Studying potential new physics with production pair of Higgs boson

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Over the course of this semester, I have dedicated time to this wonderful opportunity provided by my mentor along with the Student Engagement Fund to gain more experience with computers, the culture, and learn more about how we study physics. My experience consisted of getting the chance to take a small peak into the world of proton-proton collision study, which is much more involved than I originally expected it to be. It is fascinating how all of the scientists involved in this particular project work together and gather information necessary to explain different phenomena.

At the beginning of the semester, we spent time learning and reviewing the officially documented public results of the ATLAS experiment dated March 14th 2016, titled *Search for Higgs boson pair production in the bbyy final state using pp collision data at* $\sqrt{s}$ *= 13 TeV with the ATLAS detector*. Anyone reading this for the first time with a limited background on the subject material would probably be equally as lost as I was the first time I read it. Luckily, my mentor brought me up to speed and explained to me the basic overview of the processes that take place as well as some important details necessary to learn and perform research on the data provided by the experiment. I also began learning some basic python, which is a computer programming language that if used properly with proper syntax, one can write lines of code to tell the computer what to do with whatever data or ideas one has. This was a great learning experience for me because I had only taken one computer programming class many years ago, along with a short class last semester, and now had the opportunity to be immersed in a culture of examining graphs and other data by working with different programming languages and systems.

Looking through my progress reports and collection of tasks I worked on throughout the semester, I am overall very satisfied with the quality as well as the quantity of knowledge I gained from this experience. After the first progress report, I was already quite involved with learning how to write the code to create graphs using samples of events of collisions. I observed and made changes to the ranges and bins of the histograms I was working with and also learned how to make additional aesthetic changes to the graphs to make them more appealing, or easier to read. Alterations such as changing the line styles and colors of the different lines as to distinguish between them, putting in axes titles for labeling purposes, as well as adding a legend. I remember the legend was a bit tricky because you have to remember to draw it after the actual graph is drawn so that the computer knows to draw the small legend on top of the graph (typically in a corner taking up a small amount of space). I also learned a couple ways using code to take the graph that the code creates and create a pdf. These pdf files can be viewed just the same as any other and the histograms we created can be easily read now as pdf files. At this point in project, I was getting comfortable with moving around the system and going in and out of different areas where we would find samples that were root files and use them in different python codes to examine the qualities in comparison to each other. I created another python file that gathered different samples of events and created graphs that we could examine, which required fixing the bins and ranges of each sample and also defining each sample with a different color for easy distinction during observation. Once we had a few graphs to look at, I learned how to add code that would normalize all of the graphs so they would be even easier to read. This normalization means we shrink down the size of the graphs by integration so that the simple shapes can be studied and compared. More specifically, we

were also looking for the samples in comparison to the others with the highest energy. Although I was unable to figure out the code before the end of the semester, we were still able to view them by means of comparison to the others on the same graph. Even without the code we were able to see the leading and sub-leading pT (momentum) of jets and photons. Toward the end of the experience, I was able to finish a code that was designed more generally to plot all of the histograms I wanted in a list, basically at the same time by executing one code, which can also compare any combination of samples desired. This was interesting having the ability to view any of the samples we wanted, which were all normalized and easy to view. Altogether, I had a great experience learning all that I did and could not have asked for a better mentor.

As far as my original objective was concerned, I felt that I definitely accomplished learning more about how we study in this particular field of physics and learned a lot about programming in python to make it all happen. We were able to accomplish many tasks throughout the semester, I learned more programming skills than I expected to before I began this opportunity, and also learned more about what happens during these events performed at the LHC, which is a 27km in diameter, underground hadron collider, which takes bunches of millions of protons and shoots them at each other every second at nearly the speed of light. There are a variety of specialized high-tech computer systems that work with each other to collect the data recorded from these events and determines what data to keep and which to dispose of, based on the volume of the data produced. With the amount of data produced from these collisions, it would be impossible to keep even ten percent of the data created, so the systems have to know how to work with each other to keep only the most valuable data, showing the results of the most rare events occurring.

Altogether, the impact of the Student Engagement Fund on my overall academic experience was beneficial. I was given the opportunity to learn a lot about a couple topics that I had extremely limited knowledge in and performs certain easier, smaller tasks to study the behaviors of these different components. I am very appreciative of this positive learning experience and am more interested in the subject than I was before, based on what I've learned and been exposed to. The Student Engagement Fund provides a great opportunity to students to be able to learn while getting paid, which improves the students' responsibility skills, prioritization skills, as well as communication skills. I would definitely recommend to other students to get involved with the Student Engagement Fund if they feel comfortable with the amount of classes they are taking, feel comfortable with the material covered over the semester, and are confident that they have at least between ten and fifteen hours a week to devote to the research opportunity and learn new subject matter that they may have little experience working with before.