PROCEEDINGS OF SCIENCE

Preliminary Simulation of the Scibar Cosmic-Ray Telescope (SciCRT) at Sierra Negra

Monterde-Andrade F.,[a,*] González L.X.,[a,b] Valdés-Galicia J.F.,[a] Newton-Bosch J.,[a] Morales-Olivares O.G.,[e] Matsubara Y.,[c] Itow Y.,[c] Sako T.,[d] Kawabata T.,[c] Ortiz E.,[e] Taylor R.,[a] Hurtado A.,[a] Musalem O.,[a] Munakata K.,[f] Kato C.,[f] Kihara W.,[f] Ko Y.,[f] Shibata S.,[g] Takamaru H.,[g] Oshima A.,[g] Koi T.,[g] Kojima H.,[h] Tsuchiya H.,[i] Watanabe K.,[j] Kozai M.[k] and Nakamura Y.[l]

[a] *Instituto de Geofísica, Universidad Nacional Autónoma de México. Ciudad de México, 04510, México.*
[b] *LANCE/SCiESMEX. Instituto de Geofísica, Unidad Michoacán, Universidad Nacional Autónoma de México. Morelia, Michoacán, 58190, México.*
[c] *Institute for Space-Earth Environmental Research, Nagoya University. Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan.*
[d] *Institute for Cosmic Ray Research, University of Tokyo. Kashiwanoha, Kashiwa, Chiba, 277-8582, Japan.*
[e] *Escuela Nacional de Ciencias de la Tierra, Universidad Nacional Autónoma de México. Ciudad de México, 04510, México.*
[f] *Department of Physics, Shinshu University, Asahi, Matsumoto, 390-8621, Japan.*
[g] *College of Engineering, Chubu University, Kasugai 487-8501, Japan.*
[h] *Faculty of Engineering, Aichi Institute of Technology, Toyota 470-0392, Japan*
[i] *Japan Atomic Energy Agency, 2-4 Shirakata Shirane, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan.*
[j] *National Defense Academy of Japan, 1-10-20 Hashirimizu, Yokosuka, Kanagawa 239-8686, Japan.*
[k] *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Kanagawa 252-5210, Japan.*
[l] *Institute of High Energy Physics, Chinese Academy of Sciences Yuquan Road, Shijingshan District, Beijing, 100049, China.*

E-mail: fmonterde@igeofisica.unam.mx (Fernando Monterde Andrade), xavier@igeofisica.unam.mx (Luis Xavier González)

The Scibar Cosmic-Ray Telescope (SciCRT) is a brand new detector of the Sierra Negra Cosmic Rays Observatory (SN-CRO). It is designed to observe solar neutrons and the muon background produced by galactic cosmic rays. In this work we present a Geant4-based simulation of the muon detection efficiency of the SciCRT; for this purpose we injected 10^5 muons, in an energy range from 100 to 1000 MeV, impinging the SciCRT array. Our results provide new information about the SciCRT performance and may be used to study variations in low energy galactic cosmic rays.

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[*] Speaker

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1. Introduction

The Scibar Cosmic-Ray Telescope (SciCRT) was originally designed for high energy particle experiments [1, 2]. On 2013, it was assembled at the Sierra Negra Cosmic Rays Observatory (SN-CRO) in Mt. Sierra Negra, Mexico (19.0 N, 97.3 W, at 4580 m a.s.l.) and started working on 2014. Due to modifications in the readout and acquisition systems [3, 4], the superblock 3 (SB3) and the muon layers (ML) are currently the optimally working components, the explanation for this terminology and a description of the SciCRT operating principles are given in Section 2. We explain our simulation set up in Section 3 and discuss our results in Section 4. Finally, our conclusions are summarized in Section 5.

2. The SciBar Cosmic Ray Telescope

Due to its design, the SciCRT has advantages for particle detection in comparison with detectors like the Solar Neutron Telescope of Sierra Negra (SNT-SN), [4–6]. Specifically, it is able to record particle tracks and possesses an enhanced capability to reject background particles; in this way, its design offers a higher particle identification ability, [7]. The SciCRT is a set of 14,848 orthogonally stacked bars, composed by a plastic scintillator, organized in 8 superblocks (SB). Inside of each bar, a Wavelength Shift (WLS) fiber is embedded and connected to a Multi-Anode Photomultiplier Tube (MAPMT). Figure 1 shows a diagram of these components.

When particles hit the detector, they interact with the scintillator material and photons are emitted afterwards. A fraction of these photons is absorbed by the WLS fibers, which re-emit and drive the light towards the MAPMT's. Such sensors produce an electronic signal, making particle detection possible. The ML consist of the bars comprising the two layers at the top of the superblock 1 (SB1) and the bars of the two bottom plates of the superblock 8 (SB8) and have the function of detecting muons (Figure 1). For a muon to be detected, a trigger signal must be obtained from the four ML. The remaining SB's are intended to detect other particle species, like neutrons and γ-rays. On the basis of this configuration, in the following section we explain our simulation.

3. Simulation set up

This work is based in the Geant4 code (version 11.1.1), [9]. We simulated the SB's and the ML in the Geant4 logic environment and arranged them as shown in Figure 1. The bars of the ML have a hole whereby a WLS fiber is inserted and coupled to a MAPMT as described in Section 2, the MAPMT's have a maximum quantum efficiency (QE) of 25%. We followed the characterization of the bar materials and properties reported in [8, 10], and used the QGSP BERT model for particle interactions, [11]. Based on this set up, we calculated the efficiency of the ML to detect muons. A simulation of particle injection in the SciCRT is depicted in Figure 2.

4. Simulation results

We injected 10^5 muons on top of the SciCRT with injection angles θ = 0°, 15°, 30°, 45° and 60°; the injection energies are E_{inj} = 100 MeV, 250 MeV, 500 MeV and 1000 MeV. Taking into

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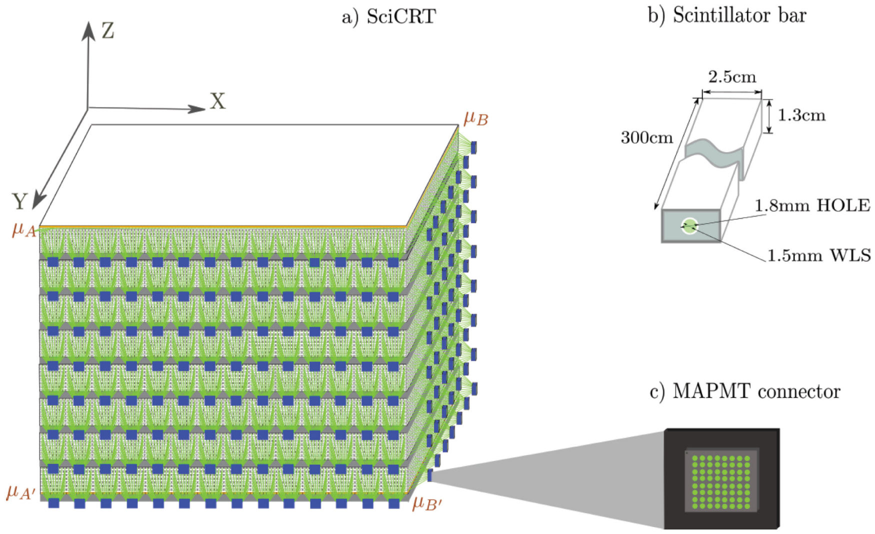

Figure 1: Diagram of the SciCRT components. A total of 8 superblocks (SB) constitute the SciCRT (a). The bars at the top of the SB1 and the bottom bars of the SB8 represent the ML. A WLS fiber is embedded in each bar (b) and connected to a MAPMT (c). Taken from [8].

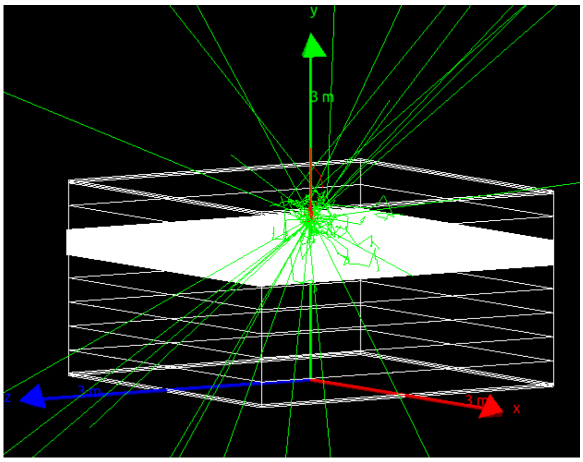

Figure 2: Visualization of our design of the SciCRT in Geant4. The scintillation bar substructure is only defined for the ML (white volume at the top and bottom). This figure shows the scintillation light emission (green lines) released after the injection of 10 muons over the top of the detector.

account the QE of the MAPMT's, an event is recorded when the emitted scintillation photons hit the sensors simulated for the four ML; on the basis of these conditions, we obtained a dependency in E_{inj} and θ in our calculation of the detection efficiency (ϵ (E_{inj}, θ)), the results are shown in Figure 3. According to our simulation, the ML have a better detection performance for increasing θ. This is explained by the longer paths that muon traverse from the top ML to the bottom ML along the SB's; which, in turn, lead to a higher light emission and thus to a greater probability to interact with the sensors. However, for $\theta = 0°$, $15°$ and $30°$, a decrease of about two orders of magnitude in ϵ (E_{inj}, θ) is observed. Such behavior is attributed to the capability of muons to pass through the

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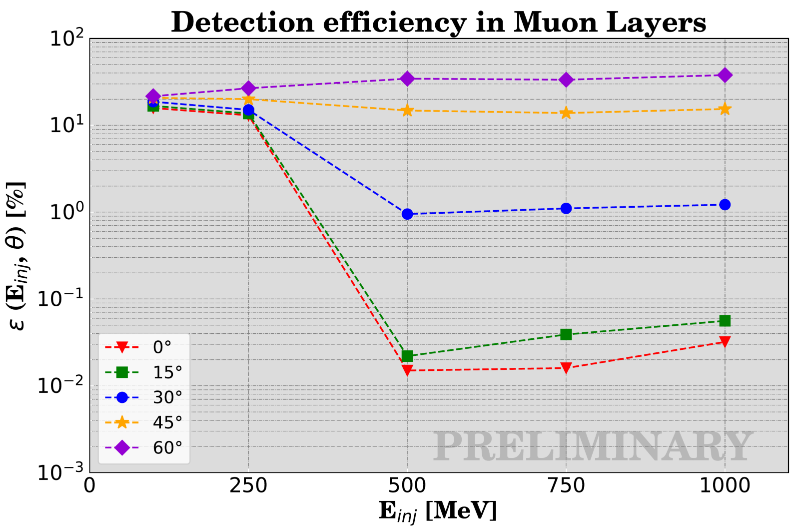

Figure 3: Detection efficiency of the ML of the SciCRT for injection angles θ = 0°, 15°, 30°, 45° and 60°; the injection energies are E_{inj} = 100 MeV, 250 MeV, 500 MeV and 1000 MeV.

whole SciCRT without being detected due to their low interaction with matter; this interpretation is also supported by the tendency of the ϵ (E_{inj}, θ) above energies E_{inj} = 500 MeV, for all θ, since no significant enhancement is observed thereafter.

5. Final remarks

Having knowledge of the efficiency of a detector to a specific particle species is crucial in order to evaluate its performance and validate its observations. In this work we have calculated the ϵ(E_{inj}, θ) of the SciCRT components designed for muon detection. We found that these ML are most efficient in the detection of muons impinging the SciCRT with angles θ = 45° and 60°; when muons enter the SciCRT with angles θ = 0°, 15° and 30°, the highest ϵ(E_{inj}, θ) is achieved for E_{inj} = 100 MeV and 250 MeV.

Our results provide new information about the SciCRT detection performance. Since the SciCRT components are under continuous optimization, we will continue working on development of a holistic SciCRT simulation that accounts for all the SB's and the ML.

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