Bull. Inst. Chem. Res., Kyoto Univ., Vol. 70, No. 1, 1992

Dependence of Pulse Heights on the Incident Position of Alpha–Particles for CsI(Tl) Scintillator with Photodiode Readout System

Shigeru KAKIGI*, Kiyoji FUKUNAGA*†, Toshiharu HAYASHI*,
Akira OKIHANA**, Takehiko KONISHI**, and Tsuguhisa SEKIOKA***

Received February 7, 1992

For CsI(Tl) scintillator coupled to photodiodes, dependence of pulse heights on the incident position of alpha–particles was investigated using a single or two photodiodes attached directly to the crystal surfaces and using a photodiode separated from the crystal with a light guide. For the last case, an uniformity in the pulse height against the change in the incident position was obtained, although the pulse height decreased.

KEY WORDS : CsI(Tl) scintillator/Photodiode readout

1. INTRODUCTION

For light charged particles of medium energy, a full energy detector should consist of thick materials. A considerable number of the particles penetrating the detector undergo nuclear reactions and corresponding pulse heights from the detector are small compared with those of full–energy loss.[1,2,3,4] Thus it is necessary to identify an event of some energy loss as due to a particle of corresponding energy or due to a higher energy particle undergoing nuclear reaction. One of methods to solve this problem is to divide the detector material into a number of laminae (stacked detector) and to record energy loss in each one.[5,6,7] The ΔE–E technique can be used for the event identification.

Scintillator CsI(Tl) coupled to photodiode readout systems is adequate to constituents of the stacked detector. CsI(Tl) crystal is easily handled because of slightly hygroscopic nature and photodiodes are suitable for a compact design of the stacked detector.[8,9] For a cubical crystal, if charged particles penetrate it from the front surface to the rear one, scintillation light produced along particle tracks can be collected by photodiodes attached to the side surfaces. Pulse heights from one of the photodiodes may be dependent on the incident position of particles on the front surface because light absorption cannot be neglected. If four photodiodes attached to four side surfaces respectively are coupled with each other, the position

* 柿木　茂, 福永清二, 林　俊治 : Institute for Chemical Research, Kyoto University, Uji Kyoto 611
** 沖花　彰, 小西毅彦 : Kyoto University of Education, Kyoto 612
*** 関岡嗣久 : Himeji Institute of Technology, Himeji 671–22
† Present address ; Yamagata University, Yamagata 990

dependence of the pulse height can be lessened. However, it is desirable economically to reduce the number of photodiodes. We have investigated the dependence of the pulse height on the incident position of alpha-particles using a single or two photodiodes and using a photodiode with a light guide.

2. EXPERIMENT AND RESULTS

A $20\times20\times20$ mm^3 CsI(Tl) crystal was used. Coordinate axes are defined as shown in Fig. 1 with a scale in units of mm. Two surfaces (top and bottom) were polished to which two photodiodes (Hamamatsu) were attached respectively with optical cement. The photodiode had a 10×10 mm^2 photosensitive area. Other four surfaces were roughly sanded. Alpha-particles were incident on the crystal through the front surface. The crystal with the photodiodes was contained in an aluminum box having an entrance window of a 2 μm aluminum foil with an air gap of 1 mm to the crystal surface. Alpha-particles from an ^{241}Am source were collimated with a 10 mm thick aluminum plate with a hole 3 mm in diameter set in front of the detector. The alpha-particles passed a 13 mm air gap befor reaching the 2 mm aluminum window foil followed by the 1 mm air gap. Thus 5.486 MeV alpha-particles from ^{241}Am source had the diminished energy of about 3.7 MeV as they reached the crystal surface. The range of these alpha-particles in CsI(Tl) crystal is very short and the scintillations were produced only inside a thin layer under the front surface.

The photodiode was operated at a reverse bias of 24 V and the output signals were fed into a preamplifier (Kokendenshi KPA121A) followed by a linear amplifier with a shaping time of 6 μs. Fig. 2 shows a pulse height spectrum of alpha-particles for the incident position at the center (x=y=0). The straight line in the figure represents the relation between the pulse height and the γ-ray energy measured with ^{60}Co and ^{137}Cs sources. The peak appears

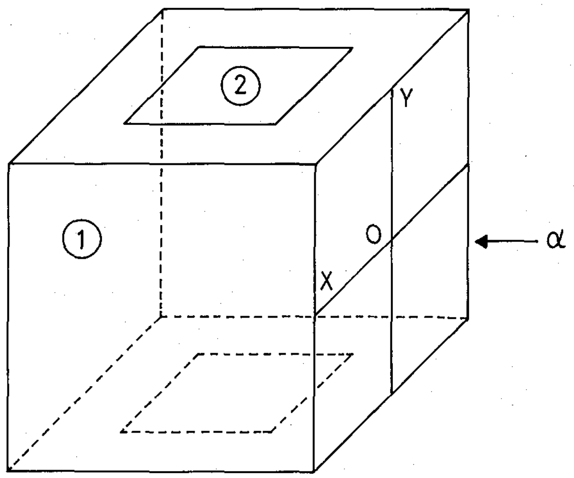

Fig. 1. Crystal surfaces coupled to two photodiodes. CsI(Tl) crystal (1) has a dimension of $20\times20\times20$ mm^3 and the photosensitive surface of photodiode (2) has an area of 10×10 mm^2. Coordinate axes are defined as shown. Alpha-particles are incident on the crystal along the z axis.

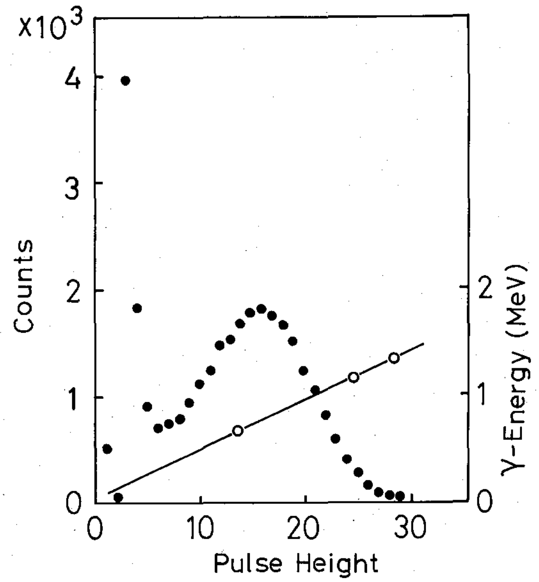

Fig. 2. Pulse height spectrum of alpha-particles from ^{241}Am souce. The incident energy at the crystal surface is estimated to be 3.7 MeV. Empty circles represent pulse heights observed for γ-rays of 1.33, 1.17 and 0.66 MeV from ^{60}Co and ^{137}Cs sources.

near 16 channels, which corresponds to the γ-ray energy of 800 keV and the noise level less than 5 channels. Now, we replaced the collimeter with a 1 mm thick aluminum plate with a hole 1.5 mm in diameter to obtain higher counting rates. The energy of alpha-particles incident on the crystal surface was estimated to be 4.7 MeV and observed pulse heights increased by a factor 2.0. We measured pulse heights changing the position of the source with the collimeter along the x or y axis.

First (case 1), pulse heights were measured with a single photodiode attached to the bottom surface. The results are plotted with triangles in Figs. 3 and 4. The pulse height decreases slowly as the position x approaches the left and right side surfaces and almost the same as the position y approaches the top surface far from the photodiode from which signals are read out. The decrease is a few per cent. On the other hand, the pulse height decreases rapidly as the position y approaches the bottom surface to which the photodiode is attached. The pulse height for $y=-8$ is reduced by 35% compared with that for $y=0$. The former fact can be explained partly as due to the change in the distance between the scintillation point and the photodiode, and the latter partly as due to the change in the photosensitive area seen from the scintillation point, although difuse reflection contributes importantly.

Secondly (case 2), we used two photodiodes bundling their output lines and connecting them to a preamplifier. The results are plotted with squares in Figs. 3 and 4. The pulse height increases by a factor of 2.2 compared with that for the case 1 and a top-bottom symmetry is found. The reduction of pulse height is about 13% for the incident positions $y=\pm 6$ and ± 8. This fact can be explained on the basis of the results for the case 1. The pulse height from a single photodiode is given as a function of the incident position y. The function for the

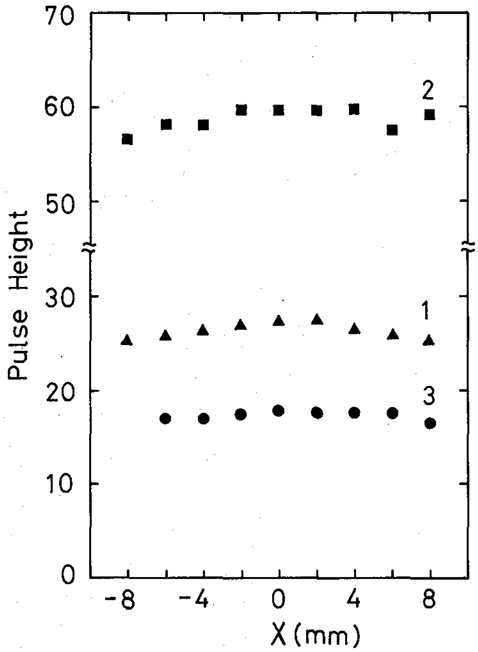

Fig. 3. Pulse heights as functions of the incident position x(y=0) of alpha-particles. Numbers 1, 2 and 3 crrespond to the cases 1, 2 and 3 in the text respectively.

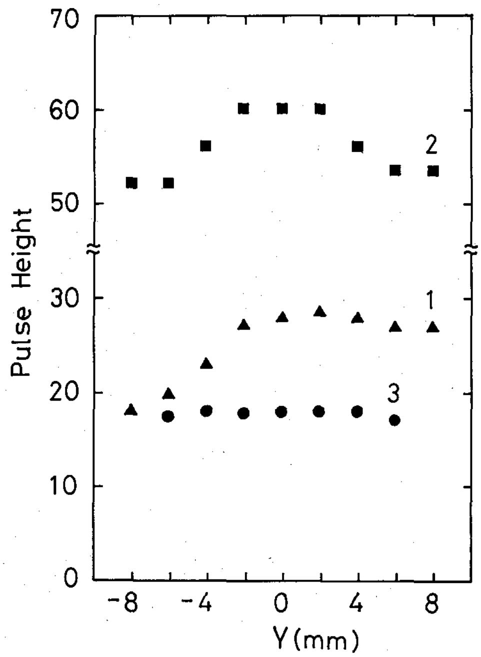

Fig. 4. Pulse heights as functions of the incident position y(x=0) of alpha-particles. Numbers 1, 2 and 3 crrespond to the cases 1, 2 and 3 in the text respectively.

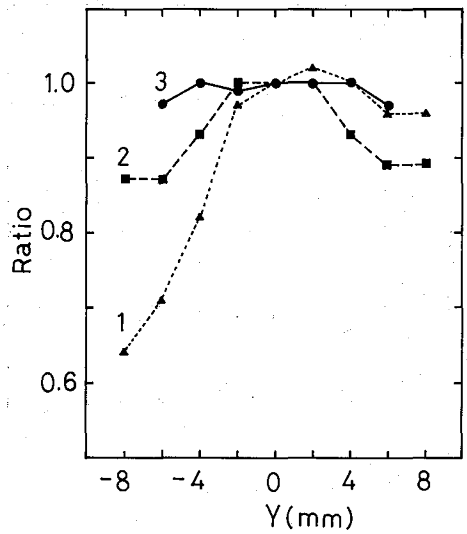

Fig. 5. Pulse heights for the incident position y compared with these for the position y=0. Numbers 1, 2 and 3 correspond to the cases 1, 2 and 3 in the text respectively.

readout with the top photodiode can be obtained from that for the redout with the bottom photodiode by changing the sign of the position y. The sum of these functions nearly reproduces the measured function for the case 2.

Thirdly (case 3), we used a single photodiode, separating it from the crystal surface with a 8 mm thick light guide of plastic. The results are plotted with circles in Figs. 3 and 4, which shows an improvement in the pulse–height uniformity against the change in the y position as well as the x one, although pulse heights decrease by a factor of 0.65 compared with that for the case 1.

The results for the cases 1, 2, and 3 shown in Fig. 4 are summarized in Fig. 5 in the form of ratio of the pulse height for the position y to that for the position y=0. Using two photodiodes attached to opposite surfaces of the crystal improves an asymmetry about the incident position of charged particles compared with using a single photodiode. Separating the photodiode from the crystal with a light guide is most effective to obtain an uniformity in the pulse height against the change in the particles incident position.

REFERENCES

1) J. M. Cameron, P. Kitching, R. H. McCamis, C. A. Miller, G. A. Moss, J. G. Rogers, G. Roy, A. W. Stetz, C. A. Goulding and W. T. H. van Oers, *Nucl. Instr. Meth.*, **143**, 399 (1977).
2) A. M. Sourkes, M. S. de Jong, C. A. Goulding, W. T. H. van Oers, E. A. Ginkel, R. F. Carlson, A. J. Cox and D. J. Margaziotis, *Nucl. Instr. Meth.*, **143**, 589 (1977).
3) C. A. Goulding and J. G. Rogers, *Nucl. Instr. Meth.*, **153**, 511 (1978).
4) A. Bracco, H. P. Gubler, D. K. Hasell, W. T. H. van Oers, R. Abegg, C. A. Miller, M. B. Epstein, D. A. Krause, D. J. Margaziotis and A. W. Stetz, *Nucl. Instr. Meth.*, **219**, 329 (1984).
5) M. Makino, R. Eisberg, K. Richie, R. Carlson and C. Waddell, *Nucl. Instr. Meth.*, **80**, 299 (1970).

6) M. Makino, R. Eisberg, D. Ingham and C. Waddell, *Nucl. Instr. Meth.*, **81**, 125 (1970).
7) R. Eisberg, M. Makino, R. Cole, C. N. Waddell, M. Baker, J. J. Jarmer, D. M. Lee and P. Thompson, *Nucl. Instr. Meth.*, **146**, 487 (1977).
8) H. Grassmann, E. Lorentz and H. G. Moser, *Nucl. Instr. Meth.*, **228**, 323 (1985).
9) P. Kreutz, A. Kuhmichel, C. Pinkenburg, J. Pochodzalla, Z. Y. Guo, U. Lynen, H. Sann, W. Trautmann and R. Trockel, *Nucl. Instr. Meth.*, **A260**, 120 (1987).