Performance of an 8×8 array of $LaBr_3(Ce)$ pixels coupled to a multi-anode PMT

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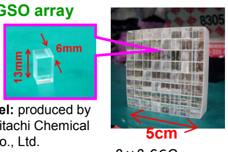
Abstract: We assembled an 8×8 array of 6×6×15 mm³ $LaBr_3(Ce)$ pixels by our own technique for an absorber of a Compton camera. The energy resolution (FWHM) of one pixel was 5.8±0.9 % at 356 keV by measurement with a single anode PMT. When the array was coupled to a 64ch multi-anode PMT and read out from 4-channels with a resistor chain, it had energy resolutions (FWHM) of 7.6±0.5 % and 5.8±0.4 % at 356 keV and 662 keV, respectively, except outer pixels.

1, Introduction –our Compton camera-

We have developed a position sensitive detector with a GSO array. [1-3]

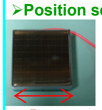
➢ **GSO array**



Pixel: produced by Hitachi Chemical Co., Ltd.
Reflector: 3M ESR with a thickness of 65 μm

8×8 GSO array Assembled by our technique

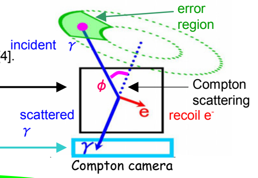
➢ **Position sensitive PMT**



8×8 multi-anode PMT
Hamamatsu K. K. (HPK) H8500
Anode size: ~□6mm
Gain: ~10^6 @-1000V
Gain uniformity: 2~4
Rise time: 0.8 nsec
Photo Cathode Coverage
Effective area: □49 mm²

➢ **Energy resolution (FWHM) of GSO array**
10.5±0.8% @ 662 keV

We have developed a gamma-ray imaging detector with GSO arrays as an absorber of a Compton camera [4].



Compton scattering angle φ is obtained by

$$\cos\phi = 1 - \frac{m_e c^2}{Ee + E\gamma} \cdot \frac{E\gamma}{Ee}$$

Ee: energy of recoil electron
E_γ: energy of scattered γ

⊿φ: ARM (Angular Resolution Measure)

Our experiments using the Compton camera

➢ **Gamma-ray astronomy (SMILE project)**

Balloon was launched in 2006 Sep. in Japan for observation of cosmic and atmospheric gamma rays.
Our final goal is to survey all sky with more than ten times as higher sensitivity as COMPTEL [5].

➢ **Nuclear medicine**

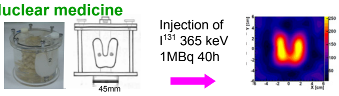
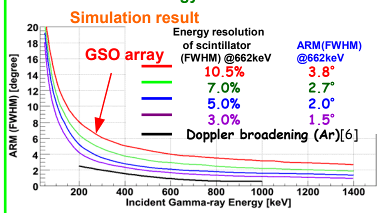


Photo (left) and image (right) of a thyroid phantom

Gamma-ray image of the phantom traced by ^{131}I

➢ **Angular resolution vs. energy resolution of scintillator**



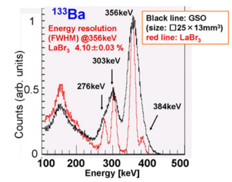
A good energy resolution of scintillator is needed for obtaining a good angular resolution.

2, $LaBr_3$

Light Output (NaI%): **160%**[7]
(cf. GSO(Ce): 20%)
Decay time: **~25 nsec**
※hydroscopic nature
→difficulty in assembly

$LaBr_3$ Saint-Gobain
Size: φ13×13mm³

➢ **Energy resolution measured with a single anode PMT (HPK R6231)**



Having a good energy resolution

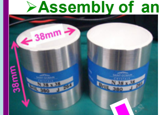
3, $LaBr_3$ array

We tried to assemble a $LaBr_3$ array for the Compton camera.

➢ **Previous researches on position sensitive detectors with $LaBr_3$**

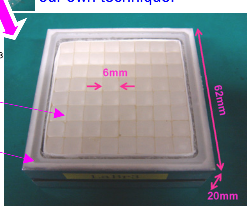
Kuhn *et al.* measured a 10×10 $LaBr_3$ array with a pixel size of 4×4×30 mm³ for an Anger-logic detector [8].
Pani *et al.* measured a 4mm thick planar $LaBr_3$ with MAPMT (H8500) [9].

➢ **Assembly of an $LaBr_3$ array**



We quarried φ38×38mm³ $LaBr_3$ into pixels and assembled the $LaBr_3$ array by our own technique.

$LaBr_3$ (Saint-Gobain)
Size: φ38×38mm³

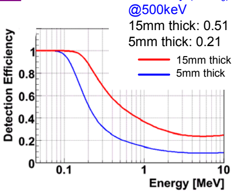


our 8×8 $LaBr_3$ array (pixel size: 6×6×15mm³)

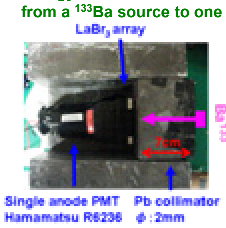
➢ **Characteristics of our array**

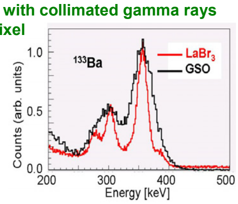
•Specific structure for the PMT
The pitch of crystal pixel is the same as PMT(H8500) anode.

•Thick
→ higher efficiency in the sub-MeV region



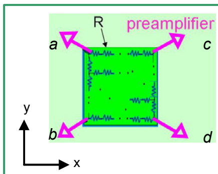
➢ **Energy resolution measured with collimated gamma rays from a ^{133}Ba source to one pixel**





Energy spectrum of ^{133}Ba
energy resolution (FWHM)
5.8±0.9% @356keV (ave. of 64 pixels)

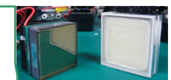
4, Readout of multi-anode PMT



Resistor chain
(a~d: output value)

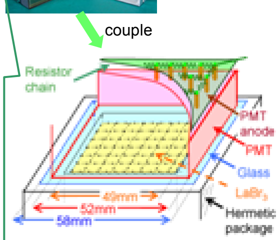
Reconstruction of image (x, y) and Energy (E) from 4 outputs

$$x = \frac{(a+b)-(c+d)}{a+b+c+d}$$
$$y = \frac{(a+c)-(b+d)}{a+b+c+d}$$
$$E = a+b+c+d$$



MAPMT (H8500) and $LaBr_3$ array

couple



Schematic view of readout by 4ch.

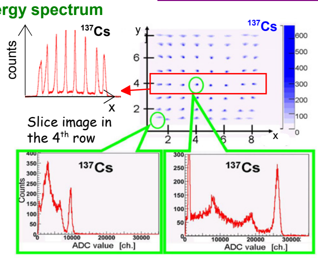
●Data acquisition system
each ch. → preamplifire(τ =5.4 μ sec) → Shaper(τ =0.5 μ sec) → PHADC
(the ways of data acquisition and analysis are the same way as GSO's)

Anodes of the MAPMT were connected with 100 Ω resistors for reduction of the readout channels to 4ch.

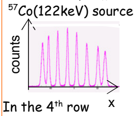
5, Performance

➢ **Imaging and Energy spectrum**

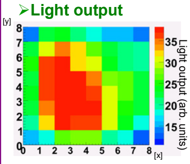
2-D/slice images by irradiation of Gamma rays from Cs^{137} (peak: 662 keV)



Cf. slice image by irradiation from ^{57}Co(122keV) source

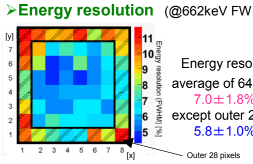


➢ **Light output**



Light output map

➢ **Energy resolution** (@662keV FWHM)

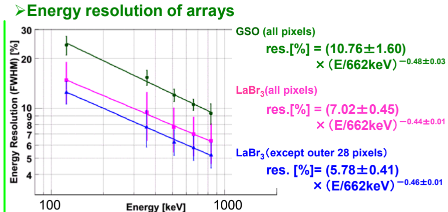


Energy res. @ 662 keV in each pixel

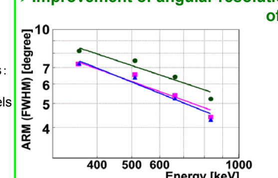
Energy resolution average of 64 pixels: 7.0±1.8%
except outer 28 pixels 5.8±1.0%

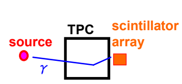
Pixels with low energy resolution tend to have low light output. pixels with low output are distributed in the outside. Since the area of glass window is larger than that of the array and PMT, the scintillation light from the outer pixels leaks from the glass window to the outside of the PMT window.

➢ **Energy resolution of arrays**



➢ **Improvement of angular resolution (ARM) of the Compton camera**





Setup for the measurement of ARM (the array is in the center of TPC)

Angular resolution (ARM) @662keV
GSO: 6.4°
→$LaBr_3$: 5.4° (all pixels)
→$LaBr_3$: 5.2° (except outer pixels)

6, Present and future works

➢ **Solution of a leakage of scintillation light**

A leakage of scintillation light from the outer pixels leads to reduce the energy resolution.
We are improving the structure of the hermetic sealing to prevent the leakage in order to obtain a better resolution in the outer pixels.

➢ **Readout of all anodes using ASIC**

It is expected to improve the energy resolution by readout of all PMT anode channels with ASIC (IDEAS VA32 HDR11) than 4-channels with resistor chain, because of a variety of PMT anode gains by a factor of 2-4.

➢ **Assembly of 4 $LaBr_3$ arrays**

To expand the effective area in the Compton camera from 5×5cm² to 10×10cm².

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Reference

[1]K. Takagi *et al.* 1982, Appl. Phys. Lett. **42**, 43
[2]H. Nishimura *et al.*, 2007, Nucl. Instr. and Meth A. **537**, 115. astro-ph/0609214.
[3] H. Sekiya *et al.*, 2006, Nucl. Instr. and Meth A. **563**, 49.
[4] T. Tanimori *et al.*, 2004, New Astro. Rev. **48**, 263.
[5] V. Schönfelder *et al.*, 1993, ApJ **86**, 657
[6] A. Zoglauer *et al.*, 2003, Proceeding of SPIE **4851**, 1302.
[7] E. V. D. van Loef *et al.*, 2001, Appl. Phys. Lett. **79**, 1573.
[8] A. Kuhn *et al.*, 2004, IEEE Trans. on Nucl. Sci. **51**. 2550.
[9] R. Pani *et al.*, 2006, Nucl. Instr. and Meth A. **569**, 296.