

## COVER PAGE

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## ACCOMPLISHMENTS

- What are the major goals and objectives of this project?
- What was accomplished towards these goals?
  - What was the technical approach?
  - Describe progress toward completion of major activities or significant objectives identified in your proposal and include significant results, key outcomes, and other achievements.
  - As the project progresses, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.
- What do you plan to do during the next reporting period to accomplish the goals and objectives?
- What opportunities for training and professional development were provided for participants?
- How have the results been disseminated to communities of interest? In particular, provide details for any dissemination not reported in the research product section of this report.

### **Response:**

We developed a structured training program to actively engage Morgan State students in research, combining theoretical knowledge and practical skills essential for heavy-ion physics. The first three (3) months of the project, trainees got weekly seminars and workshops focused on the fundamentals of nuclear theory, C++ and ROOT programming, along with steps in analyzing heavy-ion collision data. The trainees were given a weekly reading task (literature review) of which they were asked to prepare a presentation, and the PI provided direct feedback during presentations and mentoring sessions, encouraging the trainees to reflect on their progress, troubleshoot challenges, and push their skills further. These weekly constructive feedback and guidance fostered a productive learning environment and reinforced best practices in scientific research.

The trainees began C++ basics exercises from Runestone Academy, including variables, loops, and conditionals. In parallel, the trainees were working on ROOT CERN, a software used by the heavy ion community, where they worked on file input/output operations using TFile and TTree classes for data analysis, involving creation and manipulation of histograms with the TH1F class. To cement the knowledge gained, they were assigned the tasks of writing a macro to generate random numbers as they learnt about using ROOT's TRandom class. This was an important step through the learning stage, as it is essential to learn how to generate and analyze event variables in heavy ion physics. The trainees were also given a small data set collected from the picomuon detector in the lab so that they could work on data analysis skills using ROOT CERN and C++ programming.

With this knowledge and practice, the trainees and the PI were now ready to start working on a very important milestone of running the STARLight Monte Carlo to model the  $J/\psi$  vector meson production through the  $e^+e^-$  decay channel in ultra-peripheral collisions. Though initial attempts at reading configuration files were unsuccessful however, after two more attempts, they obtained successful generation of UPC events. This generated hit events, which the PI and trainees started working to understand, where the trainees worked on developing software to reconstruct parent  $J/\psi$  particles from the  $e^+e^-$  decay daughters. This showed a vast knowledge gap, which required supplementary theoretical sessions on relativity and Lorentz vectors to ensure all trainees, including sophomores new to Modern Physics, could contribute effectively.

During the summer, one of the trainees worked on the project, this time, we progressed to generating rho meson, which were then sent through the sPHENIX GEANT4 simulation, allowing the trainee to visualize how theoretical events appear in actual detector environments. This integrated approach linked theory, simulation, and experiment, deepening students' understanding of nuclear research workflows. The trainee provided weekly progress presenting updates and documenting the simulation steps, allowing her to strengthen her communication and collaboration skills.

Overall, a few of the measurable outcomes from this initial phase of the project include:

- a. trainees progressed from little or no programming experience to independently producing compilable C++ codes and ROOT-based data analyses within one reporting period;
- b. trainees demonstrated improved professional skills by actively presenting research progress weekly and creating clear documentation to support peer learning. These results illustrate that the evolution from passive learners to active contributors of the trainees, preparing them to become future leaders in nuclear physics.

## PRODUCTS

The products shown below include only Publications with a 'Published' status and Intellectual Properties with a 'Granted' status. Products with other statuses are not included in this report. The Revision Type indicates whether a product is New (newly added), Updated (existing product modified), or No Change (existing product reported without modifications) during the current budget period. Note that 'Updated' statuses may appear more frequently as products progress through the publishing process. All products listed have been reported for the current project period of this award.

### PUBLICATIONS

There are no publications to report.

### INTELLECTUAL PROPERTIES

There are no intellectual properties to report.

## PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

The table below only contains participants who have identified an affiliation with the Awardee Institution. Participants from any associated subawards may not be included in this count.

### PARTICIPANTS DETAIL

Project Role	Number of People	Total Person Months Worked
Co-Investigator	1	1
Other	1	0
Principal Investigator/Project Director	1	8
<b>Total Responses</b>	<b>3</b>	<b>9</b>

### PARTNERS DETAIL

There are no partners to report.

## IMPACT

- What was the impact on the development of the principal discipline(s) of the project?
- What was the impact on other disciplines?
- What was the impact on physical, institutional, and information resources that form infrastructure?
- What was the impact on technology transfer?
  - Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use.
  - Include transfer of results to entities in government or industry, instances where the research has led to the initiation of a start-up company, and adoption of new practices.
- What was the impact on society beyond science and technology?
- What was the impact on the development of human resources?
- What percentage of the award's budget was spent in foreign country(ies)?

### Impact Summary – Year 1

#### RENEW Program – DOE Office of Nuclear Physics (NP)

In the first year of this DOE RENEW-supported project, we made meaningful progress toward both the scientific and workforce development goals outlined in the proposal. Our work has supported fundamental heavy-ion physics research through hands-on experience building a more skilled and talented future generation scientist. Provided is a summary of a few key impacts across scientific, institutional, technological, and societal arenas.

#### Impact on the Development of the Nuclear Physics program here at Morgan State:

The DOE-RENEW project has been a major play in the establishment and growth of the heavy-ion physics program at Morgan State University. It helps train future researchers in nuclear science, detector technology, and collider physics, especially in areas related to the Relativistic Heavy Ion Collider (RHIC). The project also gives trainees experience with important software tools and modern technologies needed for nuclear and heavy-ion physics research. At Morgan, the project makes an impact in two main ways.

One prong is its connection to a major Department of Energy user facility, Brookhaven National Laboratory. Through this partnership, Morgan State trainees receive ongoing research support working alongside leading experts, who provided them a unique opportunity to learn and

They also gained access to a top research facility. This gives students not only to learn theory but also to gain hands-on experience, preparing them well for careers in heavy ion physics and other multidisciplinary fields. The second prong of the project is specifically designed to address critical questions in heavy-ion physics that align closely with the goals of the DOE's Nuclear Physics division. By focusing on these important research questions, the program at Morgan State is contributing to the national effort in advancing scientific knowledge.

Additionally, the project supports the development of future scientific leaders. and strengthens workforce development, ensuring that Morgan State can continue to grow as a center of excellence in nuclear physics research and education.

Overall, the DOE-RENEW project offers more than just research; it's about building a strong foundation for the trainees, enriching their academic environment, and fostering collaborations that will propel Morgan State University within the broader heavy ion physics community.

#### Impact on Other Disciplines:

Heavy Ion physics by enlarge is quite interdisciplinary as such my lab strategical take this approach bringing together trainees from different fields including physics, mathematics and computer science. For example, one of the trainees is a mathematics major and another studies computer science. This mix shows how our project naturally connects with other disciplines such as computational science, materials science, engineering and applied mathematics. These collaborations enrich the research combining a wide array of perspectives where each trainee to learn from one another.

As precision measurement becomes increasingly important in heavy ion physics, many of the techniques we develop for calibrating the subdetectors and analyzing data extend beyond our field. These methods have valuable applications in areas like medical imaging, where they can improve the quality and accuracy of scans; radiation monitoring, critical for environmental safety; national security, to detect and identify nuclear materials; and emerging technologies like machine learning, which can use the data patterns we study to advance AI models.

In this way, the project not only pushes forward heavy ion physics but also contributes useful tools and knowledge to a

wide range of important scientific and practical areas, demonstrating the broad impact of our interdisciplinary efforts.

**Impact on Morgan State Infrastructure:**

The establishment and enhancement of the NASRED lab at Morgan State University represent a significant advancement in the university’s research infrastructure, directly supported by the DOE-RENEW grant. When I began at Morgan State in August 2023, the now lab space was originally an old storage area that required substantial cleaning, painting etc shown in the figure 1. There was no equipment not even a desk or stool for the students to work on. Using some of the funding provided by the DOE- RENEW grant, we were able to procure a few laboratories equipment and transform the space into a bright, vibrant research environment where we can now do hands-on learning and collaboration work clearly indicated in figure 2. This foundational work has enabled trainees to engage directly in nuclear and heavy-ion physics research within a dedicated, well-equipped laboratory.

The improvements to the physical lab space have created an environment that fosters creativity, learning, and teamwork among students and researchers. The transformation from a simple storage area to an active laboratory has been critical in offering real world experience that complements theoretical training after going through the presentations. Trainees now have access to modern tools and equipment necessary for conducting high-quality research, which enhances their technical skills and prepares them for future scientific careers.

In addition to physical infrastructure here at Morgan, the project has made substantial contributions to institutional resources and collaboration networks through the formalization of a partnership between Morgan State University and Brookhaven National Laboratory laying a solid base for sustained institutional cooperation. This partnership allows for the exchange of knowledge, access to advanced research facilities, and long-term opportunities for students and faculty. By strengthening these institutional ties, the project supports Morgan State’s growth as a center of excellence in nuclear physics research.

Overall, the investments in physical, institutional, and information infrastructure supported by the DOE-RENEW grant have been transformative for Morgan State University’s nuclear physics program. These advancements provide the necessary foundation for sustained research excellence, workforce development, and meaningful scientific contributions aligned with the Department of Energy’s goals. The strengthened infrastructure ensures that Morgan State is well-positioned to contribute to future discoveries and maintain productive partnerships within the national scientific community



Figure 1: Each picture shows the NASRED after doing some initial cleaning of the space.

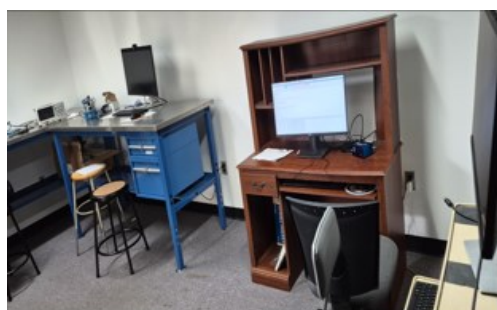


Figure 2: This is the current NASRED lab where students can now do research. The RENEW grant provided funds that was used to obtain equips to raise the lab from ground zero and we are continually working to make it better.

**Impact on Society Beyond Science and Technology:**

The main goal is to inspire and engage today's youth in nuclear and heavy-ion physics, encouraging them to pursue careers in these fields. We believe that by providing proper training and ongoing support, we can help develop confident, talented individuals who will contribute positively to their communities and the broader society.

To achieve this, we established a mentoring program led by the Principal Investigator and Dr. Willie Rockward. This program not only offers financial assistance but also provides academic, professional, and personal guidance. By paying close attention to each trainee's background, interests, and needs, we create a safe and interactive environment where everyone feels motivated to participate and succeed. These opportunities help students see themselves as future scientists and professionals who can make a difference.

The impact of these efforts is far-reaching. As trainees develop their skills, they are equipped to give back to their communities, contribute to economic development, and inspire others to follow in their footsteps. The program also helps break down barriers that often prevent underrepresented groups from entering and thriving in science and engineering fields strengthening the backbone of the society, ensuring that more individuals can participate in and benefit from scientific progress. Ultimately, our work supports innovative, and healthy society by developing a skilled, well-trained workforce ready to meet the future's energy and technology challenges

**Impact on Human Resource Development:**

For the first year of the DOE-RENEW program, the trainees gained valuable hands-on experience working with equipment in NASRED lab where they learnt to solder, identify electronic components and setup a detector to take data which they will analyze. This practical experience is essential for building technical skills and confidence. In addition, trainees developed strong teamwork abilities through collaborative projects, which is a critical attribute in our field. As shown in Figure, one trainee, Abbi, helping another, Jannatul, he was explaining to her the setup process for the detector and then how the data is stored on the Google Drive where she can access it for analysis. This exchange of knowledge highlights the importance of mentorship and collaboration, especially as these skills were vastly impacted by the COVID-19 pandemic.

These experiences contribute directly to the development of human resources by preparing students to become the next generation of skilled scientists and professionals in heavy ion physics. Moreover, the skills obtained are transferable and beneficial to several related fields such as medical physics, artificial intelligence, banking, and data science. This interdisciplinary readiness expands career opportunities for the trainees and broadens the impact of their training. The mentorship provided during the program ensures personalized guidance, supporting trainees academically, professionally, and personally. This nurturing environment encourages student retention and success, helping to build a resilient workforce which is vital to address the evolving challenges in nuclear physics and broader scientific communities. The program also fosters confidence and leadership among trainees, equipping them to contribute meaningfully to research and innovation. By focusing on collaboration and mentorship, the program replicates the teamwork-intensive nature of cutting-edge scientific efforts and enhances the trainees' readiness for professional environments. Overall, the DOE-RENEW program is essential for cultivating highly capable and collaborative individuals who will strengthen the U.S. nuclear and heavy ion physics workforce. Its emphasis on practical training, teamwork, and mentorship supports the objectives of the Department of Energy to foster a talented, and well-prepared scientific workforce that can drive innovation across multiple disciplines.



Figure 3 shows trainees collaborating