Calibration of Neutron Monitor using Accelerator Neutron Beam

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Abstract

The detection efficiency of a neutron monitor was first investigated by the accelerator neutron beam at Research Center of Nuclear Physics of Osaka University. Neutrons which were made by Li(p,n)Be interactions were irradiated into one set of the NM64 neutron monitor, and the detection efficiency of the neutron monitor was obtained. The detection efficiency of the neutron monitor turns out to 20% at <84MeV> and 24% at <168MeV> and 30% at <253MeV> respectively.

1 Introduction

Fifty years have passed since neutron monitor was invented (Simpson,1948). Now neutron monitors are widely used in cosmic ray experiments, especially for obtaining the standard cosmic ray flux. The accumulated data for fifty years are now regarded as a very important treasure of science. For example, they involve the information how the solar activity varies for a long time (Ahluwalia,1994). The data set of neutron monitors are provided by either on-line (Pyle,1999),or by the CD-ROM from the World Data Center C2 (Watanabe,1999).

However, the detection efficiency of the neutron monitor was never checked by the experiment and only it was estimated by a simulation (Hatton,1971). Recently a new Monte Carlo calculation was done (Clem,1999). It was surprising to know that both results coincide well each other. In this paper, we present the detection efficiency of the neutron monitor which was obtained by the accelerator beam at RCNP.

2 Experimental Procedure

We extended bombarding neutrons into the neutron monitor since 1996. Some of experimental results were already reported (Muraki et al.,1998;Shibata et al.,1997). The measurement of the detection efficiency of the neutron monitor has a difficulty in comparison with scintillator based neutron detectors (Muraki et al.,1998). Since the neutron monitor was made by proportional counter (BF_3 counter), it was impossible to use the time of flight technique. This difficulty can be avoided if we use the deuterium target, but in our experiment we must use a thin lithium target.

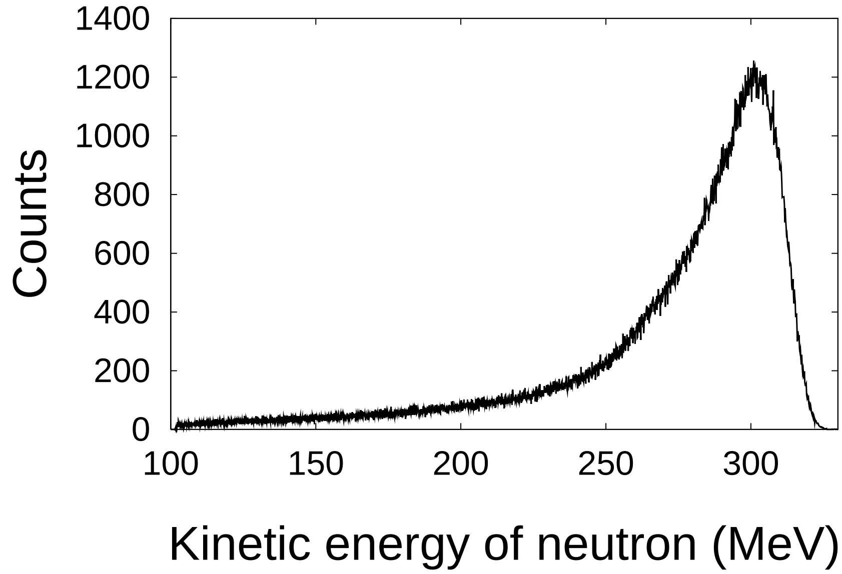

Figure 1: Energy distribution of neutrons produced by Li(p,n)Be reaction at incident protons with 300MeV.

Neutrons are produced by Li(p,n)Be reactions. In case an accelerator proton hits a peripheral neutron in the lithium nucleus, the neutron ejected by the charge exchange process keeps the primary proton energy. However in case protons collide with central necleons inside the lithium nucleus, neutrons are produced without keeping the initial energy of protons. Neutrons are produced in a wide band of energy. A typical shape of the energy spectrum of neutrons produced by the Li(p,n)Be reaction is shown in Fig. 1. The spectrum was obtained by the T.O.F. technique experimentally, using thick plastic scintillators. The ratio between the peak area and the slope area is about 1:1.

The detector consists of 2.3m BF_3 counter which was surrounded by the lead plates with thickness 6cm and polyethylene with thickness 7.5cm. We used a quarter of 4-NM-64 of Fukushima university for this purpose. The general view of present neutron monitor is shown in Fig. 2. The neutron monitor was located at 63m away from the target (Fig.3).

3 Results

The detection efficiency of the neutron monitor is reduced by the following way. The results are given in Fig. 4. First, the counting rate of the neutron monitor was divided by the incoming neutron flux. The beam intensity of the forward direction was estimated by the former experimental result at the same beam line (Muraki,1998). The differential intensity at $\theta = 0$ degree at the CMS was nearly constant in the energy range between 100 and 400MeV and it was 27mb/sr (Taddeucci et al.,1990).

However the neutron monitor cannot discriminate the incident energy of incoming neutrons and we must use the "mean neutron energy", instead of a fixed energy. We assumed the energy spectrum for neutron induced by Li(p,n)Be reaction as the curve expressed in Fig. 1. The white box corresponds to before correction (proton accelerated energy) and black box represents after correction($<$average neutron energy$>$).

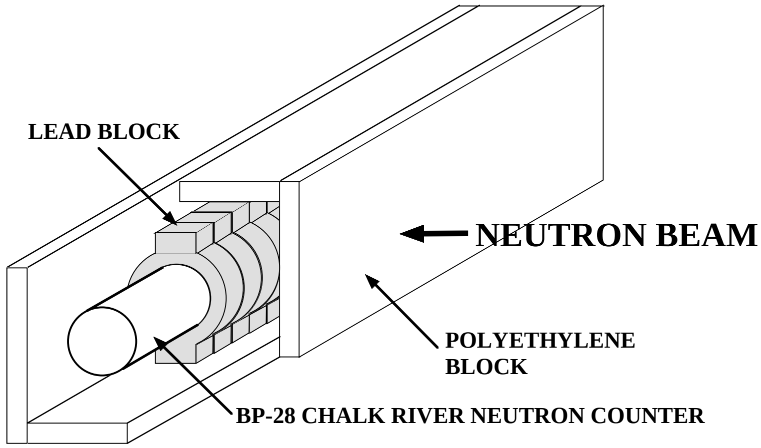

Figure 2: Schematic view of the neutron monitor which we used at the experiment.

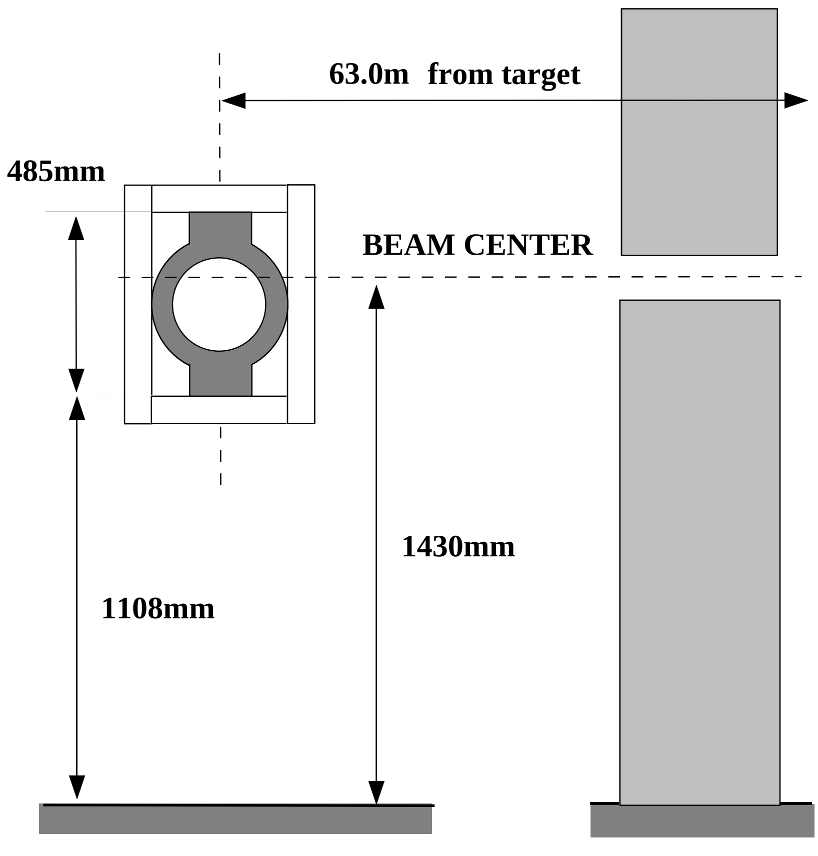

Figure 3: Arrangement of experiment (not in scale). Neutorn monitor was located at 63m away from the Li target.

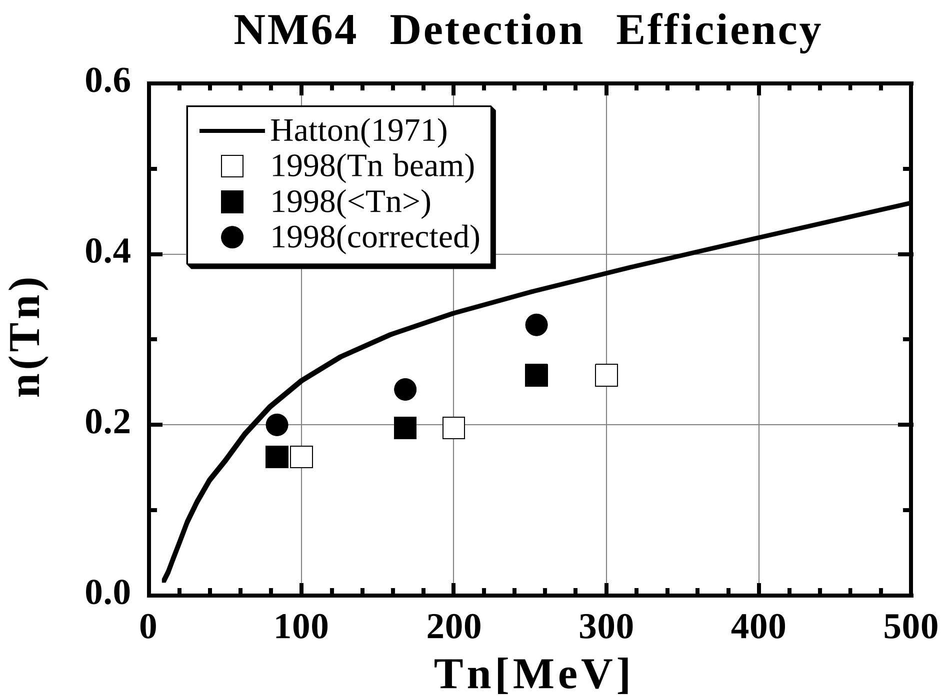

Figure 4: The detection efficiency (vertical axis) of the neutron monitor is shown as a function of the neutron energy.

Those values are further multiplied by a factor 1.23. We used only single BF3 counter in the beam experiment. However,in actual neutron monitor, many tubes are used. The tube located at the corner of the NM64 usually counts less cosmic rays. The value turns out 1.23 times less than the central tubes. Finally we have corrected this effect. Then the detection efficiency of the neutron monitor is obtained. The values are given in Fig. 4 by the black circles. Each number becomes 20% at average neutron energy <84 MeV>, 24% at <168 MeV> , and 30% at <253 MeV> respectively.

References

Ahluwalia, H.S., 1994, J. Geophy. Res. 99,11561.

Clem, J., 1999, Proc. ISSI workshop (Bern, March 1999) to be published.

Hatton, C.J., 1971, Progress in Elemantary Particles and Cosmic Ray Physics,Vol X.

Muraki, Y. et al. , 1998, Nuclear Physics(Proc. Suppl.) 60B,3.

Pyle, R., 1999, Proc. ISSI workshop ”Cosmic Rays and Earth” (Bern, March 1999) to be published.

Shibata, S. et al., 1997, Proc. 25th ICRC (Durban,1997) 1,45.

Simpson, J., 1948 Phys Rev. 73,1389.

Taddeucci, T.N. et al., 1990, Phys. Rev. C41, 2548.

Watanabe, T., 1999, Proc. ISSI workshop(Bern, March 1999) to be published.