Fabrication and Performance Test of the Cosmic Charged Particle Detector with Plastic Scintillator and WLS

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1. Introduction

In order to study the cosmic rays at different altitude and latitude in Korea, Basic Atomic Energy Research Institute (BAERI) has been constructing the detection facility of charged and neutral particles at the atmosphere. The measured cosmic rays should be precisely interpreted for the cosmic ray distinction from the environmental radiations.

The whole system consists of the neutron monitors, the charged particle detectors and signal process system. The prototype detector for the charged particle was fabricated and its detection efficiency, noise level, energy spectrum has been measured by using the cosmic rays.

The descriptions of the scintillator, PMT, WLS, fabrication method and experimental setup are presented the following.

2. Experimental Setups and Results

To measure the charged particle, the plastic scintillator and wavelength shifter (WLS) are used. The plastic scintillation detector shows a good efficiency, with the consequence that the multi-anode photo multiplier tube (PMT) is suitable for both to covering large detection area and low construction costs. The WLS transfers the photons from the scintillator to the multi-anode PMT.

2.1 Materials and Fabrication Method

The plastic scintillator is BC-408 produced by Saint-Gobain and its dimension is 1000 * 200 * 10 mm^3. In order to measure the muon higher than 1 MeV, the required thickness is about 10 mm. The BCF-91 WLS produced by Saint-Gobain is used as light guide. The absorption wavelength of WLS is same as the emission wavelength of the BC-408 scintillator [1]. H8711 (multi-anode PMT) produced by Hamamatsu is used for the prototype, respectively.

The polymethyl methacrylate (PMMA) is used for light-guide of the reference detectors instead of the WLS of prototype detector. The scintillator is wrapped by an aluminum foils to reflect the light, and the detector included PMT is wrapped by the black sheets, Teflon tape, and black tape to prevent a light leakage from inside and entering a light from outside.

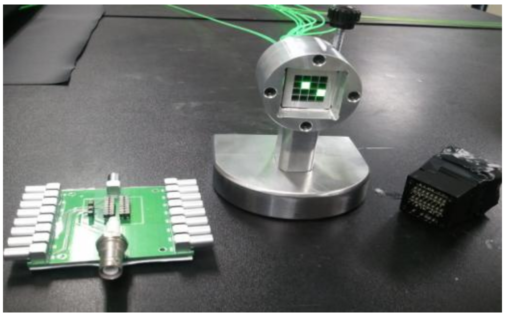

Fig. 1. Picture of the PCB circuit (left), the WLS guide and holder (center), and the multi-anode PMT (right).

2.2 Experimental Setup and Conceptual Logic

The experimental setup for the detection efficiency in fig. 2 is shown. The signals from prototype (D) and reference detectors (D1 and D2) are processed through coincidence method. The prototype detector at the middle of the reference detectors is located vertically.

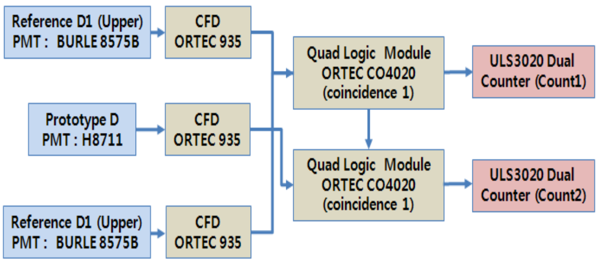

Fig. 2. Experimental setup for the detection efficiency.

For H8711 multi-anode PMT, ratio of counts 2 to counts 1 is detection efficiency. For H7415 instead of H8711, same process is performed. The availability of H8711 for charged particle detector is determined by comparison with efficiency of H7415.

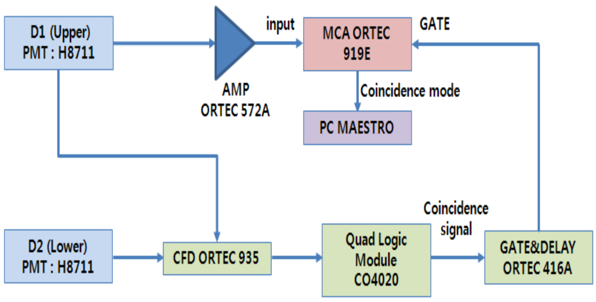

Fig. 3. Experimental setup for noise/threshold test.

The coincidence signals of D1 and D2 by Quad Logic Module CO4020 are considered as certain charged particles. The coincidence signals are entered into Multi Channel Analyzer (MCA) through GATE. Single signals are processed as response spectrum by coincidence mode of MCA.

The each channel of multi-anode PMT can be affected by the signal of fired channel. Here, the cross-talk level (%) defines the response ratio between unfired and fired channels by the cosmic rays. For the cross-talk check, total hits of fired and unfired channels are counted. The relation between fired and unfired channels is studied with dependence on the distance.

2.3 Results and Discussion

For the detection efficiency, the WLS of D is proper to using for the charged particle detection as PMMA light guide of D1 and D2. The detection efficiency of D is about 95% for operational plateau region [2]. The reason of imperfect efficiency is considered as one from somewhat unstable junction condition. Availability of H8711 multi-anode PMT is determined by comparison with detection efficiency of H7415.

ch 4	3.25	1.38	2.21	2.15	ch 1
ch 8	4.66	2.76	100	2.32	ch 5
ch 12	0.85	0.58	1.83	0.45	ch 9
ch 16	0.61	0.2	0.26	0.24	ch 13

ch 4	0.43	0.13	0.25	0.32	ch 1
ch 8	0.59	1.13	0.17	0.34	ch 5
ch 12	2.46	0.48	0.58	0.56	ch 9
ch 16	100	1.74	0.96	4.05	ch 13

Fig. 4. Cross-talk level (%) against to the reference channels (ch.6 on the top and ch.16 on the bottom).

For the cross-talk, ch.16 and ch.6 are selected as reference. The cross-talk level is smaller as distant from the reference one, generally. But the tendency is not much clear. The maximum cross-talk is about 5 %.

Fig. 5 shows the response spectrum. The response spectrum from Maestro is similar to reference response spectrum [3, 4]. The threshold/noise level is determined by relation of channels and signal scale. MCA input signal range is from 0 to 10 V and channels are 1024. The noise level is supposed to be 700 mV after ORTEC 572A amplifier. Prior to amplifier, noise level to be determined is a few mV. The noise level could not be determined clearly in that step.

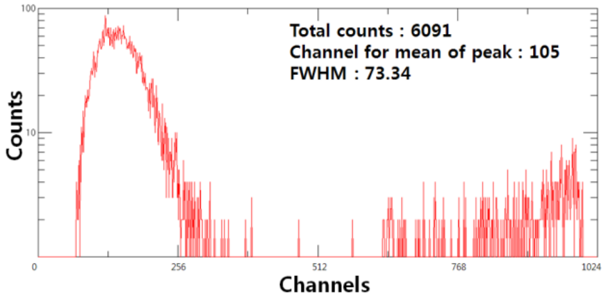

Fig. 5. Response spectrum of detector with cosmic charged particles by coincidence method.

3. Conclusions

The performance of fabricated prototypes is capable for the cosmic muon detection. The detection efficiency of D with multi-anode PMT is comparable to single PMT. It can be used as the charged particle detector sufficiently.

The imperfect detection efficiency and the cross-talk problems are caused by unstable junction of PMT and light guide, connection condition of PMT and PCB circuit.

The determined noise/threshold level will be applied to precise data acquisition. Data will be collected by adding device as the Single Channel Analyzer (SCA) for threshold set.

For the next research, a reduction of the cross-talk, approach to perfect detection efficiency and precise data collection will be performed. This plastic scintillation detector for the charged particle will be maximized to investigate the cosmic rays at the atmosphere.

REFERENCES

[1] A. Artikov, et al, Design and construction of new central and forward muon counters for CDF II, Nuclear Instruments and Methods in Physics Research, Vol. 538, p.358-371, 2005.

[2] J.S.KANG, et al, Fabrication of the charged particle detector with plastic scintillator and optical fiber, Proceedings of Autumn Conference Korean Association for Radiation Protection, Nov.24-26, 2010, Jeju, Korea,

[3] M. Robinson, et al, Measurements of muon flux at 1070 vertical depth in the Boulby underground laboratory, Nuclear Instruments and Methods In Physics Research, Vol. 511, p.347-353, 2003.

[4] N.V. Ampilogov, et al, Scintillation detector with fiber-optical readout, The Russian Academy of Sciences : Physics, Vol. 73, p. 637-639, 2009