Development of a Compton gamma-ray camera with LaBr₃(Ce) pixellated arrays for medical imaging

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• Summary
Medical imaging (functional image)

**PET**: $E = 511$ keV

**SPECT**: $E < 360$ keV

New radioactive tracer with new radioisotopes

It is possible that we obtain various images: anti-body, enzyme, protein reaction

Multi-radioisotope Imaging

With wide energy range

Simultaneous observation of some metabolisms and interactions

<table>
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<tr>
<th></th>
<th>$^{139}$Ce</th>
<th>$^{133}$Ba</th>
<th>$^{131}$I</th>
<th>$^{198}$Au</th>
<th>$^{22}$Na</th>
<th>$^{18}$F</th>
<th>$^{54}$Mn</th>
<th>$^{65}$Zn</th>
<th>$^{60}$Co</th>
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</thead>
<tbody>
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<td>$E$ [keV]</td>
<td>167</td>
<td>354</td>
<td>364</td>
<td>412</td>
<td>511</td>
<td>1275</td>
<td>511</td>
<td>835</td>
<td>1116</td>
</tr>
</tbody>
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PET

SPECT
Electron Tracking Compton Camera

- Reconstruct incident gamma ray event by event
- Gaseous TPC (time projection chamber): containing $\mu$-PIC (MPGD), GEM (Inutsuka et al., Sauli)
- Scintillation camera: Pixel array Scintillator
- Energy and 3-D track of Compton-recoil electron

10cm Scintillator

TPC $\mu$-PIC

Large FOV (~3str)
Kinematical background rejection by comparison of two $\alpha$ angles

Event 1 $\Rightarrow$ 100

Energy dynamic range: from 0.1 to ~1 MeV

Reconstruct incident gamma ray event by event
To obtain a higher angular resolution

Angular resolution of the Compton camera depends on the energy resolution of scintillator

\[
\cos \phi = 1 - \frac{m_e c^2 K}{(E+K) E}
\]

Eng. Res. (FWHM) of LaBr\(_3\)(Ce) : ~ 3 \% @ 662 keV

Loef et al. (2001)
Assembly of LaBr$_3$(Ce) array

Using our technique, we cut 5.8×5.8×15.0 mm$^3$ pixels out of two φ38×38 mm$^3$ LaBr$_3$ crystals and assembled an 8×8 array.

Saint-Gobain BrilLanCe380
Size: φ38×38 mm$^3$
Eng. Res.: ~3 % (FWHM, @ 662 keV, using HPK R6231)

1/2 attenuation length @662 keV
LaBr$_3$ (Ce): 18 mm

Effective area: 49 × 49 mm$^2$
(=PMT photocathode)

Glass window: Quartz (t 2.3 mm)
Hermetic package: Aluminum (t 0.5 mm)
4ch readout with multi-anode PMT

- Flood field irradiation image using a Charge-division method

Multi-anode PMT
HPK H8500

LaBr₃(Ce) array

54mm

4ch readout with a resister chain

- 64 anodes of PMT
- 4 ch output
- pre.AMP R=100Ω
Energy resolution (FWHM)
Using Multi-anode
PMT H8500

FWHM Eng. Res. @ 662 keV
Ave. ± σ : 5.8 ± 0.9%

FWHM(%)=
(5.7±0.4) ×(E/662keV)^-0.53±0.01
9 arrays: Energy Resolutions (FWHM) @ 662keV

Eng. Res. (FWHM) @ 662 keV
Ave. ± σ:
6.0 ± 1.0%
(15mm-thickness)
5.6 ± 0.8%
(20mm-thickness)
5.8±0.9%
(Total, 576 pixels)
Setup of ETCC

LaBr₃(Ce) arrays

Gaseous TPC

LaBr₃ TPC source

50mm 200mm

γ

e-

Source

Electron 3-D track

Reconstruction of a Compton event

Angular resolution (FWHM) [degree]

4.2 ± 0.3° @662 keV

FOV: 400cm² @10cm from TPC

356keV, FWHM

300 400 500 600 700 800 900 1000

Energy [keV]
Mouse imaging

$^{131}$I-MIBG (365keV) Imaging (ETCC & CT)

$^{65}$Zn$^{2+}$ (1116keV) Imaging (ETCC & photo)
The clinical drugs $^{18}$F-FDG (PET) and $^{131}$I-MIBG (SPECT) can image the MRMT1 (mammary tumor) and PC12 (Pheochromocytoma)
Summary

• we assembled an 8 × 8 LaBr₃(Ce) pixel array.
  – Pixel size: 5.8 × 5.8 × 15 mm³
  – 5.8 × 5.8 × 20 mm³
  – Pixel pitch: 6.1mm (the same as that of the multi-anode PMT H8500)

• Dynamic energy range: 80 – about 1000 keV.

• Energy resolutions of the array with the MAPMT (FWHM, @662keV).
  – 5.8 ± 0.9% (average of 9 arrays)

• Angular resolution of ETCC (FWHM, @662keV).
  – 4.2 ± 0.3 deg.

• We observed mouse imaging:
  – High energy isotope: ⁶⁵Zn²⁺ (1116keV)
  – ¹³¹I-MIBG (365keV) & ¹⁸F-FDG (511keV) Simultaneously
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