Performance of 64-multi-anode photomultiplier and scintillating fiber for the CALET detector

Taro Yamashita, Shoji Torii, Tadahisa Tamura and Kazuaki Anraku
for the CALET collaboration
Institute of Physics, Kanagawa University, Yokohama, 221-8686, Japan

Abstract

We report results of a performance test of a 64-multi-anode photomultiplier (MA-PMT) and scintillating fibers (SF) to be used for the imaging calorimeter of the CALET detector. The required dynamic range of the calorimeter is a few thousand, from a minimum ionizing particle to large number of particles created by a cascade shower. MA-PMT (HAMAMATSU R5900) with 8 dynode stages, instead of original 12 dynode stages, is manufactured to extend the dynamic range. Results of the linearity tests and the light yield measurements are presented.

1. Introduction

The R&D of the CALET (CALorimetric Electron Telescope) instrument is now being carried out for the observation of high-energy cosmic-ray electrons and gamma ray up to 10 TeV at the Japanese Experiment Module on the International Space Station [4]. The CALET detector consists of an imaging calorimeter (IMC) and a total absorption calorimeter. In the current design, the IMC consists of 17 layers of lead plates and scintillating fibers (SF), with the SF placed from 0 to 4 radiation length from the top surface. The length of a fiber is 1000 mm, with the cross section of 1 mm×1 mm. The total number of SF is about 40,000. The IMC is used to determine the axis of a cascade shower, and to identify the species of incoming particles.

It is planned to employ a 64-multi-anode PMT (MA-PMT) and an ASIC for the read-out of the SF. A Viking chip [2] supplied by IDEAS has suitable performance for the ASIC, having the dynamic range up to 15 pC [3]. The PMT needs to be used at the gain of $\sim 5\times10^3$ - 1×10^4, in order to match the dynamic range of the chip. Since the target gain is much lower than the typical gain of the standard PMT, we have developed a PMT with reduced number of dynodes from 12 to 8. The gain is decreased by nearly a factor of 10 by this modification. As a result, the output charge is adjusted to the dynamic range of the chip. We report on the linearity measurement of the MA-PMT with 8 dynode stages comparing to the conventional 12 dynodes MA-PMT. We have also derived the number of

pp. 2193–2196

photo-electrons for a minimum ionizing particle (MIP) to evaluate the detection efficiency of a charged particle. The result is important for distinguishing an electron from a gamma ray by finding a incident track in top SF layers.

2. Measurement of the linearity of the MA-PMT

We have used a blue LED driven by 1 kHz pulses with a width of 20 nsec as already reported for the measurement of 16 anodes PMT [1]. The setup is illustrated in Fig 1. All anodes are exposed to the LED light and the amount of light is controlled by ND filters within an accuracy of a few %. The measurements are performed at the PMT high voltage (HV) of 550 V and 650 V where the PMT gains are 4.6×10^3 and 1.5×10^4, respectively. Figure 2 shows the deviation from linearity as a function of the output charge in one channel of 64 anodes. If we allow the deviation within 20 %, the linearity is kept up to 35 pC and 60 pC at 550 V and 650 V, respectively.

Since the real width of signal pulse from SF is about 6 nsec, we estimated the linearity in real signal is 11 pC and 20 pC for each voltage by dividing a factor of 20/6. As the photo-electron number for 1 MIP is 5.8 as presented below, linearity is expected to be up to 2.5×10^3 MIP and 1.3×10^3 MIP for 550 V and 650 V, respectively.

In Fig. 3, the linearity of the MA-PMT with 8 dynode stages is compared with that of 12 dynode stages. The gain of the MA-PMT with 12 dynode stages is set as same as that of 8 dynode stages. It is confirmed that the linearity in 8 dynode stages is significantly better than that in 12 dynode stages.

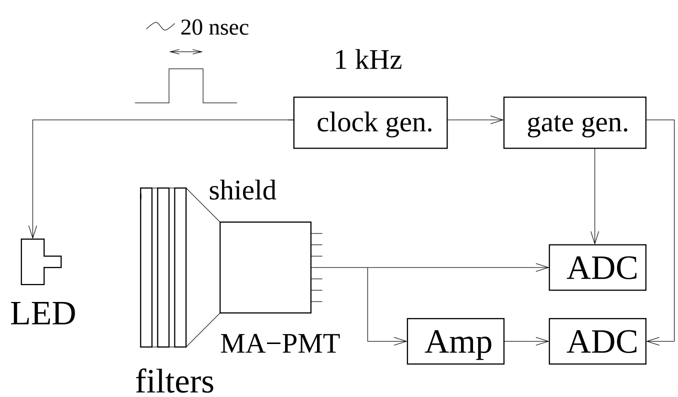

Fig. 1. Setup of the measurement

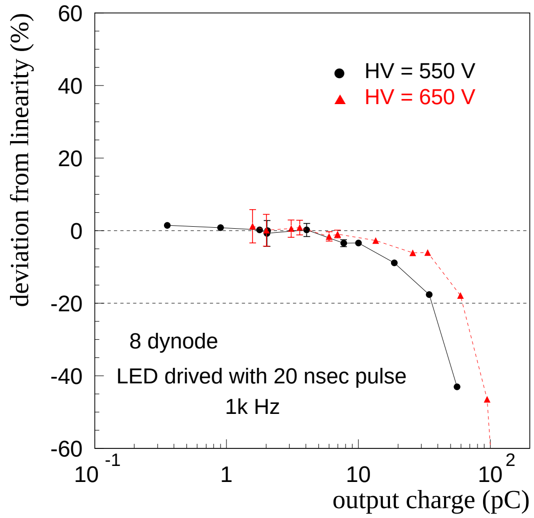

Fig. 2. Deviation from linearity as a function of the output charge, in one channel of MA-PMT with 8 dynode stages, at the HV of 550 V (circle) and 650 V (triangle).

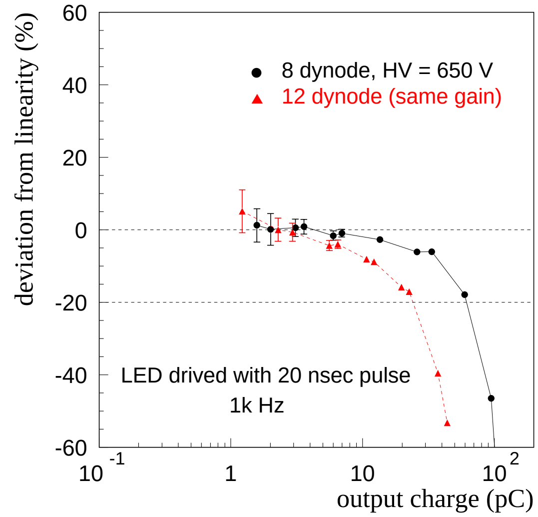

Fig. 3. Deviation from linearity as a function of the output charge, in one channel of MA-PMT with 8 dynode stages (circle) with the HV of 650 V and MA-PMT with 12 dynode stages (triangle) at the same gain.

3. Light yield of the SF with the MA-PMT

The β-ray source (^{90}Sr) is used to estimate the amount of light collected by the MA-PMT when MIP particle traverses through the SF with 1 mm thickness. We use KURARAY SCSF38 SF with the cross section of 1 mm$\times$1 mm. One end of each fiber is attached to each channel of the R5900 MA-PMT. Figure 4 shows the ADC-count distribution of the output charge of one channel when the β ray hits the corresponding SF at the position 25 cm away from the PMT. The peak corresponds to 6.5 photo-electrons. Using simulation, it is estimated that the energy deposit to the SF by the β ray is 1.12 times larger than that by MIP. Therefore, the obtained number of photo-electron corresponds to 5.8 photo-electrons. Assuming that the produced number of photo-electrons follows Poisson distribution, the detection probability of one MIP by one fiber is 92.8 % with the threshold of 0.5 MIP. The result makes it possible to estimate the detection efficiency of electron and gamma ray accurately.

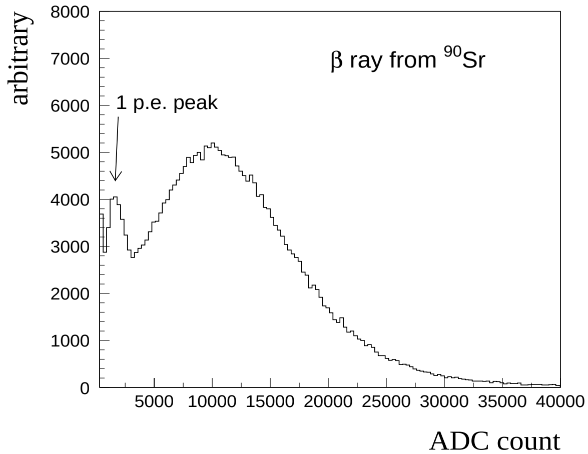

Fig. 4. ADC-count distribution of one MA-PMT channel, when β ray from ^{90}Sr hits to the attached fiber. The peak at $\sim$1500 corresponds to one photo-electron.

4. Conclusions

The linearity of 64-multi-anode PMT with 8 dynode stages is measured using LED. For the LED light driven by a pulse of 20 nsec width, the MA-PMT is linear within 20 % up to 35 pC and 60 pC at the HV of 550 V and 650 V, respectively. The result shows that the MA-PMT has attained the required dynamic range of a few thousand for the readout of SF. The MA-PMT with 8 dynode stages has significantly better linearity performance than that with 12 dynode stages at the same gain. The light yield of SF of 1 mm thickness observed with the MA-PMT is 5.8 photo-electron for the energy deposit by one MIP.

Acknowledgments

This study is carried out as a part of "Ground-based Research Announcement for Space Utilization" promoted by Japan Space Forum.

References

1. F. Cadoux *et al.,* Nucl. Phys. B (Proc. Suppl.) 113, 159-165 (2002)
2. E. Nygard *et al.,* Nucl. Instr. and Meth., A 301, 506-516 (1991)
3. T. Tamura *et al.,* in this volume
4. S. Torii *et al.,* Proc. 26th International Cosmic Ray Conference (Utah), Vol.5, 100-103 (1999b)