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### **Report of QuarkNet Activities at UIC during 2016-2017**

The QuarkNet Program at the University of Illinois at Chicago provides mentoring, organization, and collaborative structure to students and teachers at ten Chicagoland high schools that host cosmic ray detectors. UIC provides detectors and analysis software for students so they can carry out physics experiments based on detecting cosmic ray muons. During yearly summer week-long workshops new students are recruited and trained. Our Center is a joint UIC-CSU effort, however mentor Edmundo Garcia is on sabbatical to the NSF from CSU; therefore limited his QuarkNet activities this year.

The theme for activities during the entire year was established by Fellow Nate Unterman: Does the cosmic ray flux change during a total solar eclipse. Beginning in February and continuing through the fall, students and teachers created and carried out an experiment to measure cosmic ray rates during the eclipse and compare those rates during normal, non-eclipse conditions. The project was advertised QuarkNet-wide and over 30 high school groups participated. <https://sites.google.com/view/quarknet2017eclipse/home>

Detectors were designed as a compromise between gathering enough data during the eclipse and pointing resolution in the direction of the sun. Two designs utilizing the existing QuarkNet CRMDs were developed: a fixed-angle telescope where the sun traversed its acceptance over time; and a telescope on a mount that could track the sun. Students produced several prototypes, gradually increasing the frames rigidity and construction simplicity, keeping costs below \$100. Centers all around the US built detectors based on those designs. Several high school groups measured background rates and telescope pointing resolution.

During the UIC summer workshop students assembled final prototypes, made basic cosmic rate measurements as a function of zenith angle and orientation, and testing tracking schemes. A first attempt was made to observe the shadow that the sun and moon cast in cosmic rays, as compared to rates during periods of empty sky.



Attendees of the 2017 summer workshop included 5 teachers and 16 students from 6 high schools: Downers Grove South, Ida Crown Jewish Academy, Glenbrook North, Glenbrook South, Naperville Central, and Rochelle Zell Jewish High School, as well as the UIC faculty mentor. The workshop was held at Naperville Central High School from June 12-16, 2017. Participants also visited Fermilab, touring the D0 detector in the Tevatron. The students presented their Cosmic Ray results to each other during the last day of the workshop and created posters in e-Lab. Abstracts were drafted for an AAPT conference in January where the UIC group plans to present their eclipse results. Stipends are provided for summer workshop participants.

A group of 7 students and 4 teachers travelled to Jefferson College in Hillsborough, MO to observe the total solar eclipse. During the 4-day adventure, four detectors were debugged and calibrated. Rates of cosmic ray muons were obtained so that conditions of empty sky, sun in the sky, and moon in the sky could be compared to rates during the eclipse. Symmetry magazine ran a story about the eclipse project and another follow up article is planned.



Students have been working hard to extract a signal during the eclipse from background. They helped debug an e-Lab analysis tool developed by Adams and Balakrishnan that has been made available to all QuarkNet users. Students have weekly analysis goals during the fall, culminating in their trip to AAPT in San Diego to present results. Initial results are being improved by the use of several calibration and normalization techniques. Additional calibration data samples will be collected.

During the next grant period UIC and CSU will continue to visit high school sites to assist students operate their cosmic ray detectors, will mentor students on their choice of experimental activities. The center will host a week-long workshop next summer at UIC, as well as sponsor a fall weekend mini-workshop at a local high school, sponsor a virtual analysis meeting open to all QuarkNet Eclipse Project participants, and present results at AAPT.

Adams is part of QuarkNet staff. He coordinates Cosmic Ray Teacher Fellows and upgraded the Shower e-Lab analysis module to produce rates of various counter combinations every ten minutes, required for the eclipse study.

Mark Adams  
UIC Professor Emeritus of Physics

Edmundo Garcia  
CSU Professor of Physics  
(On leave at NSF 2017)