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Performance of an Improved Solar Neutron Telescope Installed in Sierra Negra Volcano, Mexico

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In order to understand the acceleration mechanism of ions at the solar surface it is essential to determine the energy spectrum of solar neutrons produced in very high energy flares. A new version of a Solar Neutron Telescope (SNT) that can measure the energy and arrival direction of neutrons is operating on the Sierra Negra Volcano at an altitude of 4580m a.s.l., in Mexico since July 2004. In this paper we describe the scientific purpose of the experiment, details of the detector characteristics, numerical simulations carried out to estimate its sensitivity and an electronic novelty used for the DAQ. Unfortunately, since the SNT in Sierra Negra is fully operative, the location of the neutron-genetic events on the Sun did not occur at hours proper for observation at this site. We present a study of the data obtained at the station to demonstrate the reliability of the detector.

1. Introduction

Neutrons are one of the many products of solar flares; they are of particular importance since they are produced directly by nuclear interactions of the flare-accelerated ions (mainly protons) within the ambient gas of the solar atmosphere. Since the first confirmed observations of solar neutrons there has been growing interest in their detection at the earth's surface [1]. Several research groups investigated the processes affecting neutron propagation in the earth's atmosphere and the way in which the different kinds of neutron detectors react to this solar flux [2]. The neutron monitor has low sensitivity (~1%) to the high energy muon background (E > 1 GeV) [3], it is very stable and has a high sensitivity to neutrons with energies down to 10 MeV [4].

2. The Sierra Negra Solar Neutron Telescope

The SNT must be preferably located at as high an altitude as possible to minimize the atmospheric path length, and near the equator to have a high rigidity cutoff for ions. We have chosen Sierra Negra Volcano in México (19.0°N, 97.3°W), as one of the best possible places to locate a detector. The location fits nicely in a longitudinal gap between the Chacaltaya and Hawaii detectors (see Figure 1). The new SNT is a 4 m^2 array of 40 cm thick plastic scintillators, surrounded in the four lateral and the top sides by gondolas of anti-coincidence proportional counters (PRC).

The SNT can also determine solar neutron spectra based on a signal pulse height discrimination at four different channels corresponding nominally to E > 40 MeV, 80 MeV, 120 MeV and 160 MeV. The basis of the detector design are plastic scintillators where the energy of incoming neutrons is measured in terms of the range of protons produced by interactions with carbon and hydrogen nuclei in the scintillator material. Beneath the array, four layers of PRC are located to determine the arrival direction two for the E-W and another two for the N-S. The directions are determined from the protons produced by neutrons interacting with the scintillator material. To simplify the work required to have proper electronic circuits to correctly measure each channel intensity a Complex Programmable Logic Device (CPLD) was an innovation used in this detector [5]. Above the top anti-coincidence gondola there is a 5 mm. lead plate in which 67% of incoming photons are converted into electron-positron pairs. To reduce background coming from the sides, the PR counters are shielded from any low energy photon background by 10 mm thick iron plates. A schematic diagram of the whole SNT is shown in Figure 2.

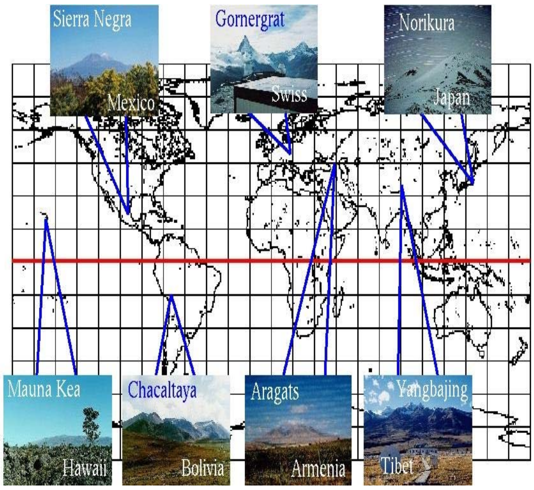

Figure 1. World map showing Solar Neutron Telescope network.

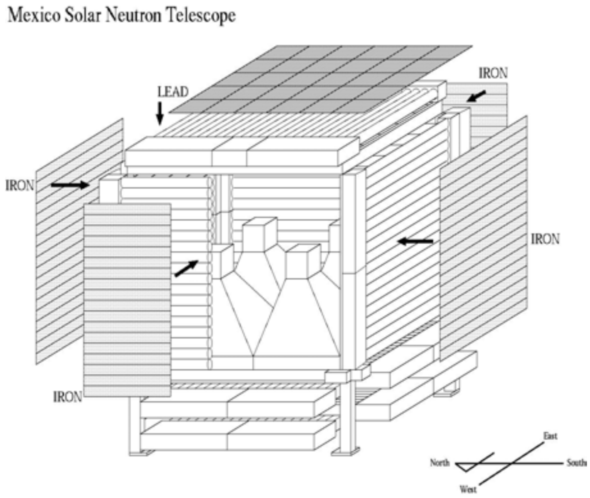

Figure 2. Schematic view of the SNT at Sierra Negra Volcano. Four $1m^2$ scintillators are shielded by anticoincidence system. On the top of the telescope, a 5 cm thick lead plate is installed to convert background photons in e^--e^+ pairs. Below of the scintillator, four layers of PRC array are used to identify the arrival directions of neutrons.

3. Data Analysis

The SNT data are plotted using a special prepare software (SNGraphic) developed in Java language. Figure 3 shows counting rate vs time plots for four selected detection channels: the neutron flux in the lowest energy channel (S1 with anti), the total flux energy channel (S1), the total neutron flux (anti-all), and the flux of intensity in the first channel for muons (mu1). The total time span is one day. Fluctuations are small showing the stability of the detector.

The statistical data analysis shows that the SNT is stable. We use random blocks of three continuous days, since July 2004, of data in the statistical for four channels (S1, S1 with anti, anti-all, and mu1). The average time of the counting rate was 3 min and we use the Anti-All channel data (solar neutrons in all energies). The Figure 4 shows an example of the data distribution for the channel anti-all.

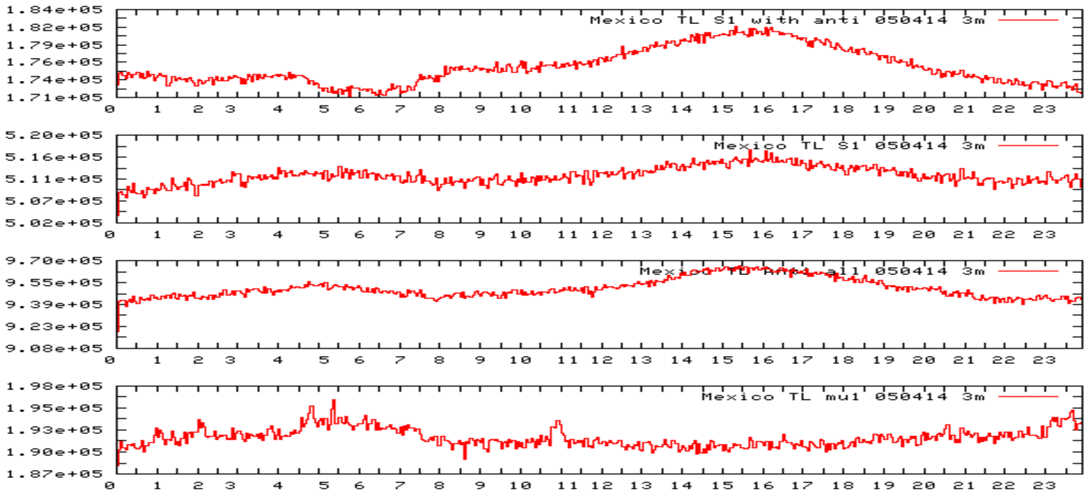

Figure 3. Time intensity profiles for four selected channels (S1, S1 with anti, Anti-All, and mu1) of the Sierra Negra Telescope.

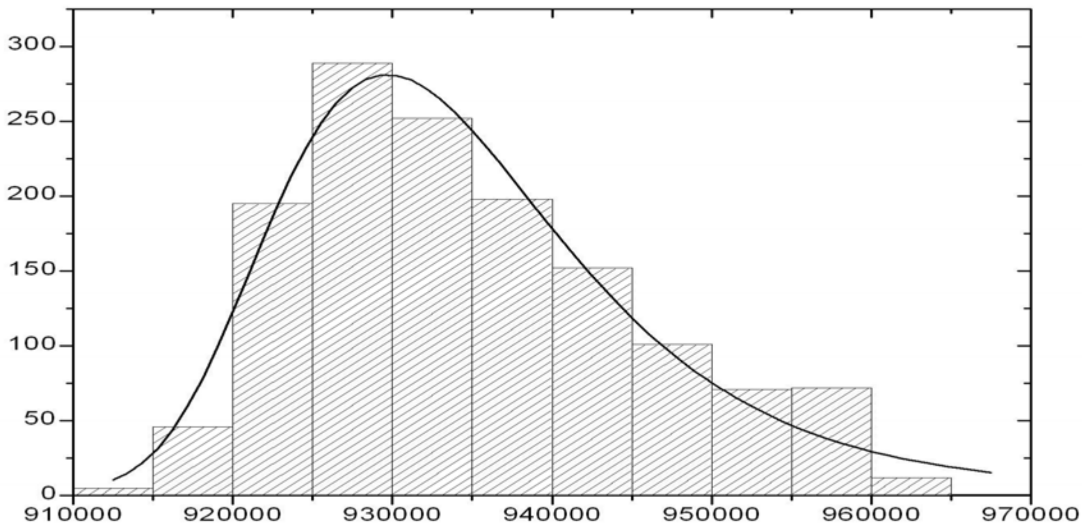

Figure 4. Data distribution for a block of three continuous days (April 17, 18, and 19 of 2005), using the anti-all channel and 3 min average counting rate.

The σ average variation is 0.55%, the average counts are 19850 (counts/min)/m^2, and the $\chi^2 = 0.6$.
In comparison with the SNT at Mount Norikura, the variation of Anti counter is 0.2%. This is not surprising because the SNT at Norikura is eight times larger in area than the SNT at Sierra Negra.

4. Conclusions

The SNT detector was completed and set in continuous operation in July 2005. The counting rate at Sierra Negra Volcano with the anti-coincidence gondola active is 19800 (counts/min)/m^2. This rate appears to be reasonable on the basis of Monte Carlo calculations. The σ variation is 0.55%. This is a very stable condition when we compared with the SNT at Mount Norikura.
Unfortunately, since the SNT in Sierra Negra is fully operative, the location of the neutron-genetic events on the Sun did not occur at hours proper for observation at this site.

5. Acknowledgements

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