Summer 2021 Quarknet Workshop at Syracuse University

The Syracuse group hosted a Quarknet workshop from Aug 16-8, 2021. The program was developed by Prof. Steven Blusk, Shane Wood (Quarknet Staff), and our lead teachers Michal Madden and Brian Bealer. Nine teachers were able to join the workshop (after a couple of late cancellations). We also had two Quarknet fellows, Paul Sedita and Helen Coyle join us and lead some of the activities. A photo of the participants during a tour of one of the high-energy physics laboratories at Syracuse is shown below.

Photo showing the Quarknet 2021 participants: (Front row, left to right): Michael Madden, Prof. Steven Blusk, Prof. Matthew Rudolph, Helen Coyle, Brian Bealer; (Back row, left to right): Chad Gregory, Paul Sedita, Patrick Ferrick, Craig Dowler, Josh Buchman, Anne Huntress, Marge Hartquist. Not shown is Shane Wood, who took the photo.

The group included a good mixture of long-time participants (Madden, Buchman), few-year participants (Bealer, Ferrick, Huntress and Hartquist) and first-time participants (Dowler and Gregory).

The three-day workshop program is available at the following page

https://quarknet.org/content/2021-syracuse-particles-detectors-and-neutrino-data-workshop

Monday's program featured a mix of talks and activities introducing basic particle physics concepts. Teachers were introduced to the "Shuffling the Particle Deck" activity to discuss how one might organize the quarks, leptons and bosons in some sort of logical order. The activity was followed by a general talk on the Standard Model by Prof. Steve Blusk, which was accompanied by numerous questions. Also, Prof. Blusk answered some of the questions posed in advance of the workshop. After lunch, we spent a little time going through the Quark Workbench activity and the recent online version. Afterward, we engaged in an activity to give teachers some experience in representing decays using Feynman diagrams. Teachers were given "puzzle pieces" and were asked to look up a decay (on a given web page), choose a specific decay, and then use the puzzle pieces to represent the decay subject to a set of rules:

- Charge must be conserved
- A *d* quark can transform into a *u* quark by emitting a W-; a *c* quark can transform into an *s* quark by emitting a W+, and W bosons decay into either:
- A W- decay into either a quark-antiquark: $\bar{u}d,\ \bar{c}s,\ \bar{u}s,\ \bar{c}d$, or *a pair of leptons:* $e^-\bar{\nu}_e, \mu^-\bar{\nu}_\mu, \tau^-\bar{\nu}_\tau$, (for W^+, replace all particles with their antiparticles)
- Gluons can only produce quark-antiquark pair of the same quark type. (e.g. $u\bar{u}$)

By going through the process, teachers learned some things that they hadn't realized during the presentation.

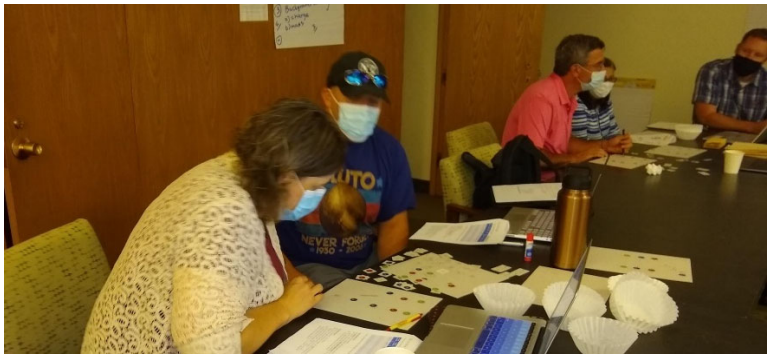


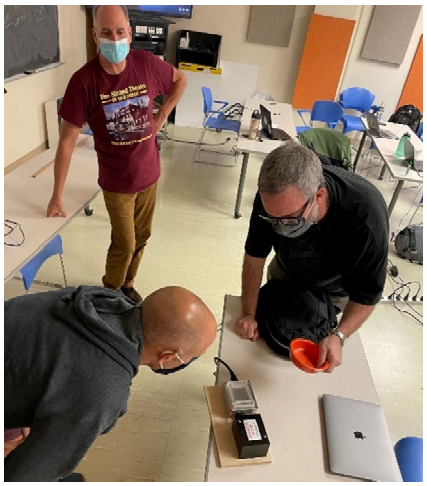
Photo showing teachers working on the decay diagrams activity.

The day concluded with a short talk by Prof. Sheldon Stone on multi-quark states, such as tetraquarks and pentaquarks, and a discussion of what we had gone through during the day.

The focus of Tuesday's activities was detectors. We worked through the "Making Tracks 1" and "Making Tracks 2" Quarknet activities, followed by a talk on detectors by Prof. Matt Rudolph. After a short break, we brought the group up to the one of the high-energy physics cleanrooms where the Upstream Tracker (UT) detector construction is taking place (see figure on page 1). Teachers got to see UT modules, as well as see them under a microscope. They were shown the microscopic wirebonds that are used to connect one microscopic electronic component to another. They could also see completed UT staves, that are being readied to ship to CERN. After lunch we engaged in the "Case of the Missing Neutrino" activity using D0 data, followed by some videos and discussion on how to make a neutrino beam. The day was finalized with a discussion of "complementary variables", uncertainty and the Heisenberg Uncertainty Principle, led by the Quarknet fellows, Paul and Helen.

We began day 3 by working with the Minerva MasterClass measurement. Teachers scanned individual events, and classified them as being "good proton + muon" events, or now, and for those good p+muon events, saving the measured momenta of each particle in an excel sheet. We then combined everyone's data, and investigated various questions about the total momentum seen, and what that might imply.

This year, we also invited teachers to engage in a Share-a-thon. The idea was for the teachers to share with the group some activity, demonstration or lab activity that they thought was really exciting. Most of the teachers brought something to share, and in some cases, they brought extras for other teachers to take back with them. Below, we show a photo of Michael and Chad checking out the miniature spark chamber that Patrick built from various components. Chad is holding an old FiestaWare plate that has (radioactive) Uranium Oxide in the glazing. When brought close to the chamber we could see (and hear) the sparks!



After the Share-a-thon, we discussed implementation plans and worked on the survey of the workshop.

After the workshop, our new attendees were very enthusiastic and indicated that they would like to continue with the Quarknet worskhop next year.