Properties of a new cosmic ray detector (SciCRT) installed at Mt. Sierra Negra, Mexico

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Abstract: The SciCRT (SciBar for the Cosmic Ray Telescope) is a new project for a new multi-purpose cosmic-ray experiment. The main scientific aim of the SciCRT is to measure solar neutrons and to monitor cosmic-ray muons with high angular resolutions. It is installed at Mt. Sierra Negra in Mexico, 4,600 m above sea level. The detector was calibrated using cosmic-ray signals at INAOE (Instituto Nacional de Astrofísica, Óptica y Electrónica) in Puebla, Mexico at 2200 m as.l. The detector consists of 14,848 polystyrene scintillator bars (2.5 cm × 1.3 cm × 3 m) with TiO₂ coating. Wavelength shifting fibers inserted in the scintillator bars are connected to multi-anode photomultiplier tubes (MAPMTs). The deposited energy in each bar is recorded. The trigger of data taking is produced by the collection of hit signals from all the MAPMTs through the VME module with a FPGA chip. In this paper, the detector configuration, the data acquisition system, and the trigger logic to measure both neutrons and muons will be presented. Some of the most recent cosmic ray data from the experiment will also be shown.

Keywords: solar neutron, SciCRT

1 Introduction

In order to understand the mechanism of ion-acceleration at the solar surface, it is important to detect and analyze solar neutrons. By using Solar Neutron Telescopes (SNTs) have located on seven mountains near the equatorial line, they have observed solar neutrons [1][2].

Recently, we have constructed a new SNT that is based on the SciBar as the Cosmic Ray Telescope (SciCRT) project [3]. The experimental status of SciCRT is presented in a separate paper [4]. This detector is also used as a muon detector as shown in [5]. In this paper, we show the results of the calibration test and the details of the hardware of the SciCRT.

2 Detector

The SciCRT consists of the detectors, the readout circuit and the environmental monitors. Unlike the SNT at the Mt. Sierra Negra [6] the detector part of the SciCRT is made of 14,848 plastic scintillator bars with TiO₂ coating as shown in Figure 1. The detector consist of 64 layers which have 116 bars. The dimension of each bar is 2.5 cm × 1.3 cm × 3 m. Each bar has a hole of 1.8 mm in diameter. A Wave Length Sifting fiber (WLS-fiber) with 1.5 mm in diameter is inserted into them. Sixty-four WLS-fibers are bundled and connected to a 64 channel multi-anode photomultiplier tube (MAPMT) "H8804" (Hamamatsu). Sig-

Fig. 1: SciBar detector is made of plastic scintillator bars (vertical and horizontal) and WLS-fibers (top of bars). Sixty-four WLS-fibers are bundled and connected to a MAPMT [7]. nals from MAPMTs are processed by an analog to digital converter (ADC). When a charged particle is injected to this detector, we can identify a trajectory of the particle by using ADC data. On the other hand, a neutron is i-
Fig. 2: The time profile of normalized trigger rate of the SNT and mini-SciCRT at Forbush decrease event.

determined when a recoil proton is produced in the detector. Therefore the trajectory of one neutron is identified in the middle region of the detector. To select neutron events, the outer bars are used as anti-counters.

The readout circuit of the SciCRT consists of MAPMTs, ADCs, Front End Boards (FEBs), Back End Boards (BEBs) and Trigger boards. Each MAPMT is connected to a FEB which has two application-specific integrated circuit (IDEAS VA32HDR11 and TA32CG). TA has discriminators and makes a hit signal when any one of the MAPMT anode signal exceeds the threshold level. VA makes slow shaping from the MAPMT anode signals and hold voltages when it gets a trigger signal. Two package of TA/VA are connected to upper 32 anodes (8×4) of MAPMT and lower 32. 8 FEBs are connected to one BEB which has ADCs and processes voltage conducted from the VA. Finally, the role of the trigger board is to make a trigger signal from hit signals collected by related BEBs. The environmental monitors record the temperature, the time of PC and GPS, and applied voltage in MAPMTs.

3 Calibration and Measuring cosmic-ray background

A prototype detector named as mini-SciCR was installed at the top of Mt. Sierra Negra, 4,600 m above sea level, before the transfer of the SciCRT. It had 2 MAPMTs and 20 cm scintillator bars. Observation results for background cosmic-ray by the mini-SciCR shows good agreement of the Monte Carlo simulation [8]. Through the Forbush decrease event on Mar. 7 2012, its applicability as the cosmic-ray detector including neutron and muon monitor was confirmed. Figure 2 shows the temporal evolution of the counting rate of the Ì½30MeV channel of the SNT and mini-SciCR at Sierra Negra. The data for the SNT are observed in the scintillator boxes parts with 30 cm thick and of the area of 4 m². The vertical axis is normalized by the own average counting rate before the flare. The vertical dashed line indicates the start time of the solar flare and CME, and the black circle and red square show the normalized counting rate of the SNT and the mini-SciCR, respectively. Both data show same decrease rate even though the volume of detector is different.

The SciCRT was installed in INAOE (Instituto Nacional de Astrofísica, Optica y Electronica), 2,200 m a.s.l., in Mexico. Through measuring the background cosmic-ray profile, the SciCRT is calibrated. We had tested the data acquisition system including all the MAPMTs and electronics in Nagoya, Japan, before sending them to INAOE. Therefore all the data obtained in INAOE are compared with those obtained in Nagoya. We developed a new structure consisting of eight Super Blocks (SB) to support the detector plate horizontally different from the accelerator experiment for which they were placed vertically, as shown in Figure 3. We put 16 layers (half of them are connected to MAPMTs at X side, the other half is connected to Y side) in one SB. Every SB structure consists of 5 mm thick steel I-beam and 3.8 mm thick steel square pipe. It makes 82 m gap between each SB. The bending of scintillator bar is a few centimeter at maximum and negligible in comparison with the length of bars with 3,000 mm.

We tested data acquisition system using cosmic ray using 2/8 of the total bars of SciCRT in August 2012. Figure 4 shows the typical data of calibration test. The left panel is ADC distribution of one anode for three different high voltages for the MAPMT. We can find the difference of the 3 histograms. The right panel is the relation of the average gain of 64 channels and high voltage for one MAPMT. The points of diamond and star indicate data of Nagoya with Xe lamp and INAOE with cosmic-ray background, respectively. In Nagoya, 5 different voltage data were taken with the trigger of synchronized lamp. On the other hand, in INAOE, the trigger is made by the logic of (X upper layers AND Y upper) OR (X lower AND Y lower). The vertical axis is normalized by the value of 700 V of a standard MAPMT. Both graph show exponential formula and similar to each other. We can get the best voltage to set demanded gain from the graph.

We measured cosmic rays by using 5/8 of the whole SciCRT and muon counters of top and bottom in November 2012. Figure 5 shows an event sample of cosmic ray detect-
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Fig. 5: Trajectory view of X side (top panel) and Y side (bottom panel). The color channels show scintillator bars which get signals, with the color varies depending on ADC count. We used upper 5 SBs and, the top and bottom layers. The horizontal lines are gaps and the dashed lines are estimated line by only the top and bottom data.

Fig. 6: Trajectory view of a shower event.

Fig. 7: The top panels is particle trajectory view of one MAPMT and 4 side anti bars which as red color regions. The left panel is a event of side anti hit and right one is Not (see in the text). The bottom panel show 1,000 fitting lines, and left and right panel is anti hit and Not, respectively.

Fig. 8: The hit signal ratio by some thresholds levels determined by reading program. The horizontal axis (ADC count) are put offset so as pedestal peaks become zero.
cosmic ray by 4 difference thresholds of TA chips which are controlled by BEBs and determined by PCs. The vertical axis of the figure indicates the ratio of the event, when TA returned hit signal. We can find that the threshold level works properly to select hit channels.

4 Summary
The SciCRT project using SciBar detector will be started at the top of Mt. Sierra Negra, 4,600 m above sea level. The SciCRT was calibrated in Nagoya, INAOE and here. First of all, we found the mini-SciCR has sensitivity to cosmic rays through the Forbush decrease event analysis. Next, the SciCRT has the ability of both muon hodoscope and particle identification. Also, the system of the side anti counters in SciCRT is able to reject inclined particles. We can set the best voltages of MAPMTs and thresholds by the test of difference voltages and thresholds. The stable data taking will be started soon.

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