

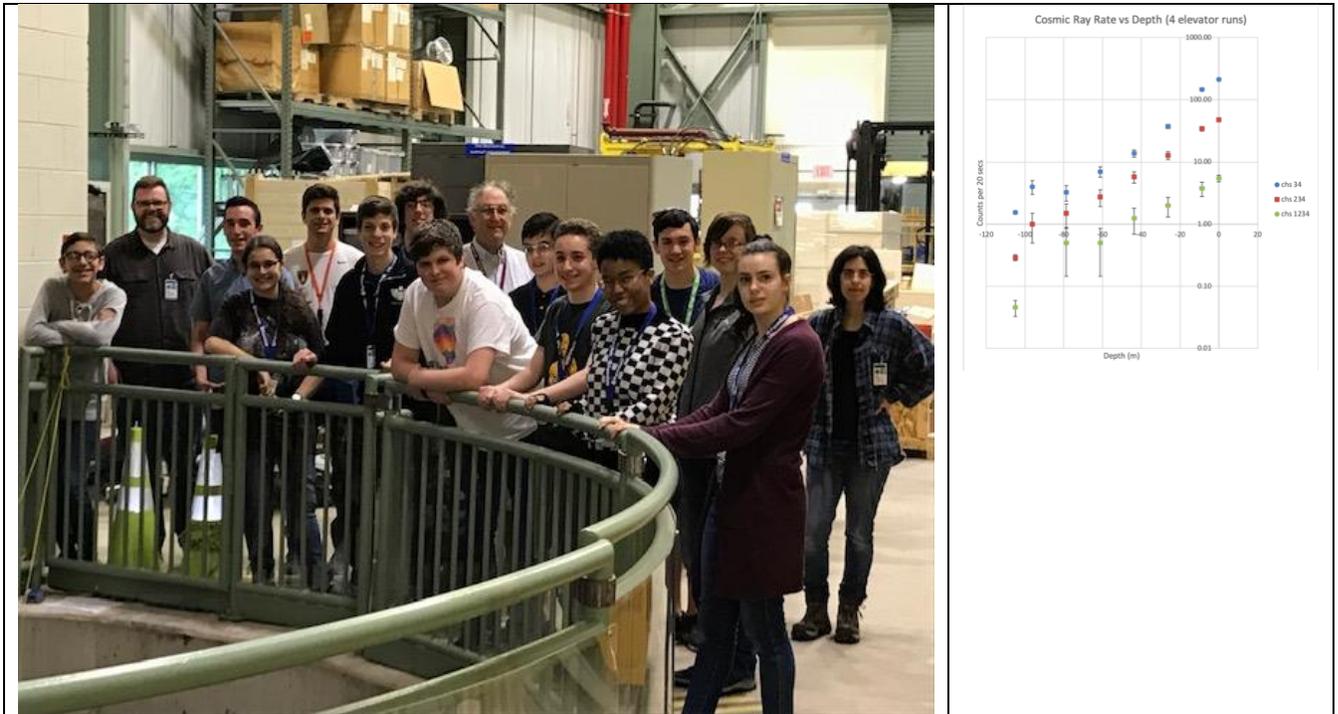
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Report of QuarkNet Activities at UIC during 2019-2020

The QuarkNet Program at the University of Illinois at Chicago and Chicago State provides mentoring, organization, and collaborative structure to students and teachers at ten Chicagoland high schools that host cosmic ray detectors. UIC-CSU provides detectors so that schools can carry out physics experiments based on detecting cosmic ray muons. This year because of COVID, our summer workshop was held virtually.

MUSE

Last year, six schools submitted a proposal to Fermilab and carried out an experiment to measure cosmic ray rates in the MINOS tunnel 103m underground as a function of distance from the access shaft. Cosmic Ray Fellow Nate Unterman serves as spokesperson. Analysis was developed during the fall of 2019, with the entire group meeting three times at high schools, culminating in the presentation of final results in four talks by teachers and students at the AAPT conference in Orlando Jan. 2020. Participants were also excited to observe neutrino interactions with their detectors in the MINOS tunnel and to correct their cosmic ray measurements for the presence of the neutrino beam. Results from a secondary goal of measuring cosmic ray rates versus depth is shown below along with a photo of collaboration members.



MUSE Collaborators at the MINOS access shaft and muon rates from elevator.



MUSE Collaborators presenting at AAPT, January 2020.

Students and teachers submitted an article on MUSE to *The Physics Teacher*. The article has been accepted pending responses to reviewer comments.

Summer Workshop

The UIC summer workshop (July 12-14, 2020) was attended by three teachers and two students. Due to the Covid-19 crisis, the workshop was held completely remotely. Participants were able to perform an analyses on the speed of muons and explored the Shower analysis to measure the rate of multiple muons in cosmic ray air showers with detector separation distances spanning from 1m to 66m. Teachers had the opportunity to discuss their approaches to remote learning and decided to move several QuarkNet detectors to homes so experiments could continue even though schools remain inaccessible.

Students and teachers from the 2017 QuarkNet Eclipse project submitted an article on their cosmic ray measurement to *The Physics Teacher*. The article has been accepted pending responses to reviewer comments. Substantial reanalysis was performed by a small group of students over several months, including some students now attending universities.

Several teachers moved their detectors from their schools to their homes so that they could continue to collect data. Additional components we required so that the GPS systems could be left in place in the ceilings of their schools. Unterman and Adams have been collecting standard data sets to serve for cosmic ray analyses in e-Lab for QuarkNet groups who don't have a detector or current accesses to their detector. One detector in a public space near teacher Unterman's home experienced a direct hit by a tornado on August 10th. Another detector in his home 100m away

from the tornado lost power. Several students plan to search for any changes in muon rates in that data set during the next academic year.

During the next grant period UIC will continue to mentor teachers and students remotely and help them carry out experiments utilizing their cosmic ray detectors. Additional analyses will be performed utilizing the MUSE data. The Center hopes to host a week-long workshop next summer at UIC, as well as a virtual winter weekend mini-workshop.

Adams is a member of QuarkNet staff. He coordinates Cosmic Ray Teacher Fellows and continues to upgrade the e-Lab analyses.

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