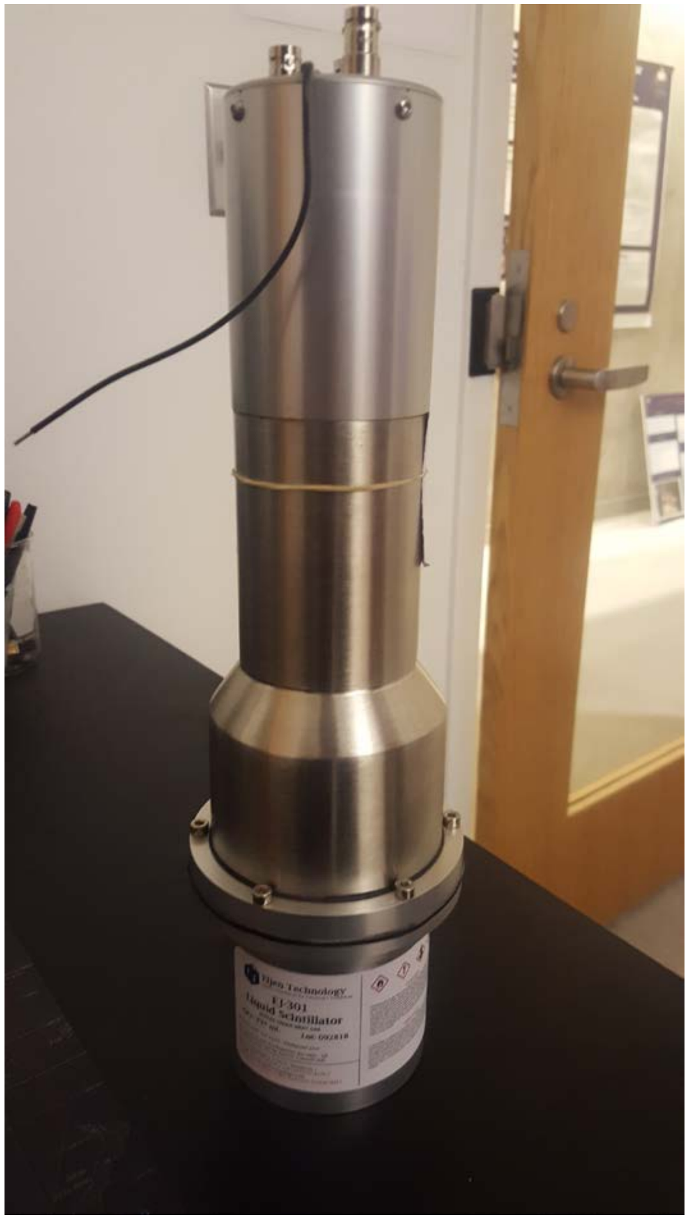




The neutron bubble detectors will be placed in a wooden stand that has 72 possible positions which was built by SPS and senior students John Thomas and Jackson Nolan, can be placed in any position, with respect to the AmBe source and the LINAC. In the above photos the array can be mounted on tripods as well as stand on its own. This array will be used to first measure a 1/r^2 dependence after which it can have the bubble detectors faced in towards the center of the hollow array and shielding can then be placed on the outside of the array covering the holes. This can also be fitted with mounts that can be used to hold the high purity metal foils if needed. This array can also be used to conduct metal foil experiments with the LINAC.



This second apparatus shown above is used to measure a uniform radial distribution around the AmBe source while holding the high purity metal foils. These foils are irradiated in multiple conditions, the first is uncovered meaning it is the bare foil in direct radiation, the second is a foil that is covered in Cd to absorb the thermal neutrons as it has an incredibly high thermal neutron cross section. As both of these foils undergo beta decay the total neutron absorption can be determined based on: measurement time, irradiation time, rest time, cross section, percent abundance, and mass. Once the neutron absorption is determined for both foils, the number of neutrons absorbed by the covered foil are subtracted from the neutrons absorbed by the bare foil to determine the number of neutrons that were absorbed in the thermal range by the bare foil. This is how we plan to build the neutron spectrum for neutrons produced below 200 keV and by layering the the high purity metal foils other than Cd such as; Dy, W, Au, and Cu we will be able to localize new energy windows. This is done by causing the epithermal and resonance neutrons to thermalize as they pass through the foil layers. They absorb only the remaining neutrons of a specified energy.



The last experimental setup is the organic liquid scintillator, this new scintillator has just been purchased and is due to arrive by the end of November. This new scintillator will be placed in front of the AmBe source to record both neutrons and gammas in a 200 keV to 22 MeV range, although we do not expect to see many neutrons above 5 MeV. This scintillator is attached to a pmt and high voltage divider allowing for pulse shape discrimination. The advantage to this new scintillator is that it can have the organic liquid changed and have a different liquid mounted to the housing allowing a new detection range. This idea will be explored after multiple successful experiments at MGH in the near future. With this scintillator we will also be able to test the effects that radiation shielding will have and will provide further insight into the results from both the neutron bubble detectors and the high purity metal foils.

Plan for Carrying Out Proposed Project

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

- Personnel - Who will be involved in the research activities and in what way? How many participants are likely to be SPS members?
- Expertise - Are there SPS members or others with special expertise that will help to ensure success?
- Research space - Where will the research activity be carried out? Is there lab space or other space that will be designated for this activity?
- Contributions of faculty advisors or the department (equipment, space, etc.)

The research is conducted primarily by our research team which includes John Thomas, Jackson Nolan, Erick Bergstrom, Molly McDonough, Brian Hassett, and Dylan Barbagallo who are all active members of SPS. As we add more students to our group, we encourage them to join up in SPS.

Experts in the project include John Thomas, Jackson Nolan, Erick Bergstrom, and Molly McDonough. Although John, Jackson, and Erick are all graduating seniors, Molly will be taking the responsibility of being the most 'expert' member of the team, ensuring all persons entering the project are properly trained.

The research space is currently at Mass General Hospital in the Oncology department. We use MGH's AmBe source located in their Proton Center and Varian TruBeamLINAC to conduct experiments. Our equipment is kept in the Nano Science Research Laboratory at Suffolk University in the Physics department. In addition to this space, the physics department has also funded our new organic liquid scintillator.

Project Timeline

This section should detail the timeline for carrying out the project. Include key milestones and the dates by which important steps need to be completed in order to finish the project on time (within one calendar year). Plans for preparing and submitting the **interim report (due May 31)** and **final report (due December 31**) should be included on the timeline.

Experiments will be conducted in the Mass General Hospital Oncology department and Proton Center as often as student and MGH staff schedules allow, minimally once per month. The initial experiment with the new organic liquid scintillator will be conducted in early December. By December 21, the data from experiments using both high purity metal foils and the new organic liquid scintillator to detect neutrons produced by the AmBe source is expected to have been processed. Results of experimentation conducted with the 15 MV LINAC are currently being processed, and we intend to submit them for peer reviewed publication by the end of 2018. We then intend to present the results of these, and subsequent experiments at the APS April Meeting, April 13-16. All experiments conducted using materials purchased grant funding will be included in both the interim and final reports.

Budget Justification

This section should justify the expenses outlined in the Budget Proposal. For example, if funding will be used to purchase a specific piece of equipment, explain here why that piece of equipment would be useful for the research activity. (The actual budget must be submitted as a separate file, created in conjunction with the "ΣΠΣ Undergraduate Research Award Proposal Budget Template.") Note that payment for student services is not an eligible budget item.

Include information about any money or supplies coming from other sources that will leverage the funding requested from SPS. Include in-kind funding and support (borrowed equipment, etc.) that will be used in carrying out the project.

As radiation experiments are conducted, detectors need to be replenished as they reach the end of their working lives. We have found that after several exposures to neutron radiation, the bubble detectors do not recompress correctly, leaving bubbles from previous experiments still in the detectors and making counts inaccurate. Similarly, the high purity metal foils, lose purity after each time they are irradiated, as well as becoming tarnished by the scintillator gel used to detect their decays. New bubble detectors must be purchased to conduct experimentation to show 1/r^2 dependence of the neutron flux from the source. Several different types of high purity metal foils have become too degraded to be used in experiments, limiting our analysis of energy windows below 200 keV. The scintillator detector will be used to detect in energy windows greater than 200 keV.

Bibliography

Cite all resources referenced in the proposal here.

Nolan, J., McDonough, M. and Thomas, J. (2018). *Mapping the Neutron Flux Distribution Near a Medical LINAC*. [online] Society of Physics Students. Available at: https://www.spsnational.org/the-sps-observer/fall/2018/mapping-neutron-flux-distribution-near-medical-linac [Accessed 15 Nov. 2018].

Society of Physics Students. (2018). *About SPS*. [online] Available at: https://www.spsnational.org/about [Accessed 14 Nov. 2018].