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SCROD: An Update

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Abstract: We report on the status of the SCROD project, which aims to install a wide array of cosmic ray detectors in high schools. The most interesting innovative element of this approach is a novel avalanche photodiode (APD) based scintillator readout using pixellated Geiger-mode devices "solid-state photomultipliers") requiring only a low voltage supply (tens of volts) and very minimal support electronics and yet offering excellent stability and noise rejection.

Introduction

The project we describe here[1, 2, 3], known as *SCROD* for *S*chool *C*osmic *R*ay *O*utreach *D*etector, is based on an idea which is simple but has great potential: install cosmic ray detectors suitable for continuous muon counting and detection of building-sized (or larger) extensive air showers in high schools and relay collected data via the internet to a central repository which is accessible to all participating schools. The principle aim of the project is education, but there is potential for contribution to cosmic ray physics as well. Involving students in a project making real measurements in a living field seems more likely to spark an interest in physics than the usual ritual of repeating century old experiments whose conclusions are foregone. A number of groups are pursuing similar programs (*e.g.* CROP, CHICOS, ALTA, WALTA, NALTA, SALTA, etc.) [1] using various approaches and recycling equipment to various degrees. Here we discuss our approach and the current status of the work.

Physics Potential

Several processes could give rise to very long-range correlations to which SCROD could be sensitive. One is the Gerasimova-Zatsepin (GZ) effect [4, 5, 6], 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, it would be interesting to search for such events.

In the GZ effect, the distance by which nuclear fragments are separated upon arrival at the earth depends on their deflection in the magnetic field of the solar system. Recent analysis [5] for iron nuclei has indicated that very large separations are to be expected. For iron nuclei with energy around 1 EeV, for example, most separations will be in excess of 100 km. Clearly, extensive detectors are required to observe such events. Figure 1 shows roughly the expected rate for various separations.

There are also other conceivable mechanisms to produce a similar effect. For example highly energetic dust grains could dissociate and give rise to

1. Relevant web pages are:
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http://crop.unl.edu
http://www.chicos.caltech.edu/
http://csr.phys.ualberta.ca/alta/
http://www.phys.washington.edu/walta/
http://www.hep.physics.neu.edu/scrod/
http://csr.phys.alberta.ca/nalta
http://faculty.washington.edu/wilkes/
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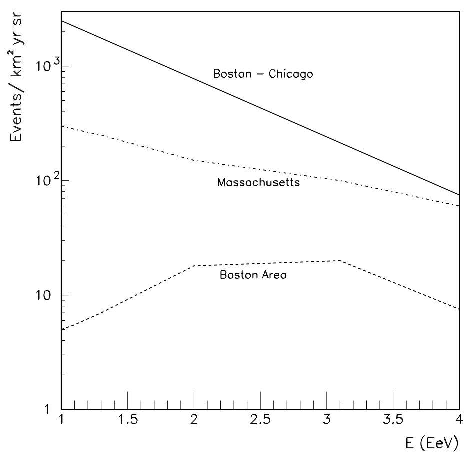

Figure 1: Expected rates versus energy for correlated events due to iron nuclei disintegrating on solar photons. This figure (with thanks to Alan Watson) is for events arriving from a direction close to the sun. The three lines show approximate rates characteristic of the separations attainable in different geographical areas (the Boston area, the entire state of Massachusetts, and a separation of roughly the distance from Boston to Chicago.)

widely-separated showers [7]. One might also conceive of dramatic cosmic events that may also pepper the globe with many high energy cosmic rays all at about the same time. 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. Finally we note that there is already some suggestion of experimental evidence for long range correlations in the literature [8, 9].

Education Goals

The goal is that students, under the advisement of professional physicists and their teachers, will be responsible for the day-to-day running of the experiment, for the data analysis and search for time correlations, and will in some cases devise unique projects using their station. We are also consulting with area teachers to begin developing ways to use the apparatus to catalyze related classroom ac-

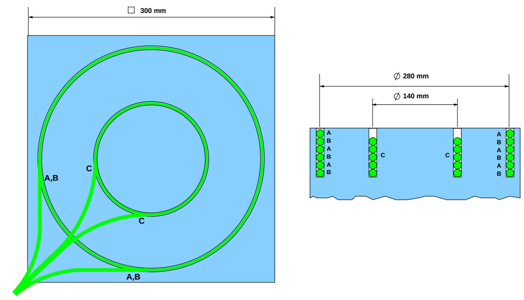

Figure 2: Schematic representations of scintillators with embedded wavelength-shifting fibers.

tivities. At the current prototype phase, we are involving a few high school students and beginning undergraduates directly in the development efforts.

Detector Description

The hardware proposed for the detector sites consists of the following main components: 1) a set of plastic scintillating tiles with wavelength-shifting fibers; 2) avalanche photodiodes to read out the fibers; 3) a GPS-based system to time-stamp the signals; 4) a personal computer (PC) for local data acquisition and 5) the Internet to provide an inexpensive wide-area data acquisition system. A single station will be equipped with 3–5 separate scintillators, arranged on the school rooftop.

Scintillating Tiles with APD Readout

The scintillator we use is adapted from technology developed for the LHC-b pad/preshower detector [10], and comprises a 30×30 cm plastic scintillator slab with two circular grooves machined in it. Three wavelength–shifting fibers (Bicron BCF-91) are embedded in the grooves, one in the inner grove, two in the outer, to shift the scintillation light into the sensitive region of the readout apparatus and to serve as a light guide. The scheme is illustrated in Figure 2. The entire assembly is wrapped in white Tyvek paper to increase light collection efficiency.

For fiber readout we use an avalanche photodiode (APD). APDs are essentially photodiodes with an internal gain mechanism. They can have high quantum efficiencies, exceeding those of photomultiplier tubes. They are also mechanically robust [11, 12, 13] and easy to use.

Our latest innovation is the use of pixellated Geiger mode APD's which are based on a relatively novel device structure[14]. While there are many subtleties in the fabrication, the basic idea is simple: divide the active area of the APD into a large number of independent individual cells ("pixels") all connected in parallel. Now bias the device for Geiger mode operation and think of each pixel as a tiny light-activated switch. If n photons are incident and n is small compared to the number of pixels, it is unlikely that 2 or more photons will hit the same pixel, so the current produced will be n times that produced if one pixel is hit - in other words, the operation is linear, even though each pixel acts as an absolute "yes/no" Geiger mode APD. Since each pixel is small, response time and recovery time can be very short, and the effective capacitance involved which needs to be recharged is also very small. Timing resolutions of tens of picoseconds are readily achievable. A recent commercial devices we have used is available from Photonique, SA in Switzerland[15]. Figure 3 shows the structure of such an APD .

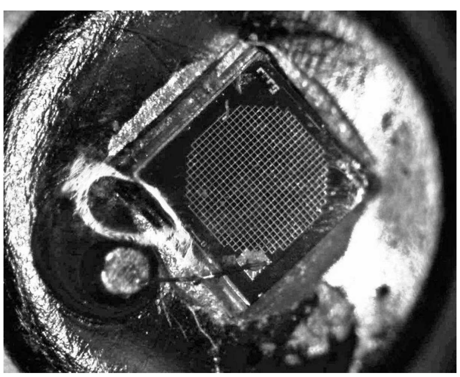

Figure 3: Photograph of the pixellated device structure. Sensitive area is 1mm×1mm with 556 pixels.

Figure 4 shows a test setup to compare PMT and APD readouts of the same signal from a real scintillator [16] with the results for muons shown in figure 5.

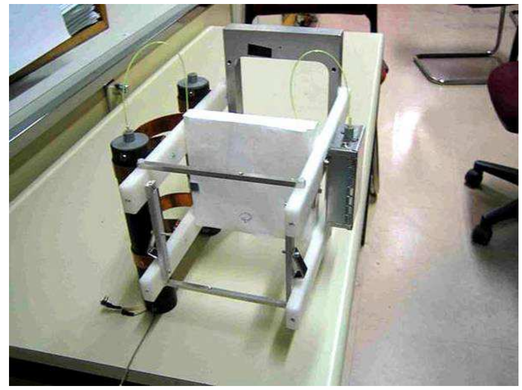

Figure 4: Scintillator (150mm×150mm×15mm from Kharkov, Ukraine with 1mm diameter Y11 wavelength shifter), exposed to 20 GeV muons at room temperature (22C) read out with a pixellated Geiger mode APD and PMT to produce the adjacent plots.

GPS Timestamp and Data Acquisition

In the current prototype version, the amplifier signal is passed through a discriminator to generate a TTL pulse, which is used to latch the time of each hit. The time is broadcast from a central board comprised of two sets of counters, one of which records the number of pulses delivered by the GPS receiver's 1 pulse per second (1PPS) line, while the other is clocked by an on-board 100 MHz oscillator and reset each second by the 1PPS line. The timing resolution offered by the fast rising edge of the 1PPS signal is about 40 ns. Each scintillator has its own time latching circuitry which converts the time to serial RS-232 signals and relays it to a serial port in the computer; there is one serial port for each scintillator. This design is reasonably modular so that a given site can easily attach another scintillator, or in principle any other piece of hardware which records data that should be timestamped. We are investigating the use of another GPS timing board produced at Fermilab [17].

This design also allows for very simple electronics. Our prototypes were constructed by first-year undergraduate students using quite inexpensive off-the-shelf components. As much as possible, we are devising a purely offline software trigger; all hits are stored in their respective serial ports and

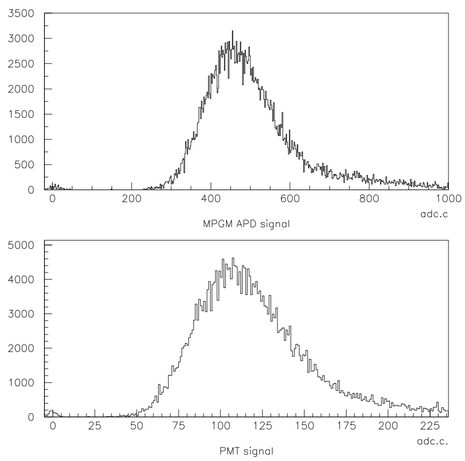

Figure 5: Upper plot shows spectra for APD readout (40 photoelectrons), with lower plot using Philips XP2961 green-extended PMT (26 photoelectrons)

accessed by reader programs running as separate threads on the PC.

Summary

SCROD is an ongoing project which has been refined over several years and is now based on very simple and robust technology. We hope to find funding soon to begin bulk deployment.

Acknowledgements

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