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Internship at Jefferson Laboratory

I arrived at Thomas Jefferson National Accelerator Facility on June 2nd and stayed until July 31st, 2013. During my stay I assisted in multiple projects. I aided in kinematic simulation and fitting for an experiment on the drawing board. I also set up a computer for testing of new hardware for Deep Virtual Compton Scattering, or DVCS. And finally I helped to set up an experiment and take measurements to test the accuracy of a Photomultiplier Tube used in QWeak experiments.

1. The Structure Function of the Pion

My first project was to help write and analyze a program which simulates an experiment that JLab would like to perform in the future. The goal of the experiment is to measure the distribution function of the pion cloud surrounding the neutron. These meson clouds play an important role in other Deep Inelastic Scattering experiments as they are a noticeable contribution to the reactions. Thus by having a better idea of the distribution of these mesons, we can have better control and knowledge of other DIS experiments. The setup is a deuterium target being hit with an electron beam. The neutron inside the deuterium target changes into a proton and pion and the electron emits a virtual photon which scatters off this pion thus separating it from the proton, as shown in figure 1. The purpose of the simulation is to model the kinematics of this reaction so that other collaborators can begin to design detectors based on the simulated angle, momentum, and energy. It also gives an idea about whether the experiment is plausible. The simulation had been written years before and had been modified multiple times, thus it needed to first be checked to make sure it had the correct variable ranges, constants, and equations. Then I began to write root macros selecting various kinematic conditions and their correlation with the cross section and structure function of the pion.

Wanting to correctly represent the chaos of nature, we next began to randomly generate values for some variables and calculating the rest of the equations from them. As we did this it became evident that the subroutine that computes the structure function for the pion, the equation for which is shown in figure 2, had been corrupted. The function we wrote was giving probability values greater than one, which is physically impossible. We had many ideas about what could be causing such behavior. We wanted to check the equation itself to make sure there were no errors. Other possibilities included the possibility that other equations were incorrect, the transverse momentum was a key figure in that regard. As we continued to study the data we thought

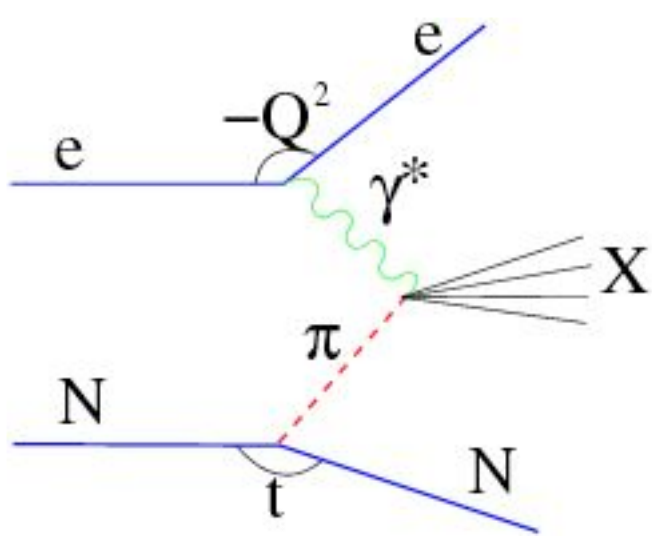

Figure 1: Nucleon, N, releasing a pion, π. The pion is then struck by a virtual photon, γ^*, released by the electron.

$$f_{N\pi/N}(z, p_T^2) = \frac{3 g^2_{p\pi^0 p}}{16\pi^2 Z^2(1-Z)} \left[\frac{\Lambda_\pi^2 + M_p^2}{\Lambda_\pi^2 + M_{\text{inv}}^2}\right]^2 \left[\frac{M_p^2(1-Z)^2 + p_T^2}{(M_p^2 - M_{\text{inv}}^2)^2}\right]$$

Figure 2: Distribution function of the pion splitting with the nucleon. It is a function of the momentum fraction, Z, and the transverse momentum, P_T^2.

that perhaps the randomization of related variables could have a part to play. In order to find what was causing this to happen, I began to simulate the equation in root, comparing it with its source and with what we got from the simulation. It became evident that we were misunderstanding the meaning of the Z term and that we also needed a better equation for the transverse momentum, P_T. We are still working to find a suitable transverse momentum equation.

2. Data Acquisition for DVCS Detector Upgrade

In preparation for the upgrade from 6 to 12 GeV JLab has also been upgrading its detectors. In order to do this they will either completely rebuild a detector or buy a new one and assemble it. When assembling the detector they must test it regularly and strenuously to ensure proper operations. This requires a data acquisition system, for JLab it is CODA, CEBAF Online Data acquisition. This is a software developed for Jlab. It is not a simple application that can be installed. It must be built and tested for the customized use it will receive. To do this I first needed to copy the main program, CODAMASTER, and all of its counter parts to the machine. All of CODA's libraries, programs, drivers, and everything can be found on the DVCS site so I could just copy it

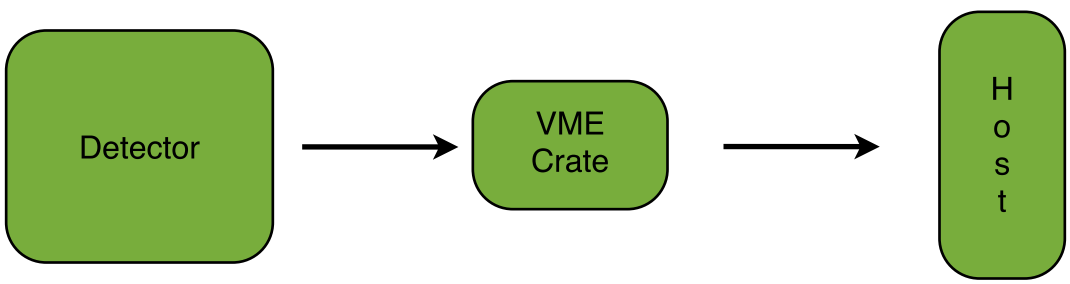

Figure 3: The transfer of data with a VME crate. The Detector sends its signal the the crate which processes it then sends it to the host computer.

from there. In order to get the program to run properly I needed to change the environment variables and path variables which told it where to find all of the libraries it needed. Once we had this complete we began to set up the VME crate. A VME crate is a crate that holds multiple computer boards at once. There is a CPU, a trigger, a number of input boards from the detector, and other possible boards. Figure 3 shows the order in which data flows through the hardware.The purpose of the VME is to process data, not store it, so it has no hard drive. It immediately sends data to the host computer through which it is controlled by the user. Because it has no hard drive to boot from, I needed to set the boot parameters for it. Once this is done it can reboot by itself.

Once we got that in we put in an ARS board, Analog Ring Sampler. It is a buffer that continually processes data samples so that as soon as it receives the trigger it can store the data. Once we had it all setup we gave it a couple test runs to ensure proper operation for the people setting up the detector.

3. Photomultiplier Test for the QWeak Experiment

The QWeak experiment uses an electron beam who's polarity is constantly changing at a constant rate. Along with this constant reversal the beam is also changing at a much slower rate due to small imperfections in the beam line, structures, processes, or other events that can change in some small way during beam operation. The detector uses photomultiplier tubes, PMT's, to detect the particles that result from

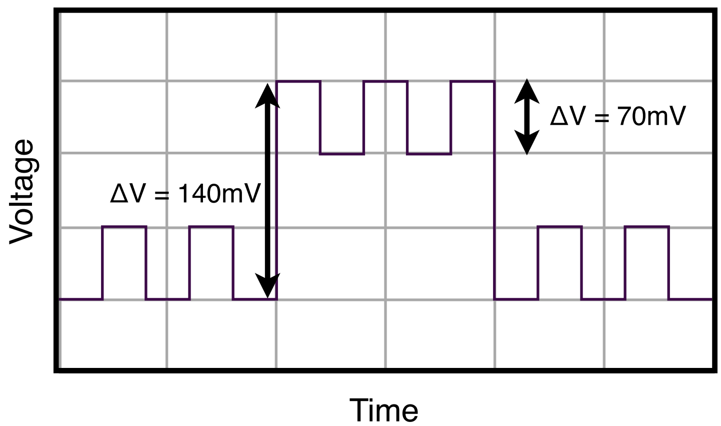

Figure 4: Voltage signal produced by the PMT. You can see that there is a fast signal and a slow signal and that it is not set at zero.

the interaction of the beam with a hydrogen target. PMT's take in light, photons, and return a voltage signal. The QWeak collaboration was interested to find out if the slow changes in the beam, due to imperfections, affect the response of the PMT with respect to the fast reversal of the polarity. More specifically, if the beam line slowly changes so that there is a short increase in the output voltage of the PMT, does that change the PMT's response to the output voltage of the fast reversal in a way that is not linear with respect to the slow change. In order to find out we began to run tests on a single PMT that was used in the experiment. This test involved the PMT with three LED's in front of it. One LED was the bias, providing a constant light source and therefore base voltage for the PMT, one was the slow signal, running around 10Hz, representing the slow change of the beam, and one was the fast signal at around 250Hz, representing the reverse in beam polarity. The study had been going on for some time before I got here. Rob Mahurin, the one in charge of the experiment, had written root macros for the data and had derived an equation to evaluate the non-linearity. He had gotten some descent results by the time Scott MacEwan and I started to work on it. During these experiments the trigger had been controlled by a clock in the NIM crate. In an attempt to increase the accuracy of the run we decided to set the trigger to the fast signal itself, thereby removing all outside influences. We also would change the voltage differences of the slow and fast signals to observe any changes in linearity. Figure 4 shows an arbitrary voltage read out the the fast change in voltage at 70 mV and the slow change at 140 mV, the frequency is not to scale. Unfortunately I had to leave before the completion of this experiment. I try to stay informed on the findings but as of now there are non that are conclusive.

4. Out Look

I had a very productive and interesting summer at JLab. I assisted with three different projects and learned about physics, equipment, and the process of an experiment at a national lab. I helped to properly simulate an experiment that is being considered for the future, set up the system by which designers and engineers will test the detector that they are upgrading, and test the linearity of a PMT from an experiment. I gained a lot of skills and experience in multiple areas of experimental particle physics. I very much enjoyed my time at JLab and all of the people I met there and look forward to a career in particle physics.