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Title: 2012 SARA Students Technical Report

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To/MS: Dr. Tim Goorley & Dr. Avneet Sood
From/MS: SARA Summer 2012 Students
Date: July 23, 2012

Technical Report

X-Computational Physics Division
XCP-3-MCC/Monte Carlo Codes
XCP-7-Transport Applications

Subject: 2012 SARA Students Technical Report

Foreward:

Attached are the reports for the XCP Division 2012 summer military academy students (SARA students). This summer, all 4 students were from the US Naval Academy. Part I is the report from Midshipmen Angelo Briccetti, Nathan Lorei, and David Yonkings. Part II is the report from Midshipman David Lorio, who arrived at LANL after the previous three students had departed. SARA students are typically at LANL only for 3-5 weeks each, and these students were all able to successfully achieve the objectives we placed before them. The intent of the XCP Division SARA student experience is to provide a diverse instruction of nuclear weapons theory and history, radiation detection measurements, and radiation transport simulation. Tours to a variety of LANL facilities are also an integral part of the experience.

Dr. Tim Goorley, XCP-3 Group Leader
Dr. Avneet Sood, XCP-7 Group Leader

PART I

SARA Program 2012 / X-Division

Authors:

USNA: A. Briccetti, N. Lorei, D. Yonkings (Part I)

USNA: D. Lorio (Part II)

The Service Academy Research Associates (SARA) program provides an opportunity for Midshipmen and Cadets from US Service Academies to participate in research at Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratory for several weeks during the summer as part of their summer training assignments. During the summer of 2012, three Midshipmen were assigned to work with the XCP Division at LANL for approximately 5-6 weeks.

As one of the nation's top national security science laboratories, LANL stretches across 36 square miles, has over 2,100 facilities, and employs over 9,000 individuals including a significant number of students and postdocs. LANL's mission is to "apply science and technology to: ensure the safety, security, and reliability of the US nuclear deterrent, reduce global threats, and solve other emerging national security challenges." While LANL officially operates under the US Department of Energy (DoE), fulfilling this mission requires mutual cooperation with the US Department of Defense (DoD) as well. LANL's high concentration of knowledge and experience provides interns a chance to perform research in many disciplines, and its connection with the DoD in both operation and personnel gives SARA students insight to career possibilities both during and after military service.

SARA students have plenty of opportunity to enjoy hiking, camping, the Los Alamos YMCA, and many other outdoor activities in New Mexico while staying at the Buffalo Thunder Resort, located 20 miles east of the lab.

XCP Division is the Computational Physics division of LANL's Weapons Department. Working with XCP Division requires individuals to be Q cleared by the DoE. This means it is significantly more convenient for SARA students to be assigned to XCP Division than their civilian counterparts as the DoD CNWDI clearance held by SARA students is easily transferred to the lab prior to the students arriving at the start of the summer. SARA students working with XCP Division were given a comprehensive introduction into nuclear engineering and physics, nuclear weapons, and radiation transport and detection via texts and lectures at various classification levels. Students also attended tours of several prominent facilities at LANL including TA-41 Ice House, TA-55 PF-4 plutonium facility, the Nicholas C. Metropolis Center for Modeling and Simulation, also known as the Secure Computing Center (SCC), and the Dual-Axis Radiological Hydro Test (DARHT) facility; in addition, SARA students accompanied by LANL staff traveled to Minot AFB in North Dakota for tours of the 5th Bomb Wing and 91st Missile Wing facilities. Students participated in a week long class on the Monte Carlo N Particle (MCNP) code to supplement their understanding of radiation transport simulations. SARA students were then tasked with using this knowledge to model radiation detectors and use MCNP to compare their models to experimental data and previously accepted models.

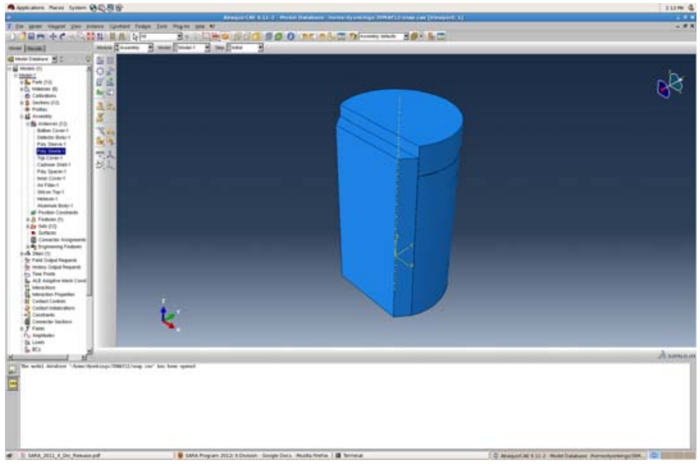
MCNP Class

SARA students were exposed to the radiation transport code MCNP (Monte Carlo N Particle Code) during a week long seminar. MCNP is the premier radiation transport code developed by LANL for use at home and abroad. The SARA students were instructed on the use of basic and advanced geometry techniques that allow for the modelling of various experiments concerned with the transport of subatomic particles. In order to process the transfer of particles, students learned about “tally counting” which is MCNP’s ability to follow and track the behavior of particles based on an internal database of particle physics and nuclear cross sections; various integrations and operations within the code gave SARA students the necessary tools to model and confirm the outputs of actual nuclear activity detectors. Techniques in variance reduction were employed to maximize precision and improve the efficiency of calculations while reducing the overall time of calculation.

The most revolutionary lesson over the course of this week long seminar was the integration of computer aided engineering (CAE) programs and the MCNP code. The newest version of the code known as MCNP-6 added the ability to import geometries from a CAE program. This allows for more complex geometries to be more easily created as opposed to using the older and more complex system of geometry definition. The SARA students uses the CAE program Abaqus to do our modeling. Because of this adaptation, users are able to create a visual representation of their experiments that allow for faster troubleshooting and manipulation of objects. Using Abaqus input files, SARA students modelled the detectors used in real experiments and produced outputs with heightened efficiency.

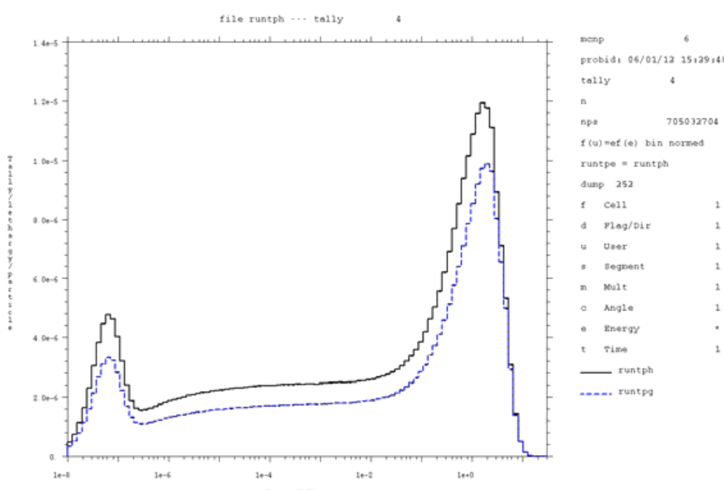
Detector Modeling

SARA Students modeled two different neutron radiation detectors using Abaqus software: the SNAP and the NPOD.



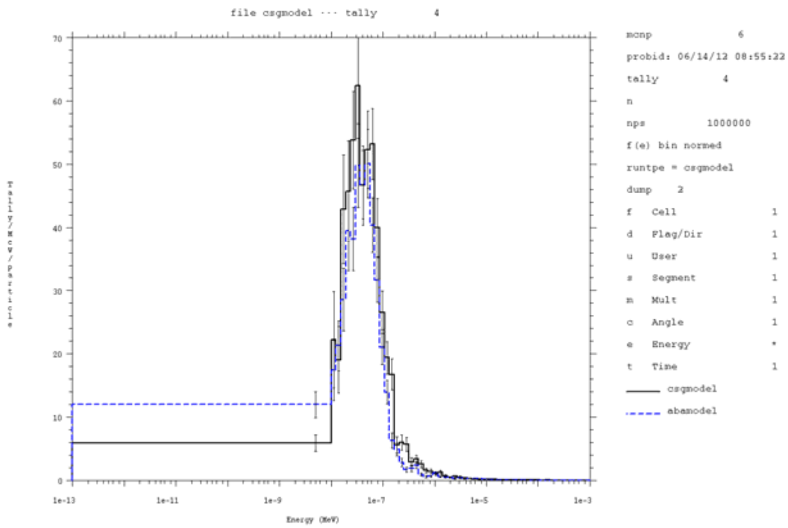
SNAP Detector modeled in Abaqus

Using the input files from these models in conjunction with MCNP, the students simulated an experiment to test the effects on detector reading from room return. Two runs of the code, one with a SNAP detector and neutron source inside an aluminum container and the other with the detector and source in open space, showed that at all energies levels the neutron flux through the detector was higher when the detector contained. This just one of the factors which need to be taken into consideration when using neutron detectors for experiments or in real scenarios..

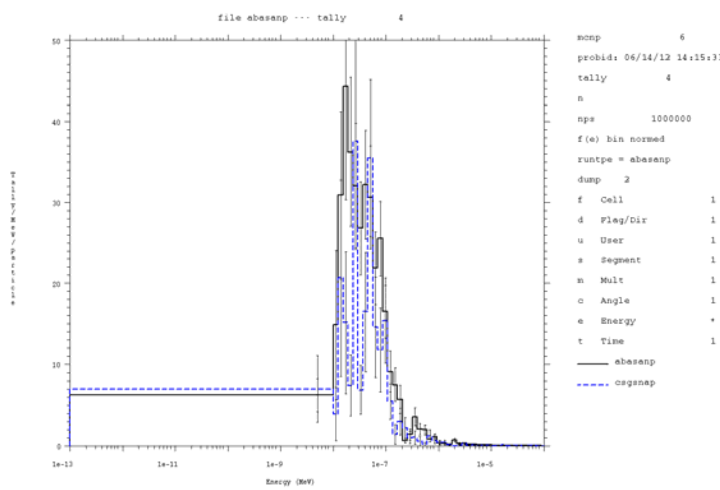


Energy of flux neutrons with and without room return

The models created by the SARA students were also compared to the Combinatorial Solid Geometry (CSG) models which have been used for years. The results showed that while the Abaqus models were nowhere close to perfect, very similar results can be achieved with using a CAE program to design geometries.



Comparison of CSG model and Abaqus model for the NPOD detector



Comparison of CSG model and Abaqus model for the SNAP detector

The inclusion of CAE mesh geometries is a fantastic addition to MCNP, which will make future modeling significantly easier for users.

Tours and Trips

SARA students were given tours of several important and historic sites at LANL to supplement their understanding of nuclear weapons from text and lecture, including the TA-55 Plutonium Facility, the TA-41 Ice House, and the DARHT facility. The PF-4 Facility in TA-55 is the only place in the United States that handles large amounts of plutonium for the U.S. nuclear weapons stockpile. TA-55 is considered to be one of the most secure areas at LANL, and the details of what SARA students saw while inside the PF-4 facility are classified.

TA-55 Plutonium Facility

The Dual-Axis Radiological Hydro Test facility allows LANL scientists to take up to five x rays from two different directions of a hydrodynamic test shot. A hydrodynamic test is a contained implosion of a mock nuclear device; the radiographs of these tests are used by LANL scientist to help ensure the safety, security, and reliability of the U.S. stockpile. While the concept of hydrodynamic testing is not new, DARHT's innovative dual axis design means it is the only facility in the world that gives scientists the ability to create three-dimensional radiographs of the hydro tests.

DARHT Facility

The Secure Computing Center houses all of LANL's supercomputers, including their most recent, Cielo. The SCC's powerful supercomputing ability is critical to LANL's stockpile stewardship mission as well as its service to the United States as a national security laboratory.

Cielo Supercomputer

Minot AFB, Colorado

For the last week of the internship, SARA students were provided the unique opportunity to see the Department of Defense's real-life application of X-division’s work in Minot, Colorado. For four days students were guests of the 91st Operations Group, 742 Missile Squadron and toured the various facilities of Minot Air Force Base.

Display of missile outside Minot AFB front gate

After attending some lectures to gain an understanding of the mission and goals of the Operations Group, students were allowed to tour a “training silo” that housed the equipment and capabilities to train maintenance crews for effective stockpile stewardship. This tour was then followed by a question and answer session with some of the maintenance staff and provided valuable insight to the precision and professionalism of those dedicated to preserving America’s deterrence capabilities.

The Operations Group gave a dynamic display of the security forces that are the “first responders” to any threat of their off-base sites. Ome of the group became intimately familiar with this highly trained group’s capabilities on an evening run that happened to stray too close to a secure facility.

B-52 bomber planes remain in service to provide the Air Force with the capability for long range delivery of physics packages and serve as a visible testament to the nation’s deterrence abilities. SARA students were able to view a static display of this behemoth and speak with pilots and weapons officers that are responsible for for carrying out this mission. The opportunity to ask questions in a relaxed environment led to a deeper understanding of life as a military officer, which all students will become upon graduation, and the realities of deterrence missions.

B-52 with complete weapons loadout

On the final day in Minot, students sat in on a mission briefing and planning session that takes place daily to prepare missileers for a twenty-four hour watch in a launch control center. following this, students accompanied watch standers into a launch control center and toured the facilities. Besides the secure facility from which launches are initiated, students also viewed the support activity centers and spoke with those whose mission is to support missileers on watch. This particular tour and accompanying briefings demonstrated the gravity of the 91st Operations Group’s mission and the professionalism of the DoD personnel charge with our nation’s defense. Additionally, this provided LANL with the opportunity to present information and updates about the labs involvement with maintaining and improving the the integration of lab projects provided to the DoD and specifically the Air Force.

Research Project

The SARA students spent one week doing real life calculations using the SNAP and NPOD neutron detectors. The reading were taken off of a CF-252 source at different heights from the concrete floor, different distances from the source, and with different moderators around the source. The measurements were taken on the ground, one half meter off the ground, and one meter off the ground at distances of one half meter, one meter, and two meters. Each measurement was also done with the source surrounded by one and a half inches, three inches, and six inches of polyethylene, as well as a measurement with one and a half inches of polyethylene and one and a half inches of steel, just the one and a half inches of steel, and with a bare source.

Experiment Setup for one and one half inch steel moderator, one half meter off the ground and one half meter from source

Additionally, measurements were taken with people standing next to and behind the detector to see how this would affect the readings. The results from these experiments will be used to help calibrate the equipment for use in the field. Following the experiments, a MCNP simulation was run to mimic one of the experiments, and the results were compared. The simulation which ran in MCNP came out with almost double the number of particles detected in experiment (1383127 to 575547). Error of this magnitude most likely came from flaws in the abaqus models, but with some additional work it should be possible to create models which can accurately reflect real measurements. This project gave the SARA students an opportunity to see the process of running experiments in a laboratory setting. Since the SARA students had not done radiological worker training, handling of the source was done by LANL staff members, but the students were still able to see the safety measures used when working with radiation sources. These measurements gave the students a different perspective after spending the first few weeks working with computer models.

PART II

SARA Internship 2012/ XCP 3 and 7

By: MIDN David Lorio, USN

Los Alamos National Laboratory (LANL) is one of the nation's leading nuclear science laboratories that continues to strive in keeping America safe. The mission at LANL is to "apply science and technology to: ensure the safety, security, and reliability of the U.S. nuclear deterrent, reduce global threats, and solve other emerging national security challenges." At the lab, scientist and engineers focus on the maintenance and improvement of nuclear weapons, national security, space exploration, renewable energy, medicine, nanotechnology, and supercomputing.

Each summer LANL provides an opportunity for members from the U.S. Service Academies to participate in the Service Academy Research Associates (SARA) program here at the lab. This program enables Midshipmen and Cadets to receive a Q clearance, enabling them to learn and work with classified information making the internship much more interesting and educational. If accepted to this undergraduate research internship, Midshipmen and Cadets are assigned to a certain Division and Group where they will work during their time at the lab. After work, SARA students can choose from an assortment of activities to participate in, such as golf, working out at YMCA in Los Alamos, hiking, playing softball with lab employees that are friends with your brother, trips to Santa Fe and Albuquerque, and relaxing by the pool at the Buffalo Thunder's Homewood Suites long term lodging down the mountain. During their entire stay here in Los Alamos, SARA students are able to stay busy and get the most out of this trip.

During my time at the lab, from June 25 to July 20, I was very fortunate in getting assigned to the XCP Division, groups three and seven. Under the mentorship of Dr.'s Goorley, Sood, and Solomon, I was able to get a better understanding of the Theory of Nuclear Weapons, radiation transport simulations through transport applications, and neutron and gamma experiments and analysis entailing the use of the Monte Carlo Code. While at the lab, I also attended education lectures pertaining to the nuclear world as well as a tour of the more important facilities here at LANL. Each of these parts of my time here at the lab were very educational and interesting, helping me learn more about nuclear physics and its applications in the world today.

MCNP, Nuclear Weapons, and Physics

Prior to my internship at the lab, I had very little education and experience working with the Monte Carlo N Particle (MCNP) code, the theory of Nuclear Weapons, and principles of Nuclear Physics in general. Over the course of my four weeks here, however, I became somewhat knowledgeable of each of these categories.

Upon arriving at the lab, I did not have a clear of an understanding of how nuclear weapons actually worked. Dr. Goorley, group leader of XCP 3, helped me get a basic understanding of the theory of nuclear weapons through many conversations, a classified document known as the "Wash Manual", and other classified videos that contained important information of the nuclear world today. With his help and a few hours of reading on my own, I was able to get a basic understanding of nuclear weapons and how they functioned.

Another important topic that I needed to understand during my time here is the principles of Nuclear Physics. With the instruction provided from Dr. Sood and presentations created by Dr. Jim Hill, I was able to increase my understanding about particles, reactions, cross sections, fissions, and deriving and solving the neutron transport equation. I would need each of these principles to understand and help me accomplish my work during my time here at LANL.

Rather than participating in a MCNP class like the prior SARA students, I had to learn the program on my own with the grateful help from Dr. Solomon, The MCNP Primer, and The MCNP6 Book on Unstructured Mesh Geometry. After giving me a broad overview of the program, Dr. Solomon challenged me with multiple scenarios pertaining to radiation analysis and transport. With the help of the Primer, MCNP6, and a few questions for Dr. Solomon, I was able to write a code that enabled me to follow and track the behavior of particles based on an internal database of particle physics and nuclear cross sections.

Lectures

During my time at LANL, I attended a few of the summer lecture series for students. Each of these briefs talked about pertain information in the nuclear world today, such as North Korea and LANL's Stockpile and Stewardship Program. Of the lectures that I attended, I believe the one about North Korea was the most interesting and educational. Former lab director, Dr. Siegfried Hecker, presented the lecture title "What's Next for Nuclear North Korea." From this lecture, I learned a lot of important information about North Korea's nuclear stockpile, how far along they are in their weapon making process, when they may be a notable threat, and what steps the U.S. should take in controlling this situation in the Western Pacific.

Dr. Siegfried Hecker

North Korean Uranium Enrichment Plant

Tours

During my internship at the lab, I was given a tour of some of the more historic and important facilities at LANL. Of the many facilities we toured, the Secure Computing Center (SCC), the National Security Sciences Building (NSSB) archives, and the TA-55 Plutonium Facility were the most interesting, educational, and important.

The SCC is where the lab houses all of its super computers and the equipment that goes along with them. The SCC's supercomputing capability plays a crucial role in enabling LANL to serve as the U.S.'s main nuclear national security laboratory. Some of the systems housed in the SCC include the Roadrunner Supercomputing System, Luna, and Cielo. Although the Luna system is the newest, the major workhorse in the SCC is Cielo, processing 1370 teraflops per second, packing more power and memory than any other system in the LANL arsenal.

The Secure Computing Center

Cielo Supercomputer

The next facility we toured was the LANL archives located on the first floor of NSSB. In the archives, there are lockers and shelves full of important information dating back to the beginning of the lab expanding to present day. Some of the important things in the archives include diagrams of Little Boy, Fat Man, and a cross section look at the Enola Gay bomber. Each of these classified articles is an important part of the labs history as well as the U.S's success during the Manhattan Project.

National Security Sciences Building

Next on the tour were the TA-55 Plutonium Facility and the PF-4 facility inside. TA-55 is the most secure facility on LANL since the PF-4 facility inside is the only place in the United States that has the capabilities to handle the large amounts of plutonium needed for our nuclear weapons stockpile. The details of everything that were seen and discussed inside the facility is classified.

TA-55 Plutonium Facility

Detector Measurements Research Project

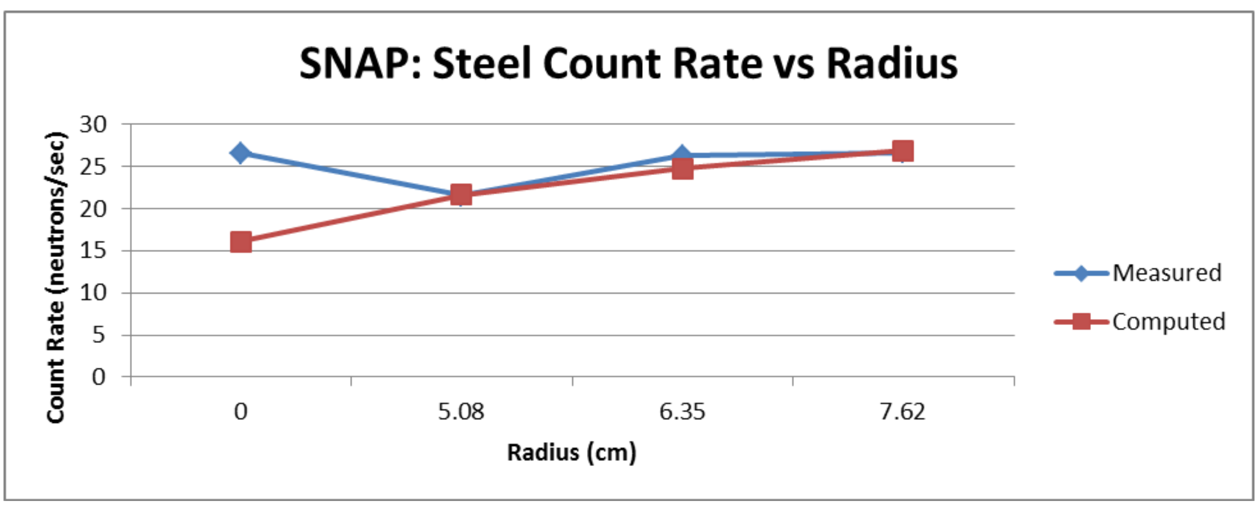
During my third week at LANL, I worked with Jesson Hutchinson, Travis Grove, and Rene Sanchez, members of NEN-2: Advanced Nuclear Technology Group, in taking measurements with SNAP and NPOD neutron detectors. For these measurements, we used a Californium (CF- 252) source and moderated it with individual or a combination of polyurethane, depleted uranium, steel, and mock high explosives (MHE). For a majority of the tests, the source, surrounded by a moderator, was a meter off the ground, the SNAP detector was a meter away from the source, and the NPOD was half a meter away from the source. A variety of thicknesses were used for each of the moderators ranging from a quarter of an inch of depleted uranium to seven inches of MHE. From each of the different scenarios we were able to determine the number and strength of neutrons that the source put off and how these moderators affected those numbers.

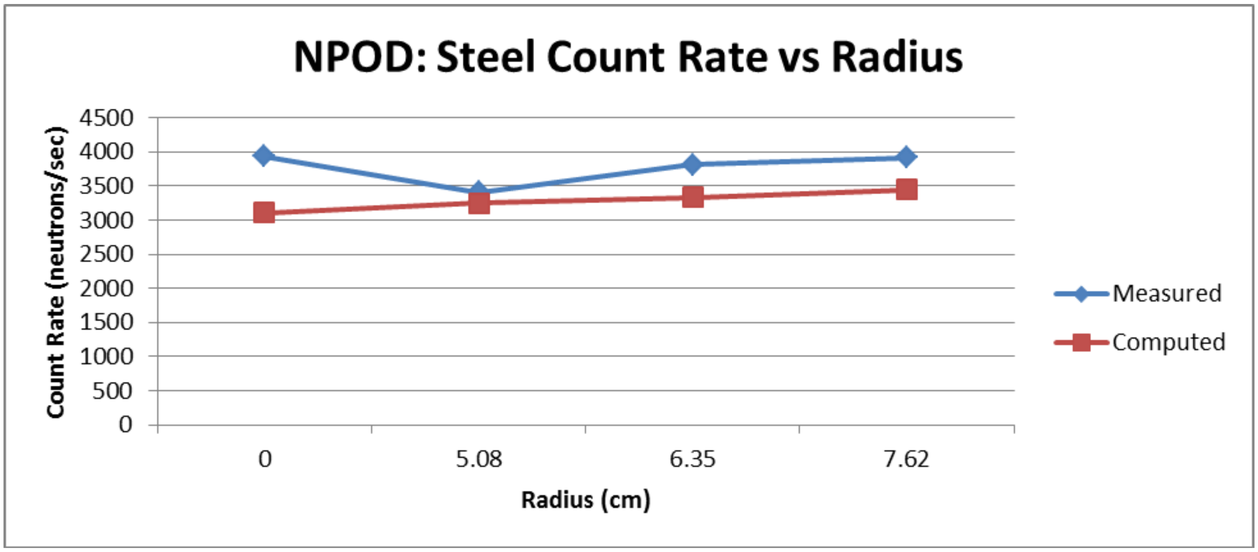
Experiment Setup with seven inches of MHE around CF-252 one meter from ground, SNAP one meter from source, and NPOD one-half meter from source.

After taking measurements with these detectors, I was tasked with comparing the experimental measurements to the ones I computed with MCNP. Below, you will find the measured data compared to the computed data for the steel and poly shells. The charts contain all of the calculated data and the easy to read graphs represent those calculations separated by moderator and detector used.

Steel Shells

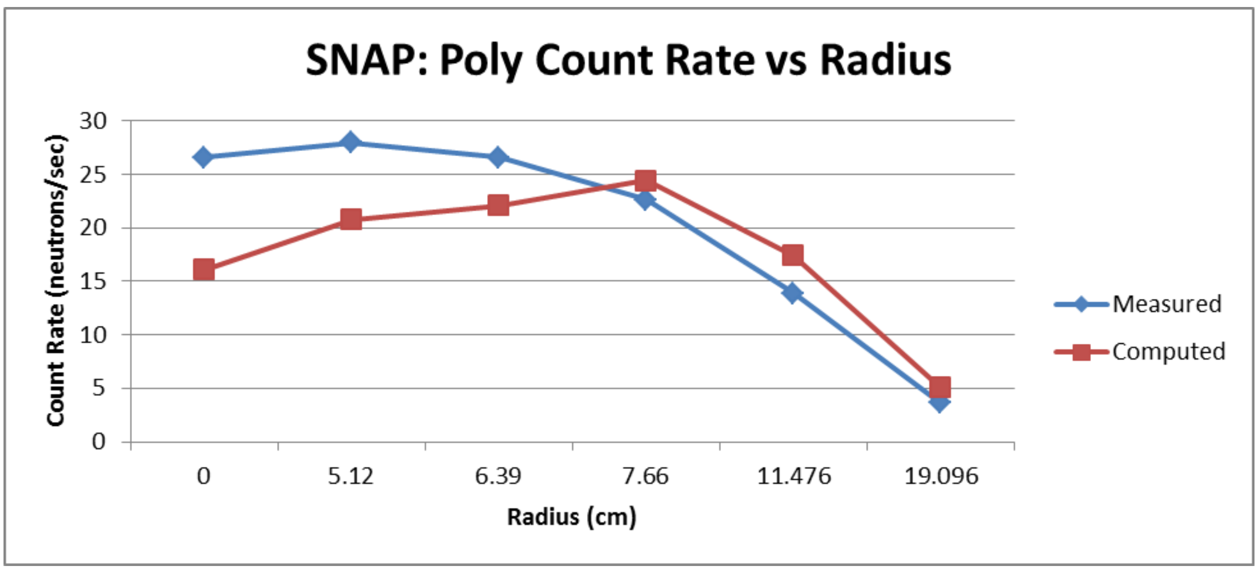
Radius	SNAP Meaured	SNAP Computed	Relative Error (%)	Radius	NPOD Measured	NPOD Calculated	Relative Error (%)
0	26.5984	16.0906	7.15	0	3930	3107.130	1.25
5.08	21.5458	21.5970	13.75	5.08	3408.123	3247.051	1.19
6.35	26.2626	24.7745	13.14	6.35	3809.236	3330.513	1.20
7.62	26.6733	26.8782	12.93	7.62	3916.497	3445.431	1.19

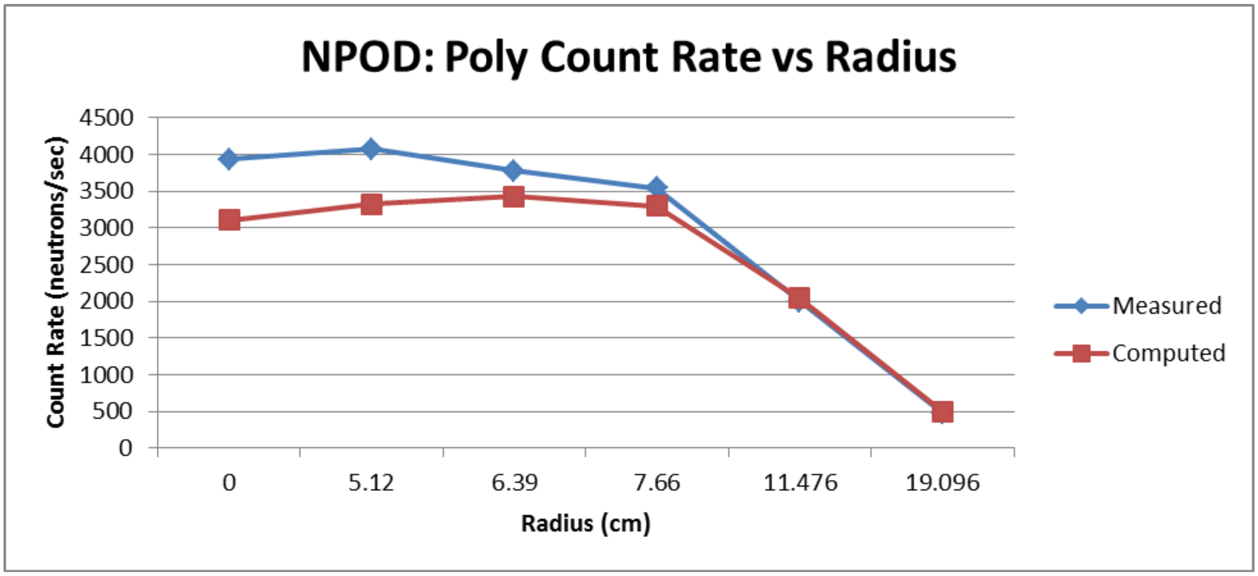




Poly Shells

Radius	SNAP Measured	SNAP Computed	Relative Error (%)	Radius	NPOD Meaured	NPOD Computed	Relative Error (%)
0	26.5984	16.0906	7.15	0	3930	3107.130	1.25
5.12	27.9744	20.7602	13.79	5.12	4070.851	3318.941	1.21
6.39	26.5575	22.1037	13.43	6.39	3772.93	3424.460	1.20
7.66	22.6472	24.4049	13.19	7.66	3541.609	3291.693	1.21
11.476	13.8591	17.3913	17.55	11.476	1995.305	2041.834	1.54
19.096	3.6544	5.0736	32.19	19.096	476.702	501.051	3.08





As you can see from the charts above, the count rates calculated from the measurements do not always match those from the computed data. A key example of this disagreement is the count rate of the bare source. From the measured data, we accounted for the count rate to be about 26 neutrons per second compared to the 16 neutrons per second of the computed data. This miscalculation may have come from a translation, measurement, or mathematical error when computing the count rate. Besides a few hiccups here and there, the data that was obtained through the measurements more or less simulates that of the MCNP calculations.

Working as an intern apart of the SARA program at LANL was a very educational and interesting experience that will never be forgotten. Over the past four weeks, I have learned more about the theory of nuclear weapons, radiation transport, and neutron and gamma radiation than I could have ever asked for. Most of this information will play a major role in my future career as a Naval or Marine Officer and I am very grateful for having had the opportunity to work at the United State's most prestigious and important nuclear science laboratory.