9th Annual QuarkNet Workshop Report
Purdue University Northwest (PNW) QuarkNet Center
June 26-30, 2023

Figure 1: Workshop participants including a virtual visit from QuarkNet teaching fellow Tracie Schroeder.

This is a brief report on the QuarkNet Workshop entitled "Computation in the Classroom", held at the Purdue University Northwest Center for High Energy Physics under the auspices of the PNW QuarkNet Center. The week-long program had participation from five high school teachers and two high school students from Northwest Indiana. The teachers were supported by the QuarkNet funding from University of Notre Dame. The workshop agenda can be found here: https://quarknet.org/content/pnw-quarknet-center-summer-2023-workshop-computation-classroom.

The 2023 workshop focused on developing coding skills, encouraging computational thinking in the classroom, creating machine learning pedagogical tools, and utilizing particle physics data in the classroom. Students in attendance additionally learned how to setup, calibrate, and operate the QuarkNet Cosmic Ray Muon Detector (CRMD). The workshop was designed to be a hands-on, interactive experience for both students and teachers.

Figure 2: Student group during the initial stages of setting up the CRMD experiment.

Day 1 of the workshop was devoted to motivating the use of computer programming and computational thinking in high school physics classes. Using interactive Jupyter coding notebooks, participants were able to model a projectile's motion in the earth's atmosphere. Programming allowed the teachers to progressively increase the model complexity to more accurately model effects such as air resistance, changing density with altitude, and changes in the force of gravity with altitude. The participants also completed an example computational lab. Participants used their smartphone accelerometer and the PhyPhox app to measure their acceleration as they walked. They then utilized numerical integration techniques to calculate their velocity and position as they walked, using only acceleration data.

During Day 2 of the workshop, the participants completed a mini-bootcamp in coding with Python. Using interactive coding notebooks, the teachers were able to both edit and run the code while also completing small learning assignments throughout the notebooks. Many teachers went from having no experience with Python to being able to import data and make a plot with Python.

Figure 3: Recording acceleration data using the PhyPhox smartphone app.

On Day 3 of the workshop, QuarkNet coding fellow Tracie Schroeder joined virtually and led the group to complete multiple QuarkNet coding activities using real data (muon mass, periodic table of elements, sunspot, and solar position).

On Day 4 of the workshop, the workshop participants were tasked by Tracie to develop a teaching lab and an associated coding notebook for analyzing any collected data. Using pair programming techniques, the participants developed a four-part motion lab for high school students utilizing Jupyter Notebooks.

Day 5 of the workshop was devoted to the topic of Machine Learning. Our goal was to provide a foundational understanding of machine learning concepts so that teachers could answer questions about machine learning in the classroom. To this end, Dr. Dolen walked the workshop participants through two interactive learning notebooks. Using open cosmic ray data from the Major Atmospheric Gamma Imaging Cherenkov Telescopes (MAGIC), the notebooks introduced multiple concepts involved in machine learning classification tasks. Initially, the participants were tasked with identifying gamma-ray cosmic ray events while rejecting hadron initiated cosmic rays. Participants identified data-based observables that could be used to separate gamma-ray and hadron events. They applied thresholds to these observables, measured signal efficiency and background reject rates, and developed Receiver Operating Characteristic (ROC) curves based on their choices. Participants were then exposed to decision tree and ensemble method machine learning tools. These machine learning methods were chosen because they are both powerful and easy to understand.

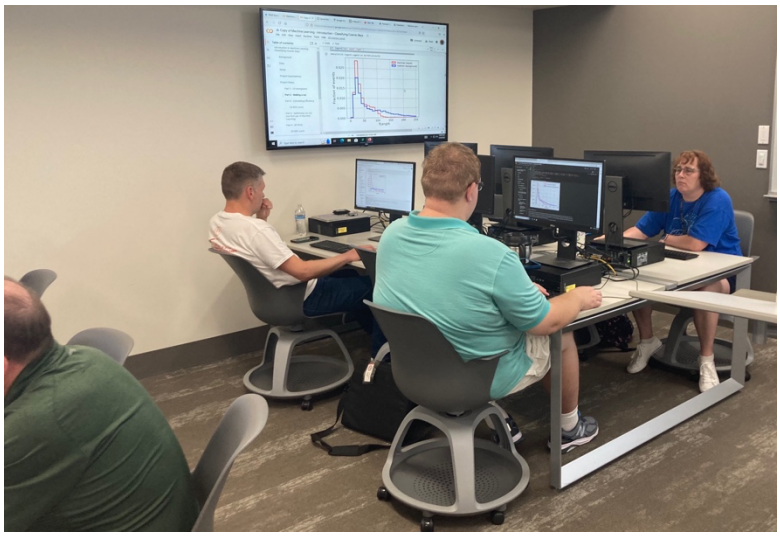

Figure 4: Making comparison histograms with Python using particle physics data.

The 2023 PNW QuarkNet workshop was a departure from previous workshops in that we devoted a significant amount of time to coding. Overall, the workshop participants provided strong feedback that the workshop was beneficial. All the participating teachers have asked to participate in future QuarkNet masterclass events. Additionally, the students who are now trained in setting up and calibrating the CRMD intend to complete a cosmic ray research project during the upcoming school year.