

A SOLAR NEUTRON TELESCOPE IN TIBET

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Abstract

A new type of solar neutron telescope was constructed at Yangbajing, Tibet (4300 m) in 1998. The detector consists of 9 m² scintillation counters with 40 cm thickness and four arrays of proportional counters which can identify the direction of solar neutrons. All faces of the scintillator are covered by the anti-counters which are made of proportional counters. Recoil protons which are kicked out by neutrons in the scintillator target are sensed by the scintillators and proportional counters. The minimum proton energy to be detected is about 40 MeV. The telescope has been continuously operating since October 1998. The performance of the telescope is briefly described.

1 Introduction:

The understanding of particle acceleration mechanisms is a fundamental subject in astrophysics. Although various kind of experiments have been so far done to study this subject, the acceleration processes for the high energy cosmic rays are not established with any certainty. The Sun is the nearest site capable of accelerating particles up to high energies. When the Sun becomes active, flares are frequently observed on its surface. Solar flares are the most energetic events occurred on the Sun and they provide us with a unique opportunity for studying the acceleration of charged

particles. The acceleration process can be studied from various emissions of X-rays and γ -rays as well as observations in the radio waveband in which certain phenomena have the clear characteristics of the emission of high energy electrons. Furthermore, some of the most powerful flares are strong source of high energy protons and ions which will be detected soon after the flare as solar particles at the Earth. Among solar cosmic rays, high energy neutrons come straight from the flare position to the Earth without the modulation of the magnetic fields between the Sun and the Earth and provide direct information about the acceleration mechanism of charged particles. High energy neutrons which are observed in the vicinity of the Earth can be created in spallation interactions of high energy helium nuclei with the ambient gas, and these must be created at the same time as the high energy electrons responsible for the hard X-ray and γ -ray emission. Thus, simultaneous observation of neutrons with radio waves, X-rays and γ -rays is crucial to understand where and how solar cosmic rays are accelerated when flares happen at the surface of the Sun.

Nagoya group is constructing a worldwide network of ground based solar neutron telescopes. These are designed to distinguish between incoming neutrons and charged particles and to get information on the neutron energy by measuring the length of the recoil proton track in the detector. Thus, this type of neutron telescope should have a high S/N ratio compared with traditional neutron monitors. Until now, such telescopes were set up at 5 different stations in the world, i.e., Norikura (137.1°E , 2,770 m, Japan) (Muraki et al. 1993 & 1997, Matsubara et al. 1997a), Chacaltaya (292.0°E , 5,200 m, Bolivia) (Matsubara et al. 1997b), Mauna Kea (203.7°E , 4,200 m, Hawaii) (Matsubara et al. 1997c), Gornergrat (7.9°E , 3,250 m, Switzerland) and Aragatz (49.3°E , 3,500 m, Armenia).

The longitudinal coverage of the detector network to watch the Sun for 24 hours will be almost completed by setting up a new telescope in Tibet.

2 Telescope and Performance

A new type of solar neutron telescope was constructed at Yangbajing (4300 m , 90.53°E and 30.11°N) in Tibet in 1998 October.

The atmospheric depth at Yangbajing corresponds to 606 g/cm^2 . The telescope consists of 9 scintillation counters of 1 m^2 each and proportional counters of $10\text{ cm}\phi$ and 3.3 m length each as shown in Fig. 1. The scintillators of 1 m^2 each and 40 cm thickness are arranged as a 3×3 square. Each scintillator equipped with a phototube (HPK R1512) detects the recoil protons converted by incident neutrons in the scintillator. The pulse height obtained by each phototube is discriminated with four levels which roughly correspond to the energy of a recoil proton of 40 MeV (E0, -40 mV), 80 MeV (E1, -80 mV), 120 MeV (E2, -120 mV) and 160 MeV (E3, -160 mV). The counting rate is measured by a CAMAC scaler and recorded every 10 seconds. The top

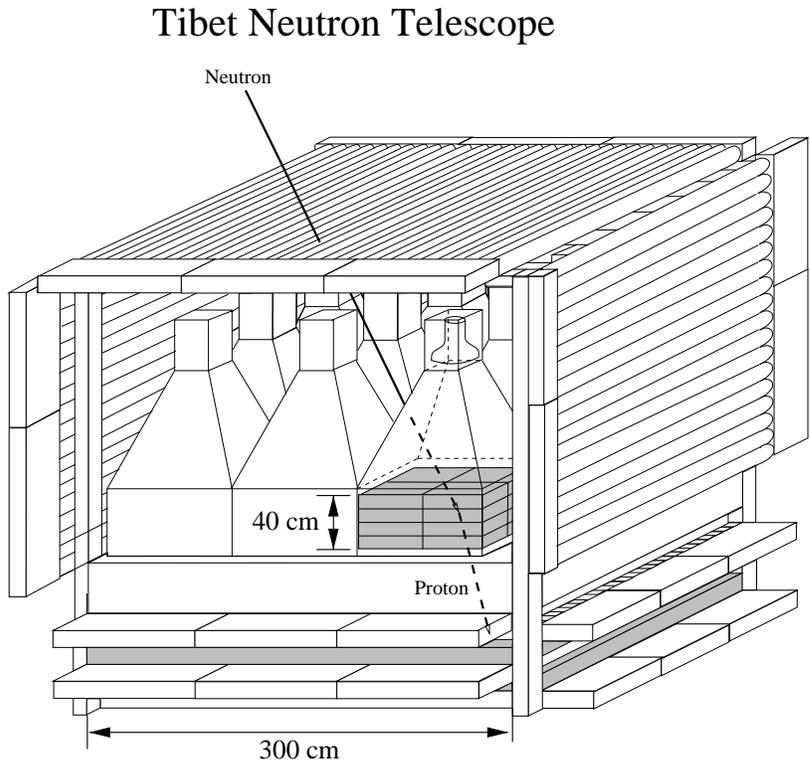


Figure 1: An overview of the Tibet solar neutron telescope.

and four sides of the scintillator array are covered by the proportional counters (anti-counters) which work to veto charged particles.

Below the scintillator array, the four layers of proportional counters are placed to detect high energy neutrons which penetrate the scintillators. The number of proportional counters in each layer is 30. These counters in each layer are aligned lengthwise at right angles with those in adjacent layers with an covering area of $3 \text{ m} \times 3 \text{ m}$. There are two sets of X and Y layer which can be used to determine the direction of recoil protons. Furthermore, two layers of wooden absorber with thickness 10 cm and specific gravity 0.8 are put between the layers of proportional counters as shown in Figure 1. The neutrons with energy higher than about 240 MeV can penetrate two layers of wooden absorber. The proportional counters below the scintillators are aligned lengthwise along east-west (X-direction) and the south-north (Y-direction). Directions of recoil protons are projected on the east-west and south-north plane in five directions each as defined in Figure 2 so that we can make 5×5 different combinations for the directions of recoil protons. The energies of recoil protons are also estimated by measuring the penetration of protons to the lower layers of the proportional counters. The maximum energy of neutrons measured by this telescope is higher than 240 MeV.

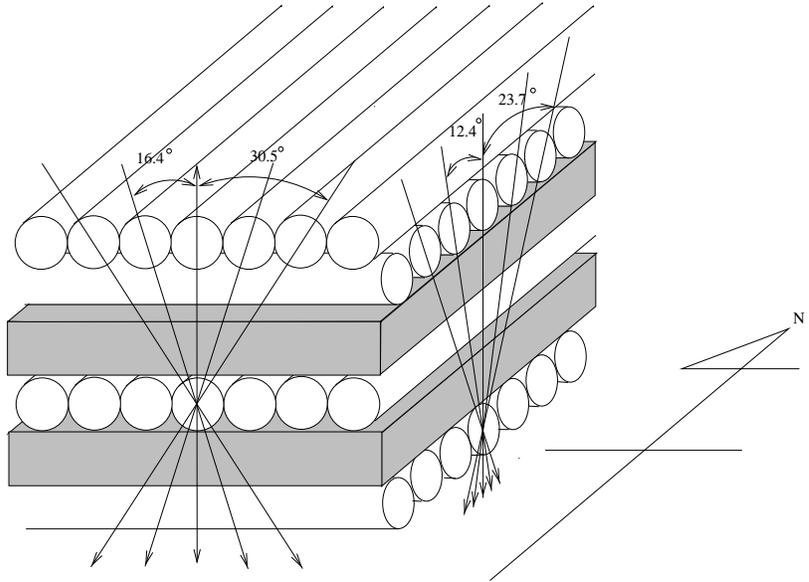


Figure 2: Five directions of recoil protons projected on the X-plane (south-north). Signals from proportional counters of the upper and lower layers are used to determine the directions.

Directions of recoil protons are projected on the east-west and south-north plane in five directions each as defined in Figure 2 so that we can make 5×5 different combinations for the directions of recoil protons. The energies of recoil protons are also estimated by measuring the penetration of protons to the lower layers of the proportional counters. The maximum energy of neutrons measured by this telescope is higher than 240 MeV.

3 Results

The solar neutron telescope has been continuously operating since 1998 October. For the scintillators, the average counting rate for charged particles at each discrimination level is measured to be about $3.4 \times 10^4 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E0), $2.3 \times 10^4 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E1), $1.1 \times 10^4 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E2), $4.9 \times 10^3 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E3). However, the counting rates with the anti-counter system (Veto mode) are reduced to about $8.9 \times 10^3 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E0), $3.9 \times 10^3 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E1), $1.9 \times 10^3 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E2), $9.0 \times 10^2 \text{ m}^{-2} \cdot \text{min}^{-1}$ (E3), respectively as shown in Figure 3. At present, this anti-counter system can not remove γ -rays contained in the background. About 60 % of these γ -

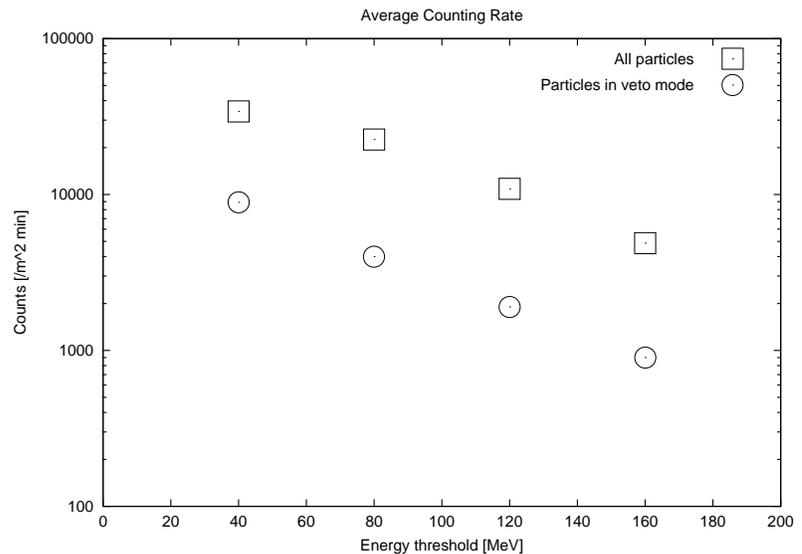


Figure 3: Average counting rates.

rays, however, will be reduced by covering the anti-counter system with the lead plate of 5 mm thickness. This improvement will be done in the near future.

The cosmic ray intensity changes with a variation of the atmospheric pressure. In this experiment, the barometric pressure coefficient for each threshold level was found as $-0.67\ \%/hPa$ (E_0), $-0.47\ \%/hPa$ (E_1), $-0.64\ \%/hPa$ (E_2) and $-0.70\ \%/hPa$ (E_3). The counting rate of the events was corrected by using these coefficients. Figure 4 shows a time variation of the counting rate of the events for each threshold level under the veto mode. The stable operation of our telescope is confirmed from this figure.

Three X-class flares successively occurred on November 22, 23 and 28 in 1998. For each flare, the local time at Yangbajing was near noon, while the Sun was observed at the zenith angle of about 50 degrees.

We then searched for an enhancement of the counting rate in association with these flares. These results are reported in the paper of this Conference (Hoshida et al., 1999).

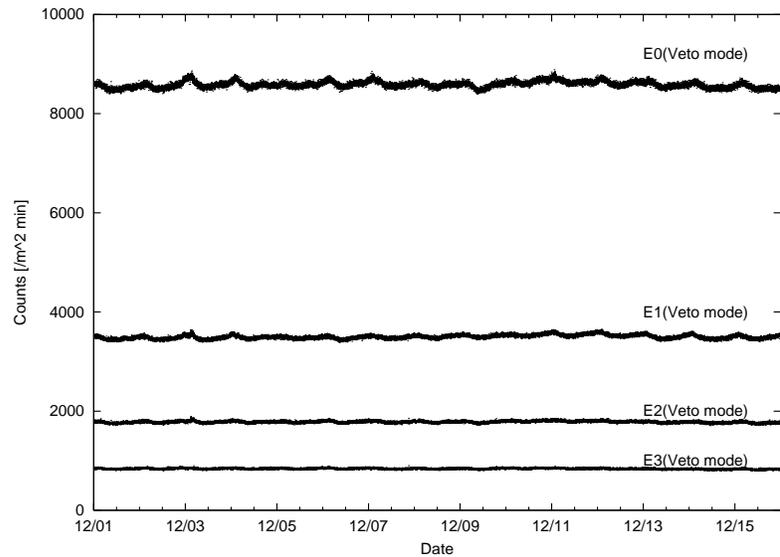


Figure 4: Time variation of counting rate for each level of E_0 , E_1 , E_2 and E_3 under the veto mode. Data are plotted between December 1st and December 15th in 1998.

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