Physics Internship with Assistant Professor Markert's Group

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This summer, I worked with Assistant Professor Markert and her high energy, heavy ion nuclear physics group. Much of this field is experimental and analytical, but I mostly worked on learning about the theory behind the experiments and did very basic work in analysis.

Some of what I learned was based on analytical work. I worked with the ROOT object-oriented software package, which is written in C++. Because of my lack of experience when it came to working with C++ and programming in general, I started with the basics like learning about different data types and commands. One of the graduate students in the lab lent me a book on how to program in C++, so I worked with that most of the time. I was assigned some simple projects to work with so as to get more familiar with using ROOT and C++. The first project that I did was to write a program with simple addition, and the next one was for the pythagorean theorem. I also did some simple work on histograms. A histogram, which I had never heard of before, is a graphical display of tabulated frequencies; it's a table that shows what proportion of cases fall into each of several categories. In my case, I learned the basics on how to make a histogram (i.e. setting bins and fills) and started working on graphs that plotted factors like momentum and time.

However, aside from the actual work that I did, most of my experience was centered around learning more about the ideas of heavy ion collisions. Assistant Professor Markert's group works with data from RHIC, the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. RHIC is used to study what the universe may have looked like in the first few moments after its creation. Intersecting beams of heavy ions, usually gold, traveling at near the speed of light are driven to a head-on, subatomic collision that lasts for only a few billionths of a second. Under ideal conditions, this collision "melts" the protons and neutrons and, for a very brief instant, frees quarks and gluons. Thousands more particles form as the area cools. Each of these particles provides a clue as to what happened in the collision zone. What makes RHIC collisions important is the theory that at the beginning of the universe, there were no protons or neutrons, just quarks and gluons. It's believed that as the universe cooled, quarks and gluons bound together and have henceforth been inseparable. Thus, RHIC allows us to "go back in time" and see how matter behaved at the start of the universe. This in itself marks a breakthrough in human understanding.

One of the most interesting results of RHIC collisions is a new form of matter called QGP, quark gluon plasma. Physicists believe that RHIC collisions can compress and heat heavy ion nuclei to the point where their individual protons and neutrons overlap, creating an extremely energetic area. For a brief time, it's thought that a relatively large number of free quarks and gluons can exist in this area as quark gluon plasma. Before any collisions, trios of quarks and gluons are bound together in protons and neutrons at the nucleus of an atom. New particles called pions, made up of quarks and anti-quarks, appear as pressure and temperature rise. When the conditions are right for a phase change, quark gluon plasma is produced. In this plasma, quarks, gluons, and anti-quarks are free of their usual bonds and so can freely bond with one another. If QGP is produced, it will quickly cool and coalesce into hadrons, any particles made of quarks. Physicists are then able to determine whether or not QGP was produced by looking at the particles that result from the collision. A collision that produces QGP will send out different kinds and ratios of particles than a collision that doesn't produce QGP.

The main experiment area that Assistant Professor Markert's group deals with is STAR, the Solenoidal Tracker at RHIC. It's a detector that's used to detect the many particles produced from ion collisions at RHIC, search for signatures of QGP, and investigate the behavior of high energy densities by making measurements over a large area. At the heart of STAR is the Time Projection Chamber, which is comprised of numerous electronic systems. The Time Projection Chamber is what tracks and identifies the particles that result from heavy ion collisions. Multiple parameters are measured by STAR as each collision occurs for signs of QGP. What the detector basically does is use powerful computers to reconstruct the sub-atomic interactions that resulted in the particles produced from a collision; this process can be likened to examining the final product of something and trying to find out what kinds of machines produced it. Histograms and other types of graphs can then be made to analyze the data that the computers record. For example, information on energy loss as related to momentum can be graphed. Such a graph would be able to help physicists determine what types of particles were created in a collision based on the idea that larger particles will have a higher energy loss at higher momentums.

In conclusion, most of what I learned was theoretical, but I did gain a bit more experience in programming. Perhaps if I had received prior training in programming, I could have gotten to more advanced projects. However, as such was not the case, I made do with more basic programming. Overall, I felt that the program was enjoyable and acted as a great introduction to more real world physics.