Kaitlin Salyer
Graduation Year: Senior
College: Science
Major(s): Physics, French
Minors(s): None
Scholar Group Membership: None

Did you received other funding for this project?: The College of Science
Could you have completed this project without CUSE funding? Yes
More details on CUSE funding assistance? I would have made every attempt to continue the research without CUSE funding; however, having the funding dramatically eased the financial burdern of being abroad for an extra two months.

Project Title: Study of ttH Events at CERN
Project Location: European Organization for Nuclear Researc (CERN), in Geneva, Switzerland
ND Faculty Mentor: Kevin Lannon
Project Type: Research

Why did you undertake this project/experience? Deepen your knowledge of a topic or issue, Research/experience necessary for senior thesis or capstone project, Prepare for graduate school (MA or PhD), Prepare for national fellowships, Career discernment and/or preparation, Internationalize your Notre Dame experience

Did your funded experience help you:
[Deepen your understanding of your coursework or field of study]: Very Much
[Discern your interests and post-bac goals]: Very Much
[Become confident in your ability to set and achieve your goals]: Very Much
[Gain a more nuanced view of local, national, or global communities]: Very Much
[Improve your written and verbal communications skills]:Very Much

Tell us about your experience.
The Large Hadron Collider (LHC) in Geneva, Switzerland, is the world's largest particle accelerator, with a circumference of 27 kilometers. Protons and heavy ions are collided at speeds just shy of the speed of light and at very high energies in an effort to discover the fundamental building blocks of our universe and to explore how it works. The most recent ground-breaking discovery there was the 2012 discovery of the Higgs Boson, or the fundamental particle which gives mass to everything. The Compact Muon Solenoid (CMS) is a detector at the LHC, and it helped discover the Higgs in 2012. CMS acts like a massive digital camera to capture an image of the smallest and shortest-lived particles known.

My research for CMS is concerned mostly with the production of the Higgs Boson with a top quark-antiquark pair (ttH). The events that we are most interested in, leptonically-decaying ttH, are incredibly rare and therefore necessitate the usage of machine learning (ML) techniques in

order to efficiently study them. We are motivated by the fact that, in learning about ttH events, we can learn more not only about the top quark and Higgs Boson (two of the most recently discovered fundamental particles) but also about how they interact with each other and what that means for our understanding of the Standard Model. In order to create very large data samples, with which to train our ML algorithm, we created what we called a GenFilter, which was designed to filter out some of the events that were irrelevant to our studies at a stage where it would ultimately save us time in running our simulations. The idea is that it would ensure that we were not running time-consuming code over events that were completely uninteresting for our project while producing the large data files we needed to train our ML algorithm well. The issue is that at some point, a bias was introduced and our computers learned the wrong thing. Algorithms trained on the GenFiltered files relied too heavily on the presence of important objects and ignored that there might be noise in the detector.

My research started with attempting to find this bias. After conducting several tests on the signal (ttH) data sample and finding that there did not seem to be anything wrong, I moved to studying the background (tt+jets) data sample. I discovered that there was a component of the background sample that were present in unfiltered samples but missing from the GenFiltered samples. We determined that this missing background were actually conversion electrons, or electrons created when high energy photons interact with material in the detector. This was the source of the bias.

Now, I have turned to studying the ML algorithm more directly and am working on pushing the limits of the algorithm. It is important to tune the algorithm to be as strong as possible without being overtrained, where overtraining implies that the algorithm has learned a statistical feature of a smaller set of the data that is not truly representative of the whole. In finding this limit of overtraining, we can create the strongest possible algorithm to do the best job at separating our signal, ttH, from everything else.

Describe the impact this project had, both on you as a student-scholar and on the people you worked with.

Living and working at CERN the last semester and summer has been a truly invaluable experience for me that only fostered my personal growth and academic development. The excitement about science and the thirst for knowledge that everyone there has really deepened my passion for physics. Furthermore, the skills I learned there aided my career discernment and bolstered my desire to pursue graduate school and a research fellowship from the National Science Foundation.

Describe how this experience is connected to your plans as a student or future professional.

With the help of my CUSE funding, I was able to continue living in Switzerland through the summer to live my dreams at CERN and conduct research which will be the basis of my honors thesis for the Physics department this year. Now that I am back on Notre Dame's campus, I will be continuing my work on this project and pushing the limits of what our computers can do. At

the same time, I will be assuming my role as President of Notre Dame's chapter of the Society of Physics Students and starting a new departmental initiative to support women in Physics. These are all ideas and goals I set when I saw the atmosphere at CERN, and I decided to bring a little bit of it back to our physics department.

After I graduate this year, I plan to enroll in a PhD program in experimental High Energy Physics, which will hopefully lead me to a career in the field of software programming. The skills and knowledge I have gained while studying and working at CERN will be invaluable as I progress toward that goal, as there is hardly a field that would not greatly benefit from the techniques in which I am becoming an expert.

This has truly been the experience and opportunity of a lifetime, as there is simply no better place in the world to learn about Physics or computing techniques than CERN, where they discovered the Higgs Boson and invented the World Wide Web.

What advice would you give other students who are planning to pursue similar projects?
To any student planning to pursue a similar project, I would advise him or her to choose a research project that initially piques his or her interest, because without an initial passion for the subject, it will be very difficult to motivate him or herself through some of the research lulls that inevitably happen. Furthermore, I think a good line of communication with one's research mentor is essential to a successful research experience, as this ensures that the project runs smoothly. Finally, it is important that any student pursuing any form of research is not afraid to take risks or ask questions. The whole reason we do research is because we do not know the answer to a question, so it is important that a student researcher is not afraid to speak up when he or she does not understand something or does not know how to approach a problem. This is why research is done in teams--it takes a collaborative effort to make any new discoveries in science.

I acknowledge that this form has been filled out truthfully and to the best of my ability. I understand that this information will be shared with many different CUSE constituencies. As such, I have provided as much useful information as I was able. I understand that CUSE will not complete my award disbursement until this form is successfully completed. If I have any questions or concerns, I will contact CUSE before submitting this form. To illustrate that you understand all of these points, please enter your Notre Dame email in the box below.
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