Measurement of cosmic ray neutron flux at points with various altitudes and longitudes

Ryozo Takasu*, **Yoshiharu Tosaka**†, **Hideya Matsuyama**†, **Hideo Ehara**†, **Yuji Kataoka***, **Atsushi Kawai**‡, **Masahiko Hayashi**‡ **and Yasushi Muraki**§

**Fujitsu Laboratories Ltd. 10-1 Morinosato-Wakamiya, Atsugi, 243-0197 Japan*
†Fujitsu Microelectronics Ltd. Japan
‡Subaru Telescope, National Astronomical Observatory of Japan
§Department of Physics, Konan University, Japan

***Abstract*. In relation to estimating soft error rate in computer systems, neutron spectra in the energy range of 1 - 1000 MeV are measured at points with various altitudes and longitudes mainly by means of Bonner multisphere spectrometer. The neutron flux measured at the top of the Mt. Mauna Kea is 20 times larger than that in Tokyo. This increase in neutron flux will strongly affect the soft error rate. We will also demonstrate a preliminary result on a spectrometer with plastic scintillators.**

***Keywords*: soft error, neutron, spectrometer**

I. Introduction

In recent days, the information on the flux and energy spectrum of cosmic ray neutrons has become quite important for the computer technology. Since the reduction of LSI (large scale integrated circuit) scaling proceeds, the effect of cosmic ray neutrons predicted to become significant. Neutrons hit the LSI of the computer and make pseudo-signals and false data. This phenomenon is known as soft error of the computer. The soft error is defined as a single event upset (data error) in a memory cell that can be correctly rewritten. The error is ”soft” because the circuit itself is not permanently damaged and behaves normally after the data state has been restored.

The soft error may cause incorrect operation of the computer system, and in the worst case, the computer system will be stopped. Therefore, the soft error may cause severe situation especially in mission critical application. Many efforts have been made to reduce soft error rate. The cause of soft error is α-particle, thermal neutron, and fast neutron. In the latest semiconductor technologies, influence of α-particle and thermal neutron is fairly reduced by using material technology. However, the influence of fast neutron still remains. Therefore we focus on fast neutron. For evaluating the reliability of computer systems, the accurate estimation of the soft error rate has become essential. In this purpose, the accurate measurement of the cosmic ray neutron spectrum in the energy range up to several hundreds of MeV has been anticipated.

In this study, we report the energy spectra of neutron in the energy range of 1 to 1000 MeV at various altitudes including the summit of Mt. Mauna Kea (Subaru Telescope, 4200 m) and Tokyo (Japan, 100 m). Reason for measuring at Mauna Kea is wide elevation span.

Fig. 1: The Bonner multisphere neutron spectrometer set in front of the Subaru Telescope on the top of the Mt. Mauna Kea.

In addition to the spectrum above, we will show preliminary results on a newly constructed plastic scintillator spectrometer.

II. Experimental

A. Bonner Spectrometer

The neutron spectra are measured by Bonner multisphere spectrometer. We used ^{3}He detectors with polyethylene moderator thickness of 30, 50, 90, 200 mm. On the basis of the counting rate data of each detector, we got the energy spectrum by unfolding with code ”UMG 3.3”. The spectrometer was set in the building of Subaru Telescope located on the top of Mt. Mauna Kea (altitude 4200 m). The measurement had been done from Oct.2007 to Sep.2008. In advance to the measurement in the building, we also measured in the open air area in front of the Subaru Telescope as shown in Figure 1.

The measurement is also done in Tokyo (Japan, 100 m altitude) by using the same spectrometer used at Mt. Mauna Kea. Therefore, relative precision is kept between these measurements.

B. Scintillator Spectrometer

The Bonner multisphere spectrometer is widely used, but its energy resolution is quite limited. In this reason, we are trying to construct the spectrometer with plastic scintillator. We use the plastic scintillator with thickness

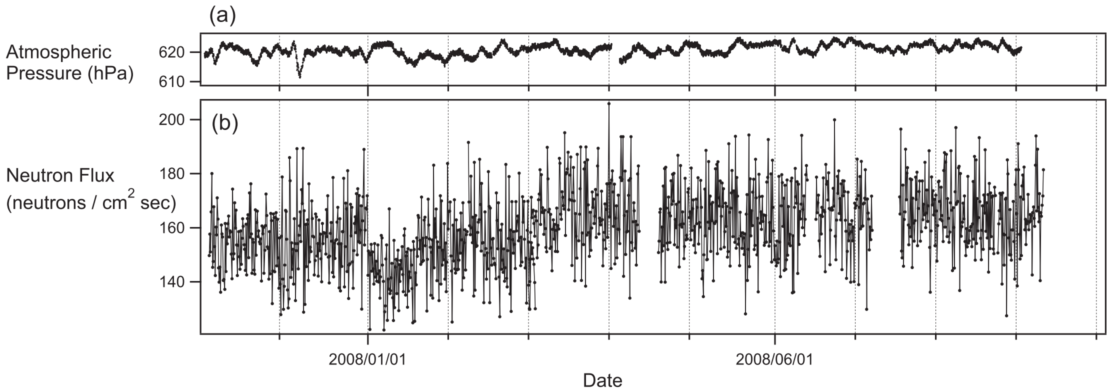

Fig. 2: Time dependence of the neutron flux measured in the building of Subaru Telescope. The flux is integrated from 8 to 1000 MeV. In trace (a), atmospheric pressure is also plotted.

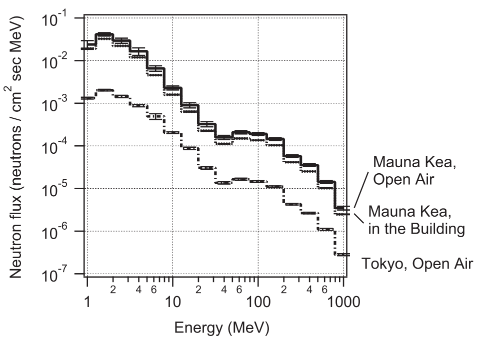

Fig. 3: Neutron energy spectra measured by Bonner multisphere spectrometer measured at the open air area and in the building of Subaru Telescope, and open air area of Tokyo.

of 10 cm for main detector. The main detector is surrounded with the plastic scintillators with thickness of 1 or 2 cm for veto signals. Anti-coincidence signal between these detectors will give the neutron signal.

III. Results and Discussion

In Figure 2(b), the neutron flux integrated from 1 to 1000 MeV is plotted as a function of time. In the time span of 11 months, the flux is nearly constant, but small fluctuation is observed. In Figure 2(a), atmospheric pressure is also plotted. As seen in the figure, there is a weak relationship between atmospheric pressure and neutron flux. This may because of the shielding effect of the air.

In Figure 3, the energy spectra of neutron measured at open air area and in the building of Subaru Telescope, and open air area in Tokyo. The whole shapes of the spectra are resembling each other, but fluxes are quite different. The flux at open air area of Subaru Telescope is 20 times higher than that of Tokyo. This value is consistent with the calculated elevation effect of 18.1 from the proposed altitude effect and the NASA-Langley

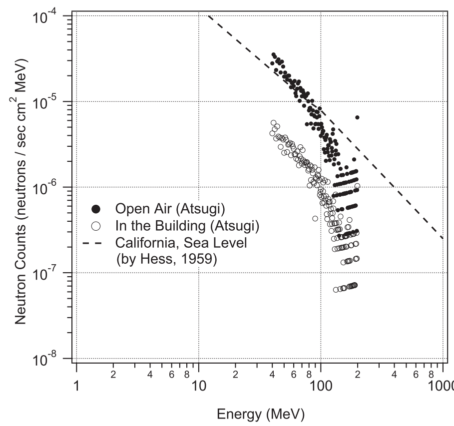

Fig. 4: Neutron energy spectra preliminary measured by scintillator spectrometer at Atsugi (Japan). Solid circles and open circles are measured at open air area and in the building, respectively. Dotted line indicates the spectrum reported by Hess et al. (1959) [1]

equation.

In the building, the flux decreases by a factor of 0.5 as a result of shielding.

In Figure 4, the preliminary spectra taken by scintillator spectrometer are shown. Solid circles depict the spectrum taken at open air area at Atsugi (Japan). Open circles are taken in the building. The ratio outside/inside of the building is large as 6, it may because the building is made of dense concrete. In addition to the spectra above, the spectrum taken by Hess *et al*. is also indicated by dotted line. There is some discrepancy between these spectra. Thus, incident angle compensation and determination of detection efficiency is now underway.

The relationship between the neutron spectra and soft error rate will be reported in a separate paper.

References

[1] W. N. Hess, H. W. Patterson, R. Wallace. and E. L. Chupp, *Phys. Rev.*, 116, 445 (1959).