SCROD: School Cosmic Ray Outreach Detector

Evgueni Gouchtchine[1] Thomas P. McCauley,[2] Yuri Musienko,[2] Thomas C. Paul,[2] Stephen Reucroft,[2] John D. Swain,[2]
(1) Institute for Nuclear Research (INR), Russian Academy of Sciences, Moscow, Russia
(2) Department of Physics, Northeastern University, Boston, MA 02115

Abstract

We report progress on applying technologies developed for LHC-era experiments to cosmic ray detection, using scintillating tiles with embedded wavelength-shifting fibers and avalanche photodiode readouts as parts of a robust, inexpensive cosmic air shower detector. We are planning to deploy such detectors in high schools as part of an outreach effort able to search for long-distance correlations between airshowers.

1. Introduction

Ultrahigh energy cosmic rays have been detected by a number of independent experiments over the last few decades [1]. The initiative we describe here, known as *SCROD* for *S*chool *C*osmic *R*ay *O*utreach *D*etector [2], is based on an idea which is simple but has enormous potential: install cosmic ray detectors suitable for continuous muon counting and to detect building-sized (or larger) extensive air showers. A number of similar or related initiatives have been proposed in the past [3], but SCROD offers a number of novel features which make it particularly attractive for large-scale deployment in schools and public areas such as libraries, community centres, *etc.*

Each detector is constructed from a set of inexpensive plastic scintillators mounted at each site and read out using a novel technology we discuss below. A PC will be used for data collection and offline data reduction. Cosmic air showers will be time-stamped using a GPS receiver and the data forwarded to a central site which will be accessible to all the collaborators. We have already developed and operated a prototype detector and software. SCROD will be able to study both shorter and longer-range correlations than are accessible to many other experiments [4] and thus will be complementary to, and for some measurements, superior to existing experiments. With detectors of sufficiently low cost, it should be feasible to instrument hundreds of sites, making this both an extensive educational program and an unequaled scientific instrument.

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2. The Detector System

A core technology we are proposing is the use of Avalanche Photodiodes (APD's) used in the CMS experiment [5]. APD's are essentially photodiodes with a large internal electric field enabling electrons to gain enough energy within the device to free more electrons in the semiconductor, thus providing gain. APD's can have high quantum efficiencies, far exceeding those of photomultipliers. They are also mechanically robust and easy to use requiring a supply of only a few hundred volts, a current-limiting resistor, and a preamplifier. Furthermore they require only a few hundred nanoamperes of current to function, making them safe for use by non-experts.

The hardware proposed at each detector site consists of the following main components: 1) a set of plastic scintillating tiles with wavelength-shifting fibers to produce pulses of light in response to incident cosmic rays (the optimization of number and spacing of these tiles is still under study and is a strong function of available funding); 2) APD's to read out the fibers and generate electrical signals; 3) a GPS-based system to time-stamp signals from the APD's; 4) the World Wide Web to provide an inexpensive wide-area data acquisition system. We concentrate on the first two components in this paper.

A photograph of a prototype scintillating tile with wavelength shifter is shown in figure 1.

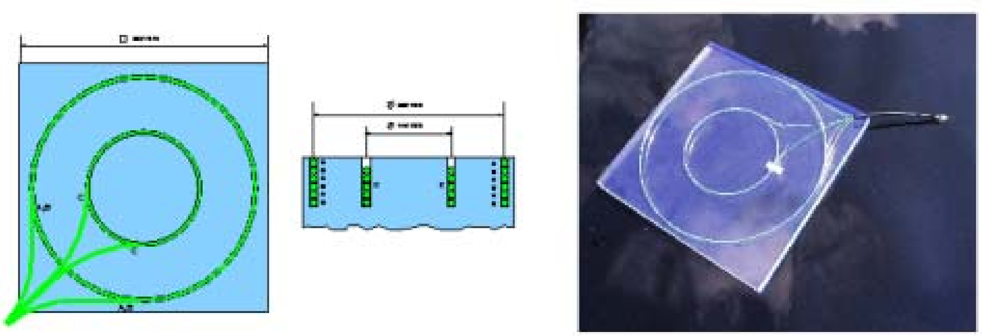

Fig. 1. Sketch and photograph of the scintillating tile with wavelength shifting fiber.

We have already tested a prototype detector with the APD readout and found that it produces a very clear signal for minimum ionizing particles (see figure 2.).

3. Physics Potential

Within densely-populated areas SCROD can function like a dramatically scaled down Pierre Auger observatory. As many of the detectors will be spaced

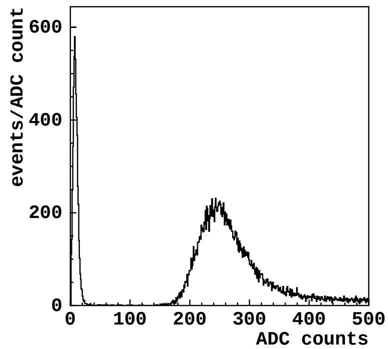

Fig. 2. Signal due to single muons passing through the scintillator using APD readout.

more closely together than the 1.5 km separation used for Auger (we anticipate separations of distances ranging from a short city block and thousands of kilometers), it will be possible to trigger on lower energy air showers. In this mode, SCROD could compliment the results of earlier experiments. Depending on what the highest energy cosmic rays actually are, it is conceivable that there exist long-range correlations among the air showers they produce. Either observation or non-observation of such correlations would be a very important result which cannot readily be obtained except by an extensive experiment of the type proposed here. One can consider, for example, the Gerasimova-Zatsepin [6] effect, in which a high energy atomic nucleus approaches the earth and dissociates on an optical photon from the sun. The (two or more) nuclear fragments can then reach the earth at distant locations, but close together in time. Since the composition of high energy cosmic rays is unknown, and its determination from single extensive air showers is complicated by sensitivities of observables to details of the hadronic interaction model chosen, this is of particularly great interest.

Highly energetic dust grains could also dissociate and give rise to widely-separated showers [7]. Dramatic cosmic events may also pepper the globe with many high energy cosmic rays all at about the same time; these have never been looked for on the scale possible with SCROD. In addition, with the GPS timing information, it will be possible to compare and correlate data taken with SCROD with those taken at neutrino and gravitational radiation detectors.

It has been suggested that cosmic rays play a significant role in influencing climate and weather [8], possibly due to their effects in seeding the formation of clouds, a subject which has only just begun experimental investigation [9]. Modulations in the cosmic ray flux associated with solar activity can be clearly monitored from the single count rates at each detector [10], and also form an important part of the collected data.

A program of educational modules will be developed through a close collaboration between physicists and the participating teachers in order to be sure that our non-university collaborators can participate in the intellectual adventure of SCROD to the fullest. We expect to publish numerous papers on SCROD results in professional journals, all to be signed by the participating students and teachers in addition to professional physicists. This will allow students and the general public be part of a major international research effort, an opportunity normally only open to those who pursue advanced degrees in the field. Another exciting possibility is to have joint publications with other experiments, adding the SCROD data to that collected by more standard (non-outreach) experiments.

4. References

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