U.S. DEPARTMENT OF ENERGY

PNNL-23694

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Summary Report for the Radiation Detection for Nuclear Security Summer School 2014

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September 2014

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 3rd Radiation Detection for Nuclear Security Summer School, 16-27 June 2014. The summer school provided students with a unique understanding of nuclear security challenges faced in the field and exposed them to the technical foundations, analyses, and insight that will be required by future leaders in technology development and implementation. The course heavily emphasized laboratory and field demonstrations including direct measurements of special nuclear material. Student evaluations and feedback from student advisors indicates that the summer school achieved its objectives of 1) exposing students to the range of nuclear security applications for which radiation detection is necessary, 2) articulating the relevance of student research into the broader context, and 3) exciting students about the possibility of future careers in nuclear security. In fact, we are beginning to see previous students both enroll in graduate programs (former undergraduates) and complete internships at government agencies like the National Nuclear Security Administration.

Table 1. Key Summer School Facts and Findings

ATTENDANCE	
number	We hosted fewer graduate students this year because of limited capacity of activities and tours. These 13 students were all U.S. citizens and came from universities across the country. Three accepted applicants dropped out of the course due to funding restrictions. This is the first year that student funding precluded attendance. Future summer school may want to fund a limited number of fellowships through academic partners such as the University of Florida.
backgrounds	Consistent with previous years, the students possessed diverse academic backgrounds that included nuclear engineering, nuclear physics, materials science, chemistry and radiochemistry. All of the students expressed interest in career opportunities in nuclear security, although not necessarily as federal employees.
origins	Students participated from the following universities: University of Tennessee (4), Washington State University (2), University of Wisconsin Madison, Michigan State University, University of Massachusetts Lowell, Colorado School of Mines, University of Cincinnati, University of Florida, and Texas A&M University.
CURRICULUM	
lectures	The largest element of the summer school was a collection of 10 lectures, a reduced number to allot more time for activities. These lectures covered topics spanning nuclear security missions, signatures accessible via radiation detection, gamma-ray and neutron detection, active interrogation, nuclear security systems, and future opportunities.
guest lectures	Nine guest lectures allowed students to interact in a small group setting with national experts on a range of contemporary topics that included treaty verification, nuclear material interdiction, and nuclear safeguards.

CURRICULUM	
activities & tours	The most unique aspect of the summer school was the hands-on activities. Each year we allocate more and more time to this critical part of the course. Activities included modeling of source-term signatures, detector sensitivity vs. selectivity, border-guard training, and energy windowing algorithm implementation. These activities gave students an appreciation for field environments encountered by technology users and exposure to the challenges faced by technology developers. Laboratory tours provided students with insight into facilities and instruments used for cutting edge research and development, including PNNL's shallow underground laboratory and the Radiochemical Processing Laboratory (RPL). A tour of the Hanford Site including the B-Reactor gave students a real-world appreciation for the nuclear fuel cycle.
student lectures	All students briefed their current graduate work to the instructors and their fellow students. These presentations allowed the instructors to articulate the relevance of student work in the larger nuclear security picture and to provide guidance on future work and potential collaborations across the national laboratory complex.
FEEDBACK & LESSONS LEARNED	
student evaluations	Students completed an evaluation form that provided both quantitative feedback to prescribed questions and qualitative feedback that specifically requested recommendations for course improvement. The students unanimously agreed that the summer school was informative and engaging, and that it improved their understanding of the nuclear security mission and how radiation detection relates to nuclear security. The highest scoring element was the tie between the science of radiation detection and its application; 92 percent of students strongly agreed that the school enhanced their understanding of radiation detection as applied to nuclear security. Their comments reinforced this notion. There was a diversity of recommendations for improvements including the following reoccurring points: 1) dedicate more time for the experimental activities, 2) distribute a detailed schedule ahead of time, and 3) identify clear expectations for student presentations and communicate them ahead of time.
key lessons learned	Activities and guest lectures formed the unique nature of the summer school. While these activities consumed most of the time and have been expanded over previous years, they should be further enhanced. Including time for post-activity analysis and interpretation should be considered. The B-Reactor tour should include the supervised but unstructured tour time rather than the brief overview and control room tour.

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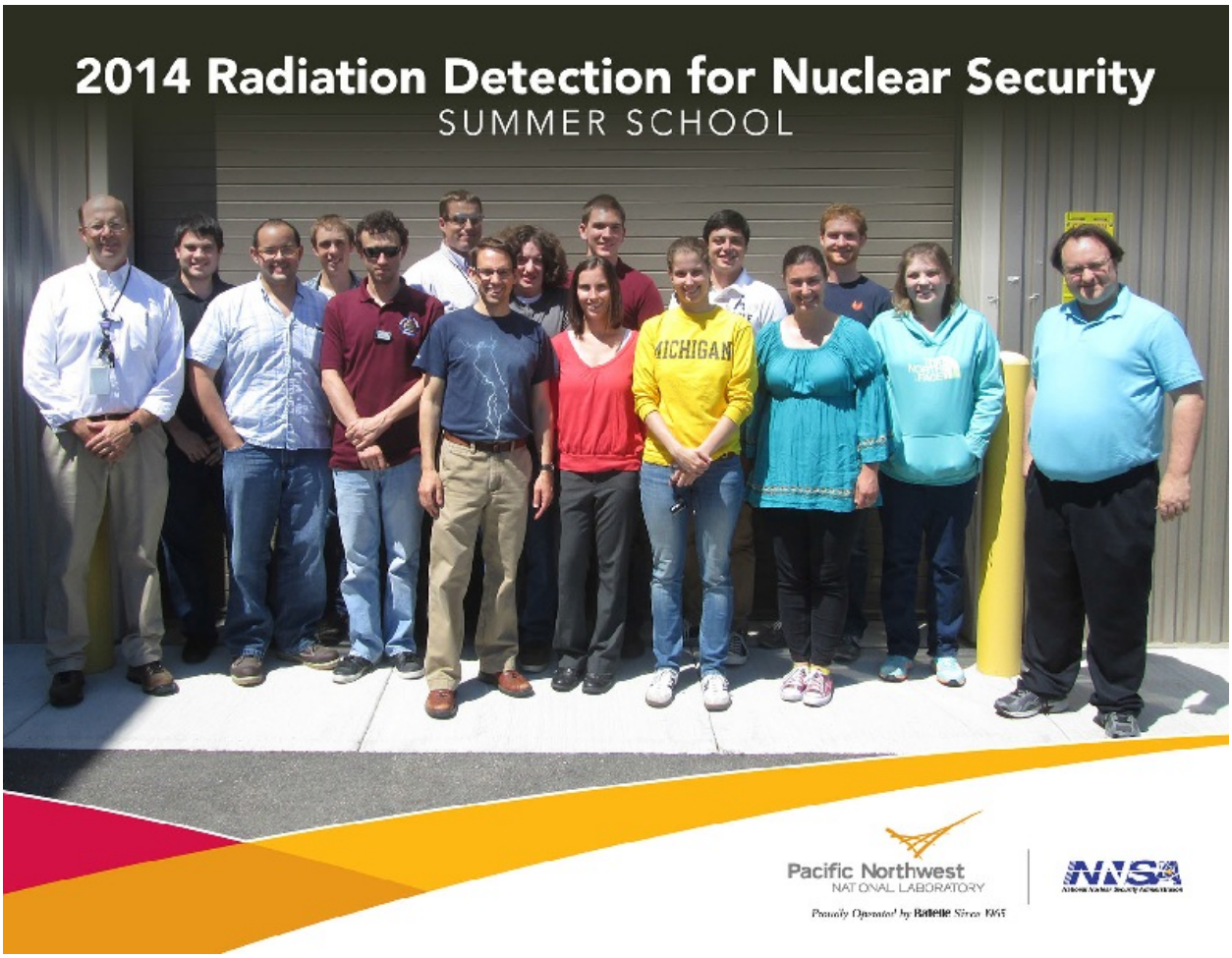
1 Introduction

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 3rd Radiation Detection for Nuclear Security Summer School, 16-27 June 2014. These students included 13 graduate students who were all U.S. citizens and came from universities across the country. This small enrollment, originally recommended by NA-22 program management, was an excellent size that fostered an intimate atmosphere conducive to sidebar discussions and in-depth involvement in activities. Both instructors and students recommend that the summer school be kept small in future years. Table 2 lists graduate student participants; Figure 1 shows a photograph.

Table 2. Graduate Students In Attendance

STUDENT	UNIVERSITY	FIELD OF STUDY	GRADUATE THESIS
Matthew Tweardy	University of Tennessee	Radiological Engineering	National security applications of radiation detection
Joseph Conner	University of Tennessee	Nuclear Engineering	Neutron imaging
Samuel Morrison	Washington State University	Analytical Chemistry	Separation and analysis of fission and activation products
Matthew Michalak	University of Wisconsin Madison	Nuclear Engineering	Fusion neutron sources with applications to SNM detection
Chelsie Beck	Washington State University	Chemistry	
Charles Loelius	Michigan State University	Nuclear Physics	Lifetime Measurement of ^{58}Zn
Emily Jackson	University of Massachusetts Lowell	Nuclear Physics	Novel Ge DSSDs
Tyler Remedes	Colorado School of Mines	Nuclear Engineering - Radiation Detection	Neutron detection in organic scintillators
Amie Norton	University of Cincinnati	Inorganic Chemistry	Sensor development in vapochromic and anion sensing platinum (II) materials
Oswaldo Pelaez	University of Florida	Nuclear Engineering	
Jennifer Erchinger	Texas A&M University	Nuclear Security and Safeguards	
Alexander Okowita	University of Tennessee - Knoxville	Radiological Engineering	Alternative ^{3}He detectors for safeguards
Blake Palles	University of Tennessee - Knoxville	Energy Science and Engineering	Fast neutron imaging for nuclear weapon dismantlement

Figure 1. Group Photograph of Summer School Participants and Instructors. Each student received an autographed copy upon completion of the course.



2 Lectures

The summer school lectures were bifurcated into two discrete weeks. The first week covered foundational knowledge of radiation detection and its application in nuclear security. This included both the physics of radiation detection and specific systems and methods deployed in nuclear security missions (Table 3). The second week consisted of a series of topical guest lectures delivered by a set of national and international subject matter experts and participation in mission specific activities (Table 4).

Table 3. Listing of Lectures

LECTURE NUMBER	LECTURE TITLE	LECTURER
1	The Nuclear Security Mission	Robert Runkle
2	The Physics of Fission, Nuclear Fuel, Enrichment, and Reactors	James Baciak
3	Signatures of Special Nuclear Material	Robert Runkle
4	Modeling Gamma-Ray Source Terms	Mitchell Woodring
5	Fundamentals of Radiation Detection: Gamma-Rays	James Baciak
6	Gamma-ray Detection & Spectroscopy	Robert Runkle
7	Fundamentals of Radiation Detection: Neutrons	James Baciak
8	Neutron Detection Systems	Robert Runkle
9	Gamma-Ray and Neutron Imaging for Nuclear Security Applications	James Baciak
10	Systems Level View of Nuclear Security	Robert Runkle
11	Emerging Trends & Opportunities	Robert Runkle

Table 4. Listing of Guest Lectures

LECTURE NUMBER	LECTURE TITLE	LECTURER
1	Emergency Response	David Bowman
2	IAEA Safeguards Inspections: Policy Drivers & Technology Requirements	L. Eric Smith
3	Nuclear Archaeology in a Bottle	Jon Schwantes
4	Fukushima Response	Vincent Woods
5	Second Line of Defense Program: A Key Element of the Global Nuclear Security Framework	David Kostorowski
6	R&D Challenges for International Safeguards	Arden Dougan
7	Dr., Dr., Give Me the News, I Have a Weird Spectrum and I am Very Confused	Jason Shergur
8	Internship Opportunities	Robert Dromgoole
9	Career Advice Panel	Tammy Taylor, Chris Aardahl & Doug McMakin
10	Comprehensive Nuclear-Test-Ban Treaty: A Detector Geek's Perspective	Cari Seifert

3 Activities & Tours

The activities and laboratory tours were the highlight of the summer school course in several ways, most notably because they provided students with hands-on experience using detectors, such as those in Figure 2 that are currently deployed in operational environments. The primary goal of these activities was to demonstrate the constraints faced by technology operators, for example the difficulty of carrying the sometimes heavy instrumentation. Table 5 provides a summary of these activities.

A set of laboratory and off-site tours gave students an in-depth appreciation of specialized instruments used in various nuclear security settings. These included a visit to the SAUNA (Swedish Automatic Unit for Noble Gas Acquisition) system which is designed for low-level measurement of radioxenon. This type of system is used as part of the International Monitoring System network of the Comprehensive Test Ban Treaty Organization. Students were also given a tour of the shallow underground laboratory where low-background detectors are assembled, tested, and used for national security applications and the Radiochemical Processing Laboratory (RPL) used for research in cleanup of radiological wastes, processing and disposal of nuclear fuels, and production and delivery of medical isotopes.

Table 5. Summary of Activities and Tours

ACTIVITY/TOUR	PURPOSE	LOCATION
Modeling Source Terms and Detector Response	Introduce students to the modeling software SYNTH and use this software to explore the variety of factors that impact the signatures, primarily gamma-ray emissions, of bulk special nuclear material.	N/A
Radiation Detectors: Sensitivity vs. Selectivity	Use a variety of radiation detectors with differing efficiencies and energy resolutions to measure the energy of gamma rays emitted by low-activity sources commonly used to calibrate and characterize detection systems.	Large Detector Laboratory
Laboratory Tours	Expose students to operational facilities and research and development laboratories.	Swedish Automatic Unit for Noble Gas Acquisition, Shallow Underground Laboratory, Radiochemical Processing Laboratory, Radiological Calibrations Laboratory
B Reactor Tour	Visit the site of the world's first industrial-scale nuclear reactor and learn about its development, construction, and operation during the Manhattan Project.	Hanford Site

ACTIVITY/TOUR	PURPOSE	LOCATION
Determining the Sensitivity of Radiation Portal Monitors	Introduce students to the operation of cargo and vehicle radiation portal monitors, including energy window discrimination, and observe the effects of shielding and naturally occurring radioactive material on the capability of portal monitors to detect special nuclear material.	Large Detector Laboratory Test Track
Border Guard Training	Participate in a border guard training activity that includes locating and identifying sources in a realistic setting.	Volpentest HAMMER Federal Training Center

Figure 2. On left, students measure detector response functions from various radiation detectors. On right, students don clean-room gear before entering the shallow underground laboratory.

4 Student Evaluations

Students completed an evaluation form that provided both quantitative feedback to prescribed questions and qualitative feedback that specifically requested recommendations for course improvements. The students unanimously agreed that the summer school was informative and engaging, improved their understanding of the nuclear security mission and how radiation detection relates to nuclear security. The highest scoring element was the tie between the science of radiation detection and its application; 92 percent of students strongly agreed that the school enhanced their understanding of radiation detection as applied to nuclear security and their comments reinforced this (see below). There was a diversity of recommendations for improvements including several reoccurring points: 1) more time for the experimental activities, 2) distribution of detailed schedule ahead of time, and 3) clear expectations for student presentations communicated ahead of time.

The students identified a variety of favorite aspects of the course that they found especially enjoyable or useful. The most common response was to the hands-on activities, especially the opportunity to work with the radiation portal monitors (RPMs) at the PNNL test track. Other frequently mentioned favorites included i) B-Reactor and HAMMER tours, ii) guest lectures on a variety of current topics by experts in nuclear security, specifically the Fukushima lectures, and iii) tours of operating labs.

Although the response was mostly positive to the course, the most common complaints from students involved the challenges of teaching to a diverse set of backrounds (some found the basic material unnecessary while others were exposed for the first time) and students suggested making more time for the experimental activities including the data analysis elements.

Table 6 lists quantitative ratings from student surveys. Unabridged student comments include the following:

When asked " My favorite part of the Summer School was"

- The guest lectures were fantastic as well as the facility tours. I strongly believe this course has enhanced my knowledge in the nuclear security field and will allow me to be much more successful in wherever my career will take me.

- I really enjoyed getting to see the intersection of policy and science first hand. Normally I see very few such practical applications of science so I feel this has been useful for understanding what sorts of careers are possible. I found getting to see what sorts of technology in the field are used for treaty verification really useful for understanding nonproliferation. I think I have far more understanding of what nonproliferation means and requires than I had before. Also getting to see B reactor was literally the bomb.

- The tours and guest speakers were great. The Hanford site tour, specifically B Reactor was a highlight. HAMMER was also really awesome to see. Going into working labs to see kind of what life is like at a national lab was a very good thing.

- During school you learn about how things work in a lab and maybe how detectors work. But the real value of this class is how it extends one's knowledge about the real world. It seems like most scientists do not understand how real world conditions cause problems and that is exactly what this class addresses. Also it was great to hear from all the guest speakers and the tours were great. I found out that there are so many more careers out there than I realized.

- Getting to see different parts of the national lab. I enjoyed meeting people and hearing about there research. I am truly an experimental chemist who loves to see application so seeing the applied side of things was great. Thank you to all of you. I have learned so much that I didn't know and I would like to get into this field if I can. I particularly liked the lecture on the airplane detector and Japan.

- Guest lectures from David Kostorowski and Dave Bowman on the national security/emergency response applications of nuclear physics. I think this is also the most important part of the school because it allows students who may have only been exposed to the academic side of nuclear physics research to explore the possibilities for more real-world applications and career paths.

- I truly enjoyed the applied scenarios. Specifically I enjoyed 3440 test track and Hammer facility exercises. From the presentations given by guest lecturers I formulated a few ideas for future proposals. I also learned which personnel at PNNL I should communicate with to discuss future research with. The best presentation in my opinion was by Vincent. The visual observation of the instrument combined with his presentation of the applied detection during the Fukishima release was a great example of the success of some of the radiation detection. My second favorite presentation was Ted Bowman's *(Dave Bowman is the correct name)* presentation. I enjoyed his presentation because of the real world detection scenario.

- Activity 7 (the RPM algorithm testing). Having worked a bit with RPMs in previous research, it was very instructive and exciting to learn more about the inner workings, operational challenges, and basics of algorithm design in the portals actually deployed on our borders and in the SLD. The guest lectures were on the same order of magnitude. Relating what we learned from the fundamentals lectures to a variety of real world applications helped broaden my understanding of not only the large impact our field makes in the technical and policy realms, but also helped display the wide array of career possibilities available to us. Of particular note were the talks by Dave Bowman, Jon Schwantes, Dave Kostorowski, Arden Dougan, Jason Shergur, and Carolyn Seifert.

- The tours of the facilities. They put into context just where all the time spent in classrooms and labs materialize into something tangible. They give a perspective on the history of the nuclear program in the US which is necessary in order to effectively move forward with technology and progress. They also put into perspective the vast capabilities of the assets the US government publicly has at its disposal. This can inspire individuals to become engaged in projects at the national labs and see just how they can contribute to our national security.

- I very much enjoyed the guest lectures. That, coupled with the tours of the facilities given by experts, was a great learning experience. Getting into the cooling tower was pretty awesome, and HAMMER was an interesting place. Being able to interact with the instructors both in and out of the classroom was also pretty great.

- In a general sense, the quality of the instructors and the relevance of the activities and guest speakers was the greatest strength. It seems like they pulled out a lot of stops to give us a comprehensive view of the many different facets of the nuclear security mission. More specifically, the visit to the Hammer facility was my favorite. All the guest speakers there were incredibly intelligent and the lectures really gave us a sense of what it is like to work in their respective fields. In addition, the fact that we got hands on experience with so many different detector systems was one of the strongest parts of the course. That really gave me a perspective on the limitations and capabilities of the real-world applications.

- The day spent at HAMMER. Guest lectures including but not limited to Eric Smith, Jon Schwantes and Cari Seifert.

When asked "I would make improvements to the Summer School by"

- Please send out the agenda out before the course starts, it was very difficult to plan flights without knowing the exact plan. Even if it is a preliminary schedule it would help. Maybe give some warning about the student presentations so we can be a bit more prepared for when we have to give them More time given for the RPM exercise, it was very hectic trying to come up with algorithms for the input in 20 minutes…

- I cannot think of many changes necessary or desirable everything was really great. Very intense two weeks!

- I would make improvements to the Radiation Detection for Nuclear Security Summer School by a bit more information before the class i.e. rough schedule, logistics, etc. More time in working labs (The second Thursday 3420 tour with the four stations could have been longer).

- Telling the students know that they are presenting about their research during their time at PNNL before arriving in Washington. That way they can make a presentation with all the figures and data that they need.

- The power plant tour left a little to be desired, I wanted to see a power plant.

- Allow for more time with the detector measurement lab (Mitch's Lab). Things got a little crazy and not everyone got to use each detector. Also (not sure you have any control over this) but please try to reserve hotel rooms with two queen beds! Those foldout couches are terrible! Maybe put students up in the guest house if it's not too expensive?

- I truly enjoyed all of the summer school. I believe the only addition would be further applied studies. If Vincent could allow us to test the systems he has at the 300 area that would be amazing. This may be an irrational request though due to the QA/QC integrity he needs to maintain. I think the course would benefit from an exercise in which the student attempts to develop shielding to defeat the portal monitors. This may help the student thought process of the complimentary detection methods necessity, active interrogation complimenting portal monitors.

- Possibly adding in more lab activities. I know the restrictions on working with visitors in the lab probably make this a difficult logistical hurdle, but the hands-on time we had in the course was very valuable in putting the lecture discussions into perspective.

- The program is magnificent as is. The only enhancement I would suggest is to implement more activities and exercises that mimic field work (i.e. the missing source on day 1, RPM activity in week 2). These are the connections that bridge graduate work that may seem far removed from reality and fieldwork that will one day become our careers.

- Giving us a schedule before we arrive. Even if it is a rough estimate, it would be better than going in being completely ignorant of what to expect. Coming from a nuclear background some of the fundamental talks were not very useful, but I know it was useful for those coming from different backgrounds. Similarly, the detector lab was not particularly interesting, but I was surprised to learn that some had never been in a radiation lab before. Nap Time! Being given more time to work with the portal monitor data would have been great. The entire exercise seemed super rushed, definitely limiting the usefulness of the exercise. Having another dinner out somewhere would be great. The first day, everything is a little awkward, so having a second shot at it would be nice. The first day icebreaker was lame. Another activity could definitely break more ice.

- Small thing, but a clearer schedule would be nice. By this I mean just add some lines to the vertical time scale so that we could see exactly when something would start or end. Also, some forward notice that we will be casually presenting our research would have helped. I found myself scrambling to dig up and remember a presentation that I could give. This could also help if certain people need to get general release for a presentation.

Table 6. Student Ratings from Summer School Survey

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I found the Radiation Detection for Nuclear Security Summer School to be informative and engaging.				
83%	17%	-	-	-
2. The Radiation Detection for Nuclear Security Summer School improved my understanding of the nuclear security mission.				
75%	25%	-	-	-
3. I believe the Radiation Detection for Nuclear Security Summer School enhanced my understanding of radiation detection as applied to nuclear security.				
92%	8%	-	-	-
4. The activities/experiments performed within the Summer School were useful.				
67%	33%	-	-	-
5. The facility tours were engaging and enhanced your understanding of the nuclear security mission.				
75%	25%	-	-	-
6. The guest lectures provided improved understanding of the challenges associated with the wide scope of nuclear security.				
75%	25%	-	-	-
7. Having student participants present on their research is an important part of the summer school agenda.				
25%	33%	42%	-	-
8. I would recommend the Radiation Detection for Nuclear Security Summer School to other students.				
100%	-	-	-	-
9. Participation in the Radiation Detection for Nuclear Security Summer School has increased my interest working within the nuclear security mission at national laboratories, or for the federal government.				
75%	25%	-	-	-

5 Lessons Learned

5.1 Lectures

1. Reduction in lecture time from previous years benefited the course. Students no longer commented on lectures being rushed nor difficultly digesting their content.

2. Scheduling the conference room blocks was very helpful toward ensuring a good presentation atmosphere.

3. The ice breaker on the first day should be replaced. The emergency response activity was a big hit and should be included again!

5.2 Activities

4. Additional time allotted for the RPM activity was not sufficient. Time for analysis should be included. The student suggestion of shielding calculations could also be coupled to this activity.

5. The modeling activity was much improved this year, but it should be further simplified to define geometries more clearly.

5.3 Tours

6. The tours went much smoother than in the past. The energy towards scheduling the HAMMER activity in detail was well worth the time.

7. The B-Reactor tour needs more time that includes a signficant chuck of unstructured exploratory touring.

6 Future Plans

By essentially all metrics the third summer school was a success. There were few surprises and the group of students in attendance was again exceptional. The acumen and engagement of the students has improved each year beyond expectations.

It was clear from the energy in the room that the activities were the most impressive aspect of the summer school. While also the most expensive to plan and execute, these activities most directly achieve the summer school's goals. The most effective path towards improving the summer school is thus to expand both the depth of existing activities and to supplement the curriculum with additional activities. A key consideration for future activity development is the need for a safeguards-relevant measurement, for example one focused on spectroscopic analysis of varying levels of uranium enrichment.

Acquisition and incorporation of additional data collection electronics and dedication of detections would improve the experimental activities.

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