<u>Personal, Relevant Background, and Future Goals Statement</u>

Introduction

I aim to advance experimental particle physics through next-generation detector development while fostering sustainable and supportive research environments. My path to physics was unconventional: I began at The Ohio State University as a Maximus Scholar Theatre major with the intention of ending up on a Broadway stage. Theatre instilled in me many valuable skills, including public speaking, creativity, confidence, and adaptability, but I soon realized I was dragging my feet to class. Science, in contrast, had never felt like work in previous courses; it was engaging and rewarding. It was once I switched to a major in Astronomy and Astrophysics that I found the thrill of challenge and discovery. My background in theatre continues to shape my approach to science. Directing productions and mentoring younger actors taught me how to communicate clearly, manage time effectively, and build collaborative teams—skills that have translated directly into my leadership and mentoring in physics. **At Pennsylvania State University, I will pursue a Ph.D. in Physics focused on uniting instrumentation and computation in particle physics while promoting mentorship and sustainability within the field.**

Intellectual Merit

My first exposure to physics research came through Ohio State's Polaris Mentorship Program, which paired undergraduates with graduate mentors for a ten-week research project. I worked closely with a physics Ph.D. candidate to model laser aberrations and their effects on orbital angular momentum. While the projects were designed primarily as introductions rather than cutting-edge research, I found myself captivated by the process of translating theoretical concepts into models. Polaris piqued my early interest in experimental work, giving me the tools and confidence to seek out more advanced research experiences.

My professional research career began in [Professor]'s lab at the Center for Cosmology and Astro-Particle Physics (CCAPP) at The Ohio State University, in collaboration with [Professor]'s group. I explored **radio neutrino detector analysis for the Antarctic Impulsive Transient Antenna (ANITA) experiment**, which was a NASA long-duration balloon experiment designed to detect radio signals from astrophysical neutrino interactions within the Antarctic ice. Neutrinos are the most elusive of the fundamental particles due to their weak interactions with matter and successfully detecting them would deepen our understanding of both particle behavior and astrophysical sources. Using the ANITA Monte Carlo framework (iceMC), I developed correlation maps for use in a convolutional neural network aimed at improving neutrino event reconstruction. Additionally, I examined the simulation's health through detailed trigger-efficiency studies to ensure reliability of results.

This experience strengthened my computational skills in Python and C++, introduced me to high-performance computing clusters, and, most importantly, immersed me in the collaborative, investigative nature of cutting-edge academic research. Working with the ANITA simulation showed me how theory, hardware, and computation intersect to extract meaningful signals from complex data. I found deep satisfaction in the process of translating a physical idea into code, testing it, and seeing real improvements in model performance. It was the first time I felt that my work contributed to something larger than myself—expanding how we detect and understand the universe's most elusive particles. That sense of purpose firmly established my commitment to pursue graduate research in experimental particle physics. Our results are currently being prepared for publication, an experience that has further developed my skills in scientific communication and collaboration.

Because I enjoyed computational work within neutrino physics, I wanted to deepen my understanding of experimental research by gaining hands-on experience with instrumentation. This motivated my application to Penn State University's Sustainable Physics: From Subatomic to the Cosmos Physics and Materials Research Experience for Undergraduates (REU) in the summer of 2025. Under [Professor], I contributed to Project 8. This experiment aims to directly measure the absolute neutrino mass, a fundamental property with profound implications for our understanding of the Standard Model and the evolution of the universe. My work focused on the **electromagnetic simulation, construction,**

and characterization of resonant cavity and antenna prototypes, essential components for detecting the faint cyclotron radiation emitted by electrons spinning in a magnetic trap. Precisely detecting this radiation would allow for the calculation of the absolute neutrino mass, directly impacting particle physics, cosmology, and nuclear physics. By systematically mapping electromagnetic fields and optimizing antenna placement, I identified designs that maximize signal detection while minimizing interference, providing crucial guidance for future instrumentation to the collaboration.

This project allowed me to see theory come alive in the lab, as calculations and simulations became physical systems I could manipulate and improve. Working directly with a detector system, analyzing responses, and iteratively refining designs gave me a tangible sense of impact and ownership over the research process. Presenting these results at the REU symposium, a Project 8 Collaboration meeting, and the SACNAS NDiSTEM conference strengthened my ability to communicate complex technical work to diverse audiences. Above all, this experience solidified my passion for experimental physics and my commitment to pursuing a career focused on developing instrumentation to advance our understanding of fundamental particles.

Broader Impacts

Beyond introducing me to hands-on research, the Polaris Program immersed me in a uniquely supportive community that emphasized mentorship and student engagement—values that were rare in my early coursework. Experiencing firsthand how intentional mentorship could build success inspired me to recreate that environment for others. To build upon the connections and lessons of Polaris and give back to the community, **I co-founded an undergraduate mentorship program titled MoMentUM: MOdel MENTors for Undergraduate Mechanics**. The program pairs upperclassmen mentors with underclassmen in core physics courses to build community, reduce feelings of isolation, and improve class success rates. I led mentor training sessions, established expectations and goals for mentor-mentee relationships, and facilitated bi-weekly meetings on topics including academic success, careers in physics and research, and imposter syndrome. In the club's first semester, I formed over thirty mentorship pairs, building a stronger and more collaborative department community. Guiding my own mentee has been especially rewarding. Since we began working together, I've seen her build stronger connections with peers, including joining a study group after my encouragement, and improve her performance on exams using study strategies we developed together. I've seen firsthand how guidance and structured mentorship can transform a student's confidence, engagement, and success in physics, strengthening my commitment to fostering mentorship in science.

Using the mentorship and leadership experience I've gained, **I will establish an undergraduate research mentorship program at Penn State to provide first direct exposure to research while fostering skills in collaboration and scientific communication.** Drawing from my experiences in the Polaris and MoMentUM Programs, I will build a club curriculum that pairs students with graduate student mentors to complete research projects, culminate and present their results, as well as provide them with college and career resources. Recognizing that founding a program like this would be challenging to undertake alone, I will assemble a group of graduate students from the Physics Graduate Student Association to develop its framework and recruit students. I will lead the structure around project-based research, communication workshops, and career guidance, including advice on applying to REUs and graduate school. I will assess the program's success using feedback surveys and statistics to refine its structure annually, ensuring that it continues to meet students' needs and contributes to departmental retention and engagement. By combining my commitments to experimental research, communication, and mentorship, I aim to strengthen the field of particle physics while supporting the next generation of scientists.

In addition to mentorship, **I have developed a strong commitment to sustainability in experimental physics**. Penn State's REU program emphasized the intersection of physics and environmental responsibility through faculty presentations on sustainable research practices and tours of Penn State's nuclear reactor and solar farm. We held guided discussions that challenged us to consider how our work could promote practical sustainability practices. Through this program, I gained a deeper understanding of sustainable laboratory practices and strategies—such as minimizing energy use, reducing chemical waste, and limiting disposable materials—to reduce the environmental footprint of scientific research. I became a certified Sustainability in Research practitioner through the REU and an ambassador for My Green Lab, an organization that promotes environmental accountability in laboratories worldwide through certification and community engagement. Beyond the lab, I volunteered for the Central Pennsylvania Festival of the Arts' Children and Youth Day, where I designed and ran a booth to teach children about recycling through interactive demonstrations and games. I loved tailoring my explanations to children's vocabulary, connecting with them through familiar products and behaviors, and seeing their excitement and understanding grow as they competed in the games and took away ideas to implement at home.

These experiences opened my eyes to the often-overlooked environmental costs of research: energy-intensive computation, fossil-fuel powered facilities, and large-scale construction for experiments. **At Penn State, I aim to contribute to the university's sustainability goals by supporting and expanding the Sustainable Labs Program**, which partners with My Green Lab to help research groups implement eco-friendly practices. I plan to conduct novel audits of laboratory and computational resource use across interdisciplinary research spaces. Collaborating with groups within and beyond physics, I will identify energy-saving opportunities, reduce waste, and improve equipment longevity across the university. I will additionally advocate for My Green Lab certifications within the Project 8 Collaboration to share sustainability guidelines with partner universities and broaden the program's impact. By integrating environmental responsibility into experimental practice, I will demonstrate that advancing fundamental knowledge and cultivating responsible, supportive research communities can progress hand in hand. Together, these commitments guide my vision for graduate study and beyond.

Future Goals

I aspire to become a professor of physics, where I can combine my passions for research, mentorship, and sustainability. I will lead a laboratory that develops innovative experimental tools while fostering an engaging, environmentally responsible research culture. I am drawn to this path because professorship would allow me to combine my passions for discovery, teaching, and mentorship. My experiences guiding mentees, leading student programs, and communicating complex ideas in accessible ways have shown me how effectively I can inspire and support the next generation of scientists. Graduate school will allow me to deepen these abilities while pursuing experimental physics with the same curiosity and excitement I first felt when I transitioned from theatre to physics.

Within graduate school, I aim to develop experimental techniques that address one of the most fundamental questions in particle physics—the absolute mass of the neutrino. Measuring the neutrino mass and improving detector sensitivity can reveal key insights into the fundamental properties of matter, the evolution of the universe, and the validity of the Standard Model. **These next generation experiments are critical to advancing both physics and our broader understanding of nature.** My work with the ANITA simulation and Project 8 experiment has prepared me to tackle this challenge, providing expertise in simulation, data analysis, and hands-on instrumentation, and **positioning me to lead the development of innovative resonant cavity systems that enhance neutrino detection capabilities.** Working both on an experiment probing the high-energy universe and another advancing the detection of neutrino mass has given me a uniquely broad perspective on the fundamental properties of the neutrino. The NSF Graduate Research Fellowship would allow me to pursue these ambitious goals with the independence, resources, and interdisciplinary collaborations necessary to develop innovative resonant cavity systems for neutrino detection, accelerating research that would be difficult to achieve otherwise.