

## Summer 2023 Quarknet Workshop at Syracuse University

The Syracuse group hosted a Quarknet workshop from Aug 14-16, 2023. The program was developed by Profs. Steven Blusk, Shane Wood (Quarknet Staff), and our lead teachers Michael Madden and Brian Bealer. Twelve teachers were able to join the workshop, which included four new teachers.

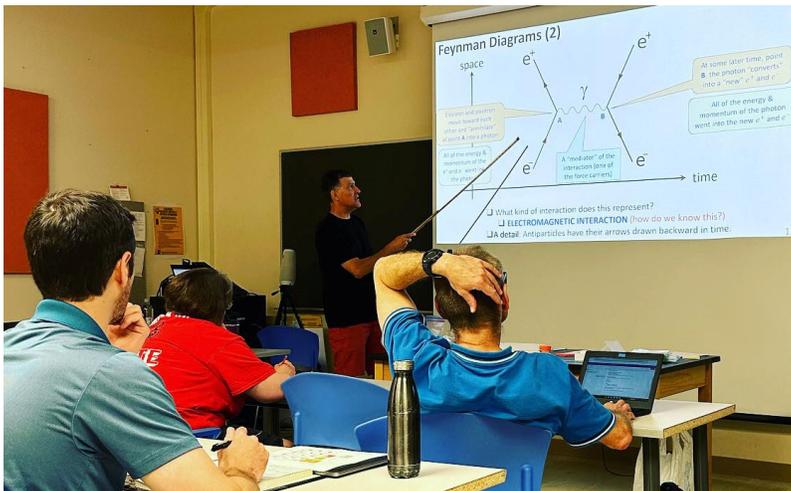


Photo showing the Quarknet 2023 participants: (From left to right): Shane Wood, Dan Kurzen, Rob Jaspersohn, Joe Powers, Charlene Rydgren, Steve Blusk, Linda Wicks, Martin Vysohlid, Sherly Hawks, Anne Huntress, Alexa Estock, Chad Gregory, Andrew Roberts, Brian Bealer.

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

<https://quarknet.org/content/syracuse-university-2023-workshop>

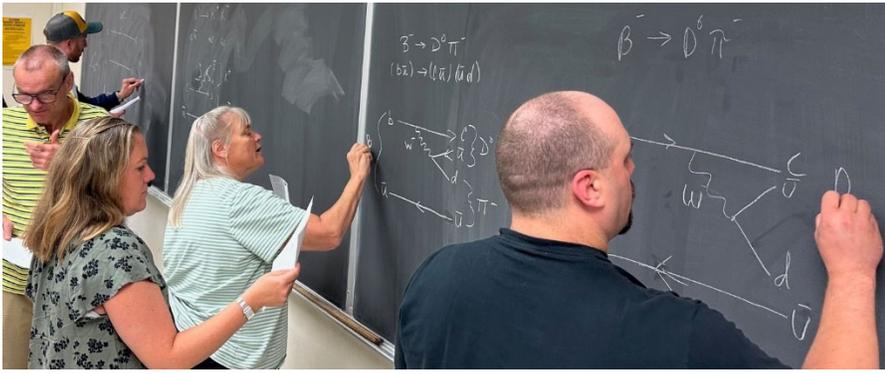
Based upon last year's teacher survey, there was a desire to understand better the weak interaction and Feynman diagrams. Those two topics formed the core of the three-day program. Monday started off with some traditional activities, including the "Big to Small" video, "Shuffling the Particle Deck", and Rolling with Rutherford", followed by a discussion. This was followed by the first talk, "Forces and Feynman Diagrams" by Prof. Blusk, followed by an activity to understand conservation laws in particle physics and how to draw Feynman diagram for the EM and Strong Forces.



After a lunch break, we had a short talk and tour of the Ross' Biophysics lab to get a glimpse of how researchers are trying to understand the inner workings of cells. Upon returning, we dived into the "DAP: Making Tracks 1" activity, viewed cosmic ray tracks in the department cloud chamber, and then worked with the Worldwide Data Day, looking at  $Z \rightarrow \mu^+ \mu^-$  decays in the CMS detector. The day ended with a discussion of the findings.

The second day opened with a reflection on Day 1 activities, and then we engaged with the DAP: Mass of the Top Quark. The focus was not so much on the mass, but the idea of conservation of

momentum, which allows one to infer that there is a missing particle in the selected sample of  $t\bar{t}$  candidate events from the D0 experiment. There was some useful discussion about how to compute the mass of the top quark from the measurements of the momenta of the lepton, jets and missing energy. This was followed by the second talk on "Weak Decays" by Prof. Blusk, followed by an activity that had teachers drawing Feynman diagrams for weak decays of heavy quarks (See photos below).

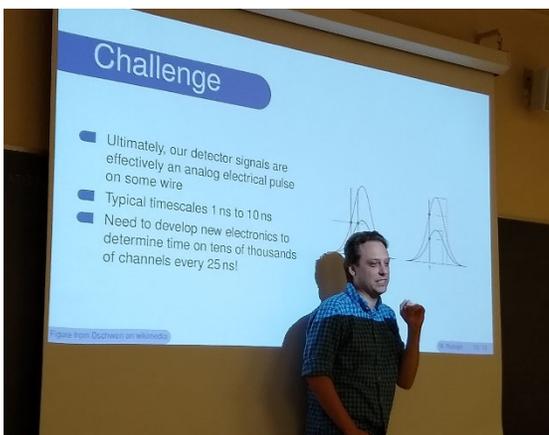


After a lunch break, staying with the theme of weak interactions, we engaged with a tutorial in neutrino physics followed by the Minerva Masterclass activity. This was another activity where one could explore conservation of momentum in collisions of neutrinos with matter. The day ended with a short discussion of the results.

The last day started with reflections on Day 2, followed by a Share-a-thon, where the teachers shared something they have found particularly useful or engaging in their classroom. There was a wide array of shared books, electronic resources and ideas, including several cool demonstrations (a couple of photos below).



After the Share-a-thon, we discussed some of the “Parking Lot” questions, namely questions that came up during the workshop that teachers wanted to understand better. This was followed by a short talk by Prof. Rudolph (below, left) on the need for precision (picosecond) timing in future particle physics experiments.



After a short lunch break, we had our second talk/lab tour of the Quantum Information laboratories, to hear about how researchers at SU are making measurements on qubits at ultra-cold temperatures.



The day and workshop concluded with an implementation discussion and teacher survey of the workshop.