Development of an 8×8 array of $LaBr_3$(Ce) pixels with a multi-anode PMT for a gaseous Compton gamma-ray camera

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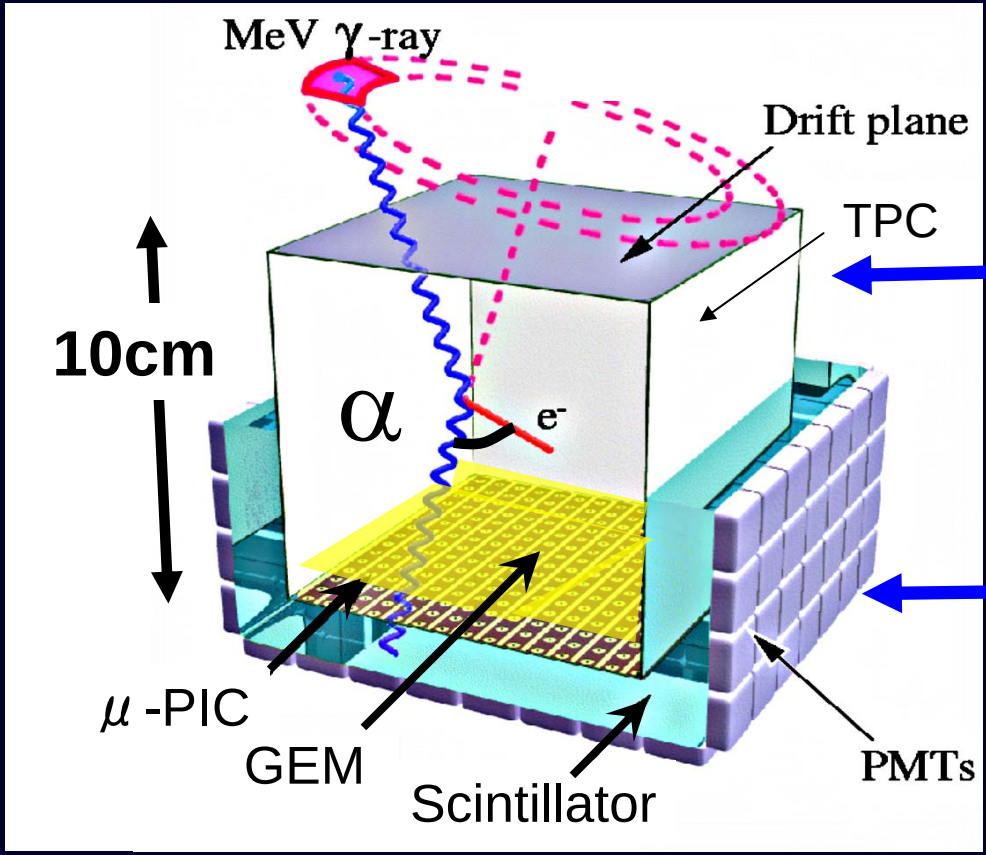
Compton gamma camera



This Camera is for Astronomy, medical imaging.

gaseous TPC
(time projection chamber) :
[containing μ-PIC(MPGD), GEM]
--- energy and 3-D track of a recoil electron

Scintillation camera:
[GSO (Ce) pixel array]
--- energy and position of a scattered gamma ray

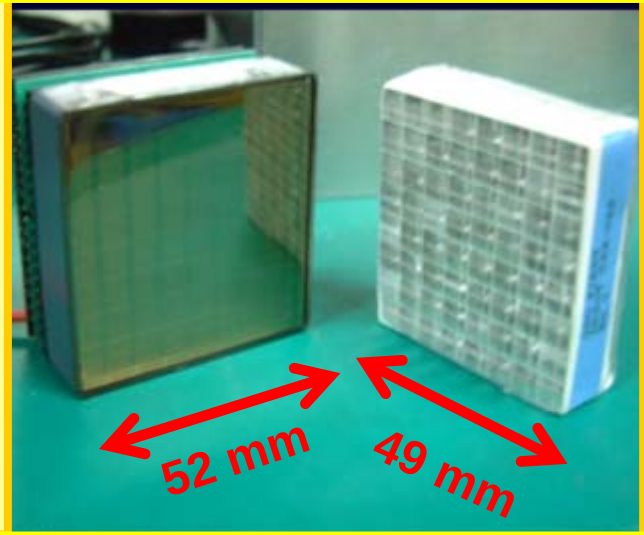
- Large FOV (~3str)
- Kinematical background rejection by comparison of two α angles

Reconstruct an incident gamma ray event by event

Scintillator array camera

8 × 8 multi-anode PMT (MAPMT) HPK H8500

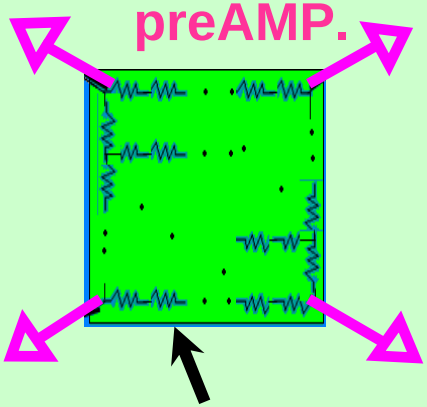
size: 52 × 52 mm²
effective area: 49 × 49 mm²
anode pitch: 6.1 mm



GSO array (8 × 8 pixels)
effective area: 49 × 49 mm²
pixel size: 5.8 × 5.8 × 13mm²
anode pitch: 6.1mm same as the PMT
reflector: ESR© (3M)

(GSO has a strong radiation hardness)

4ch readout with a resister chain



Resistor chain
All 100Ω

64 anodes of PMT

4 ch output

Charge-division method → X, Y position

Sum → Energy

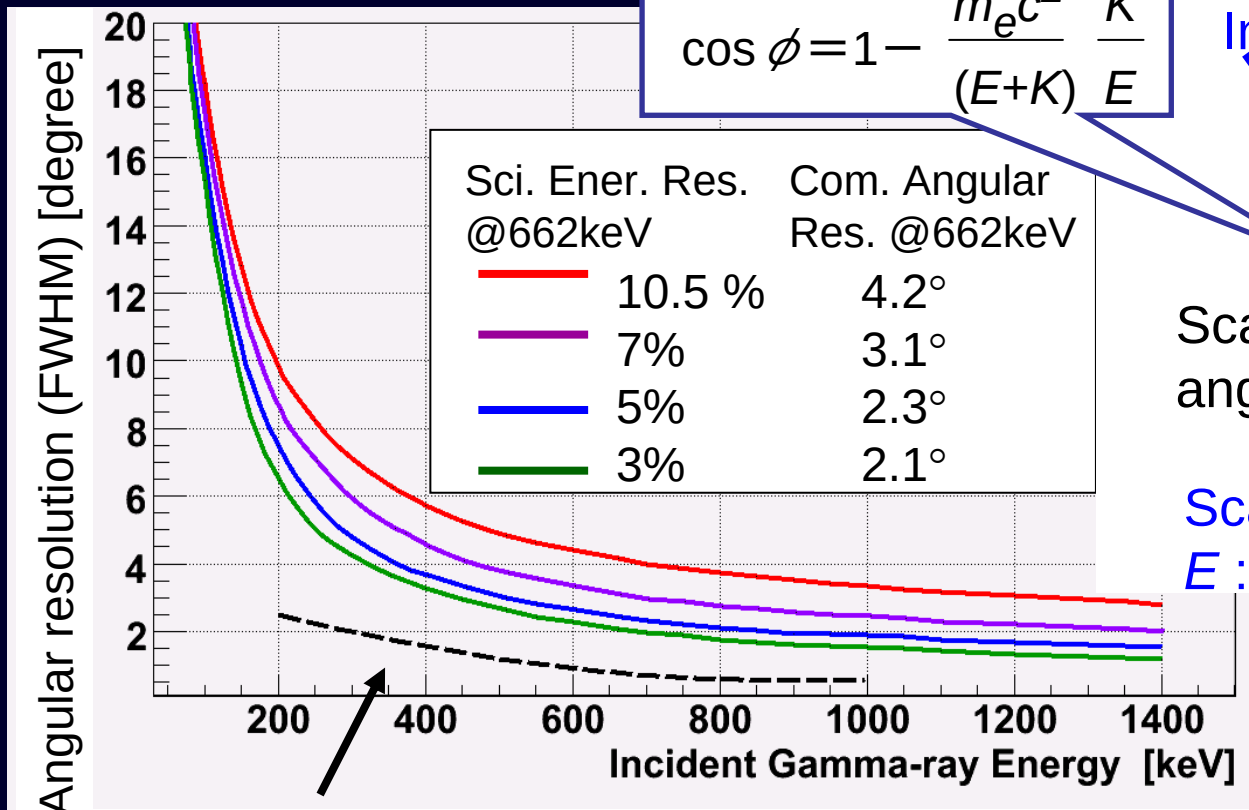
Energy resolution (FWHM)
10.7 ± 1.0 % @ 662 keV

Improvement of Angular Resolution

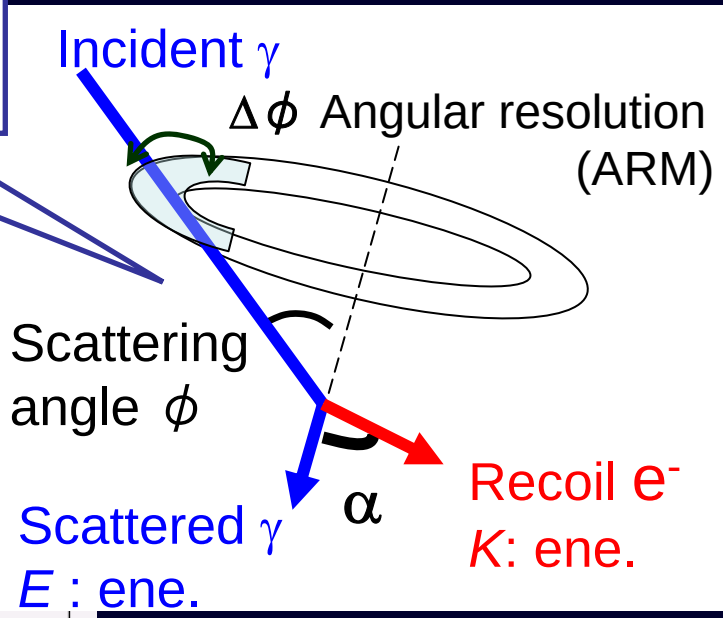
Now :Angular resolution (FWHM): 6.4˚ @ 662keV

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

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



Doppler broadening (Ar)
Zoglauer *et al.* (2003)



Calculation assuming
1, no error of position of Compton point
2, energy Res. of TPC : 30 % @ 22 keV

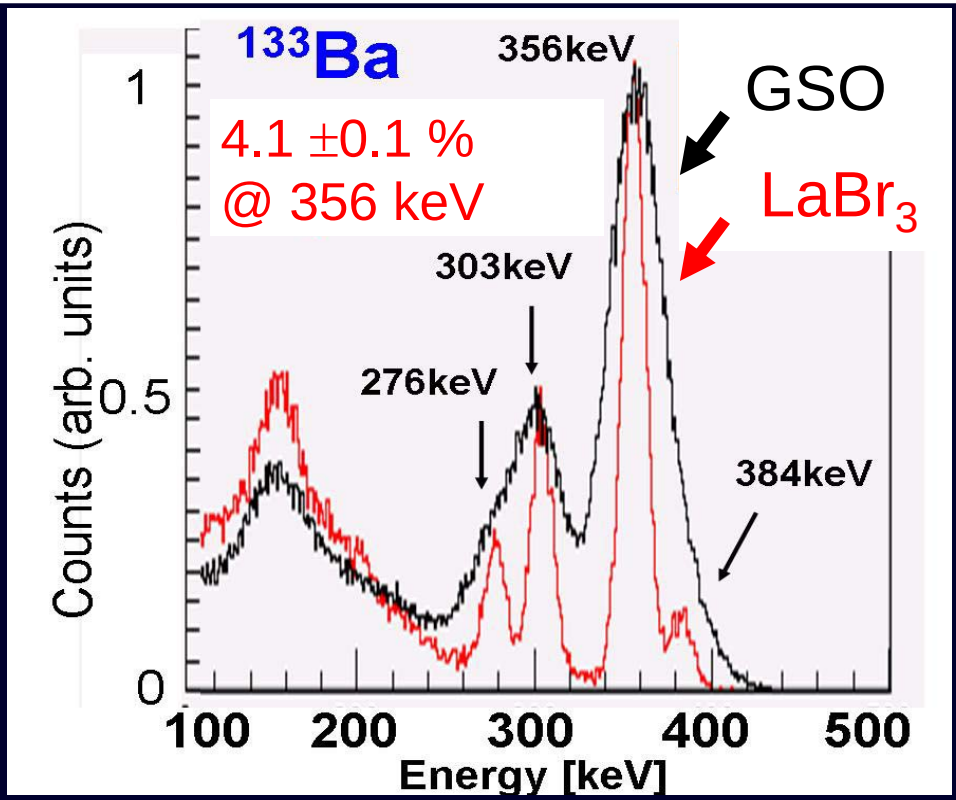
$LaBr_3(Ce)$ scintillator

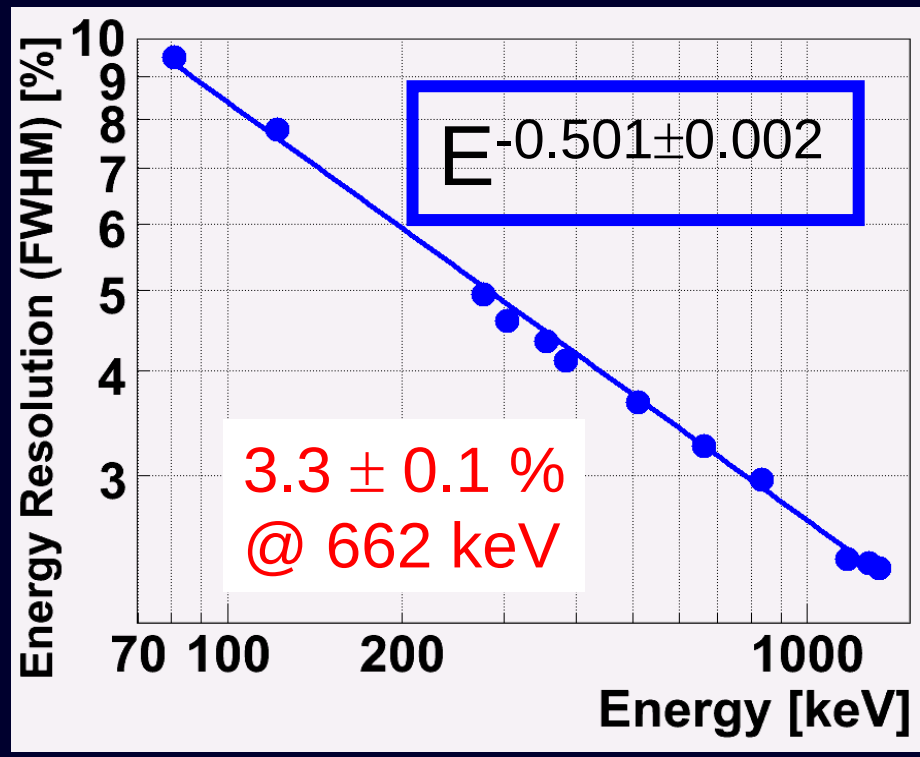
- Excellent energy resolution
- High light yield : 160 NaI%
  [cf. GSO(Ce) : 20 NaI%]
- Fast decay time: ~20 nsec
- hygroscopic

Loef *et al.*, (2000)

Saint-Gobain
BrilLanCe380
Size:ϕ38×38mm^3

Energy resolution measured with a single-anode PMT (SAPMT) (HPK R6231)

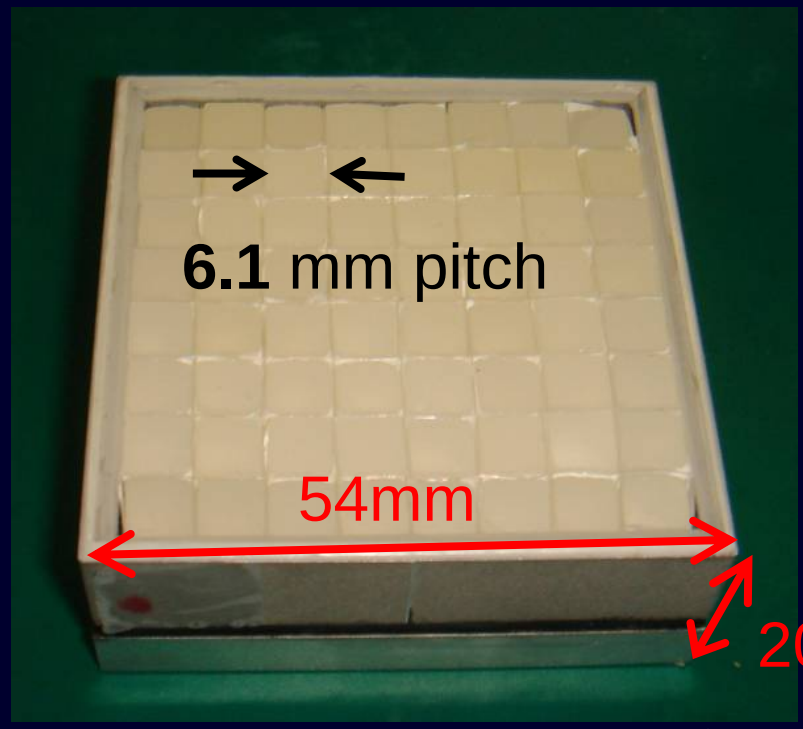




Assembly of $LaBr_3$(Ce) array

We cut 5.8×5.8×15.0mm^3 pixels out of two ϕ38×38 mm^3 $LaBr_3$ crystals and assembled an 8×8 array by our technique.

Saint-Gobain
BrilLanCe380
Size:ϕ38×38mm^3



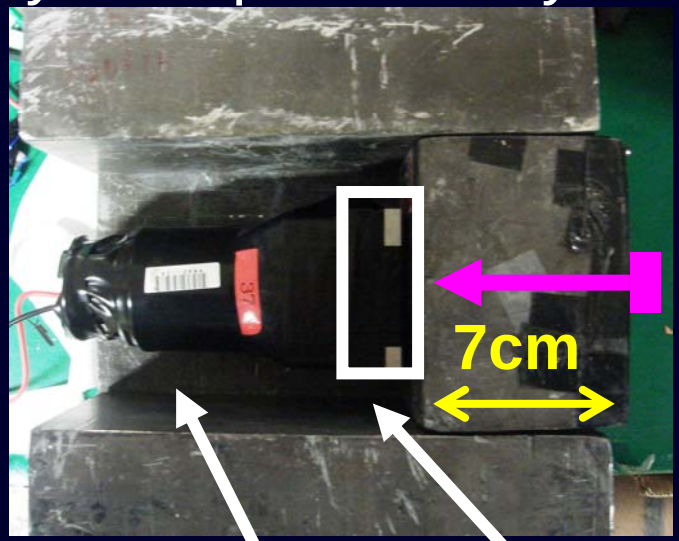
1/2 attenuation length
@662keV
$LaBr_3$ (Ce): 18 mm

Effective area : 49 × 49 mm^2
(=PMT photocathode)
Glass window : Quartz (t 2.3 mm)
Hermetic package : Aluminum (t 0.5 mm)

Performance of each pixel

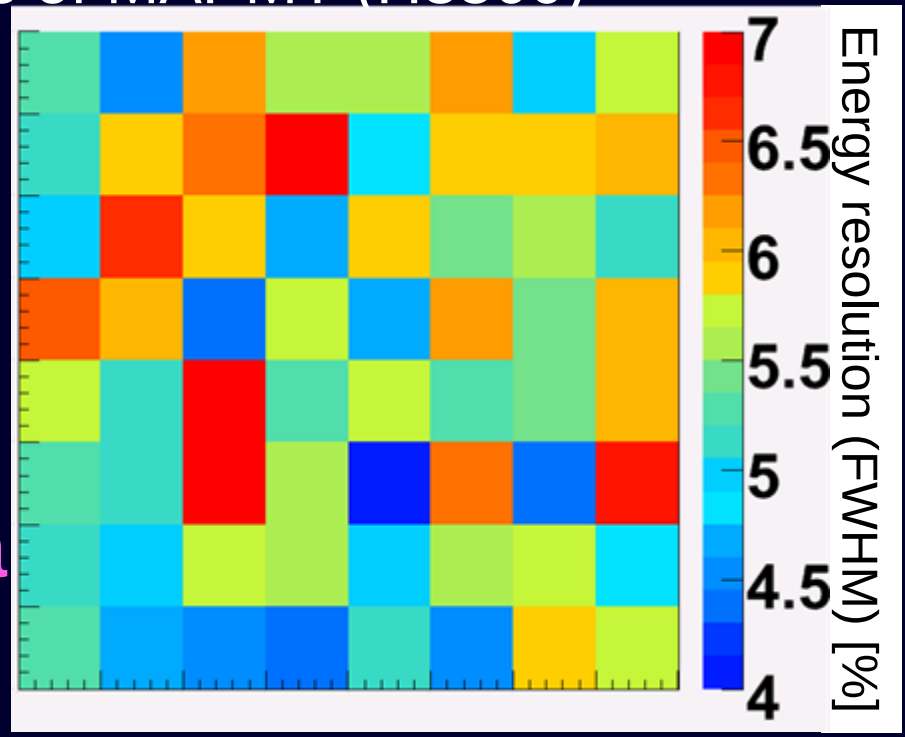
To estimate the performance without the effect of gain-uniformity (~3) among 64 anodes of MAPMT (H8500)

irradiation of collimated gamma rays to a pixel one by one



Single-anode PMT
HPK R6236
(2-inch square)

$LaBr_3$ array

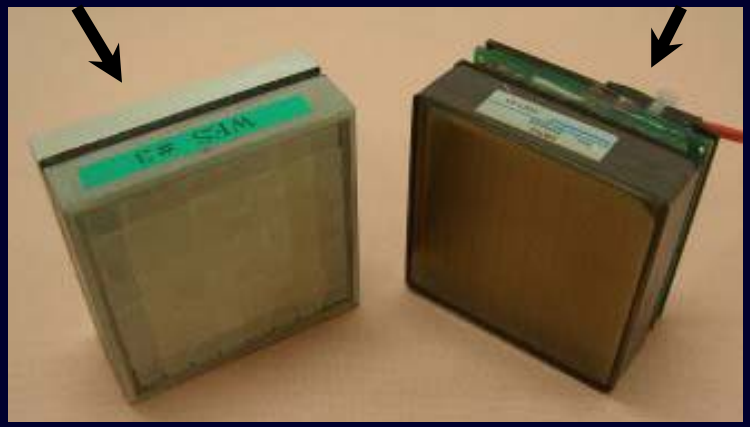


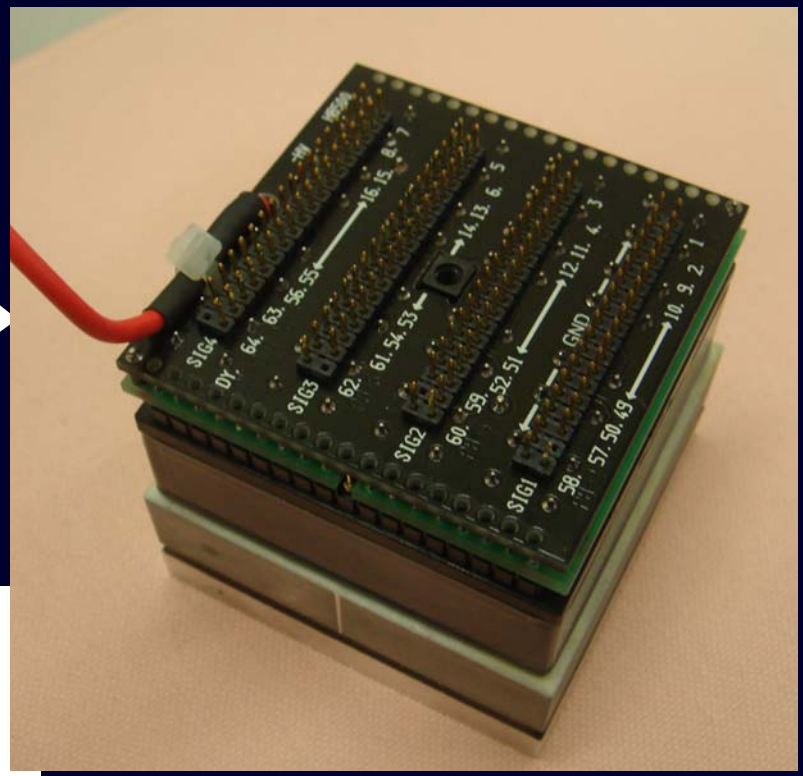
Map of energy Res. of 8 × 8 pixels

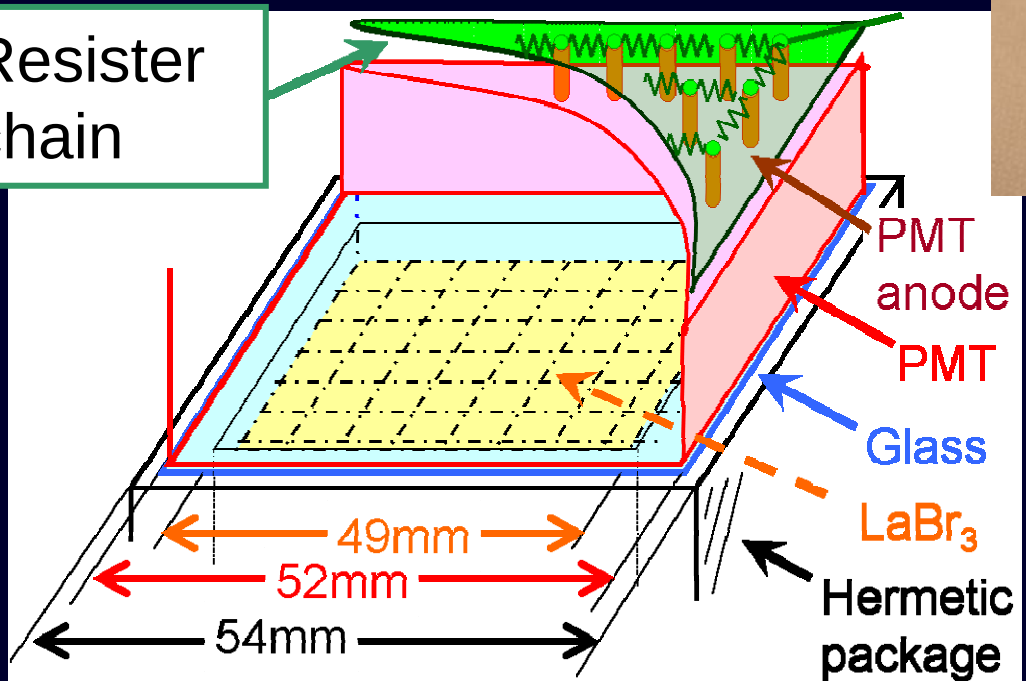
Energy resolution (FWHM)
@ 356 keV
Ave. ± RMS = 5.5 ± 0.7 %

4ch readout with H8500

$LaBr_3$ array MAPMT HPK H8500



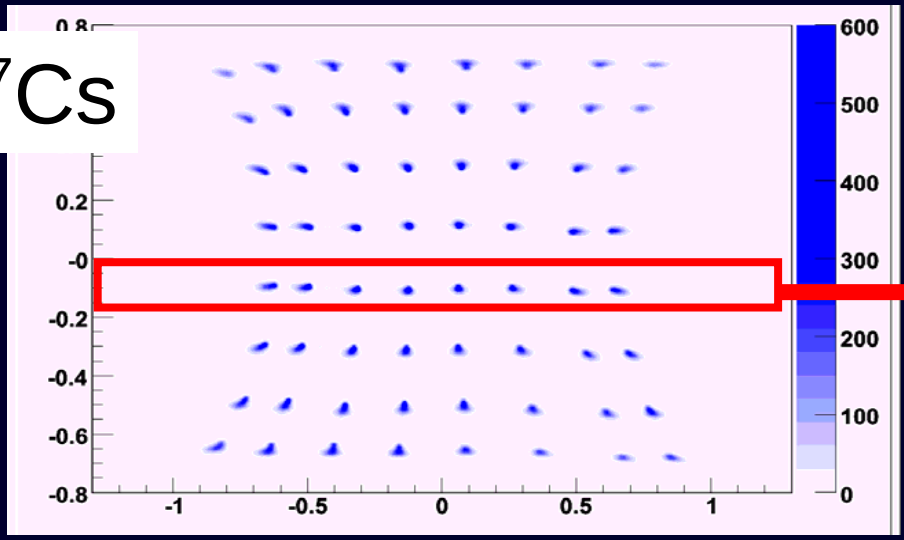


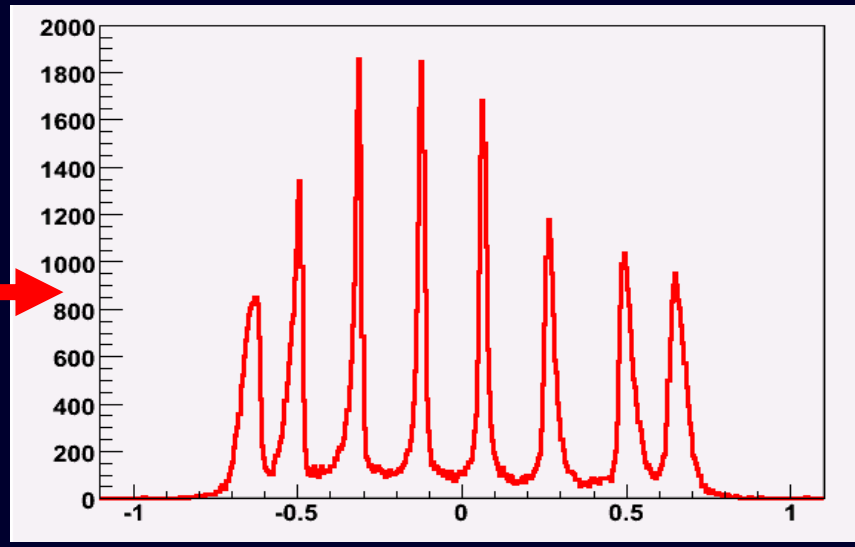


Reading system is the one for the GSO array

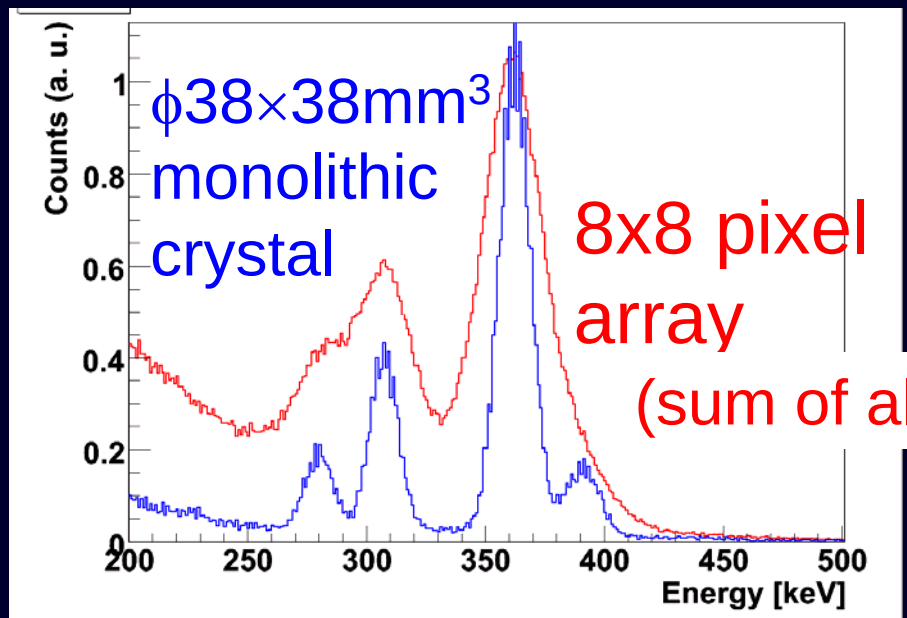
Image and energy spectrum

- Flood field irradiation image by Charge-division method





- Energy spectrum (^{133}Ba)



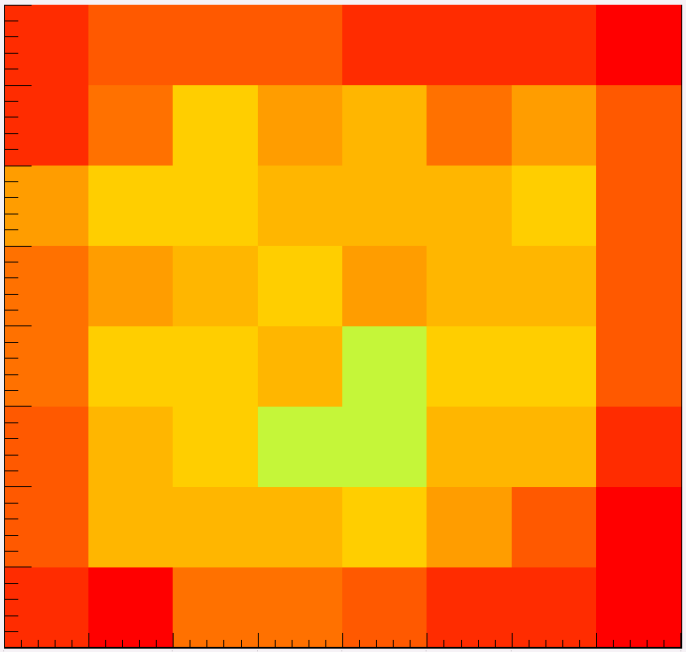
Energy resolution (FWHM) of each pixel @ 662 keV (^{137}Cs)

GSO

6×6×13 mm^3 8×8 array

Ave. ± RMS :

10.8 ± 1.0%

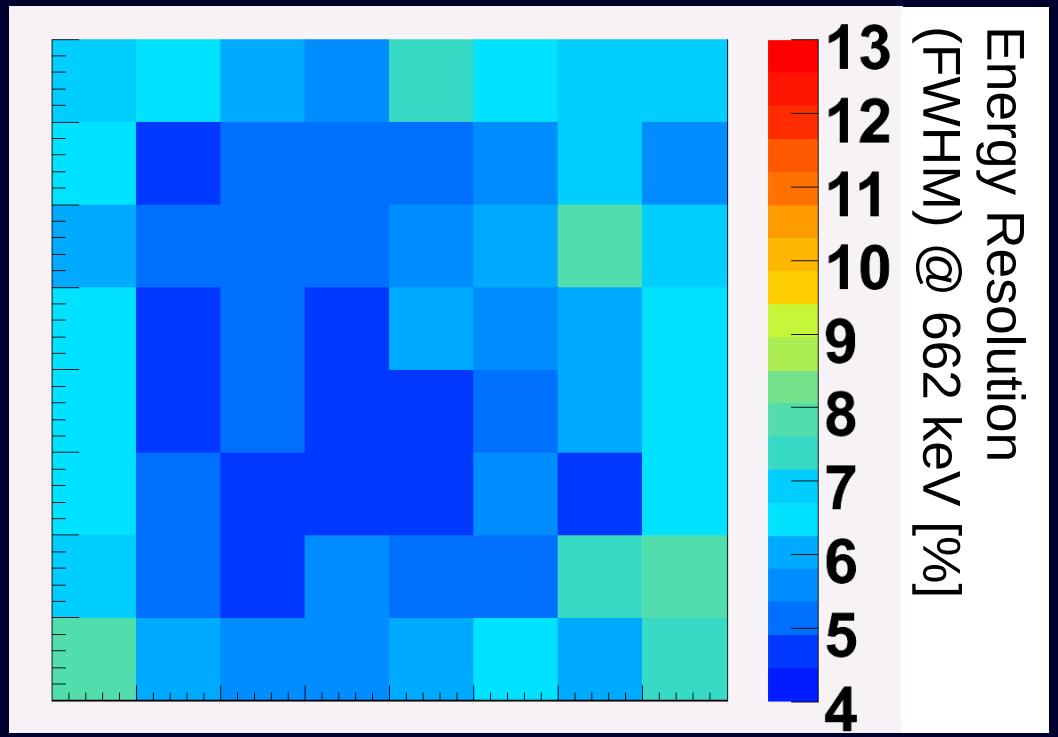


$LaBr_3$

6×6×15 mm^3 8×8 array

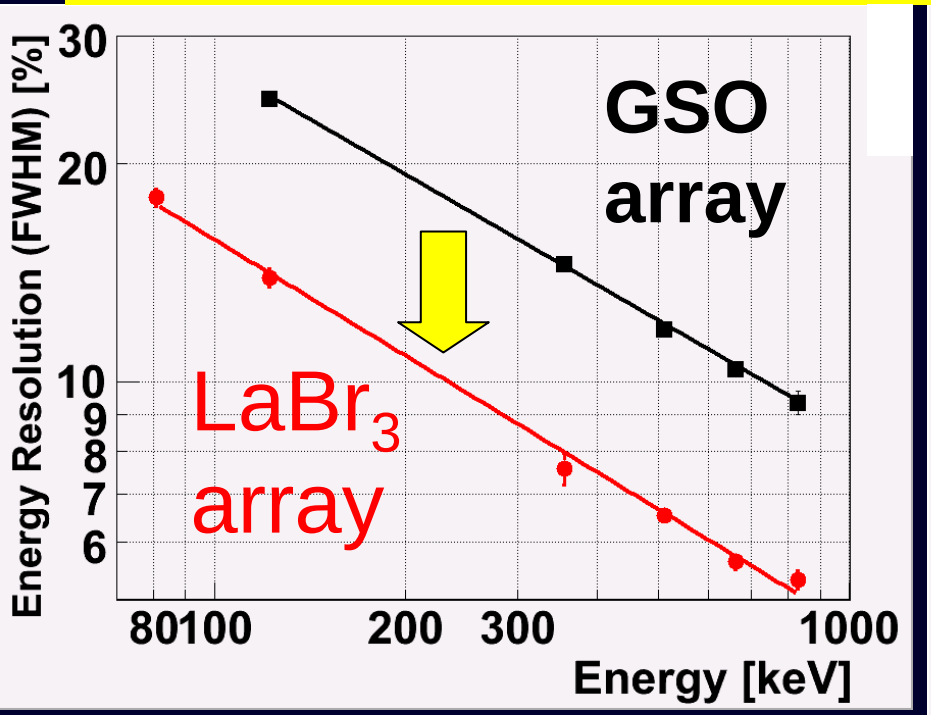
Ave. ± RMS :

5.8 ± 0.9%



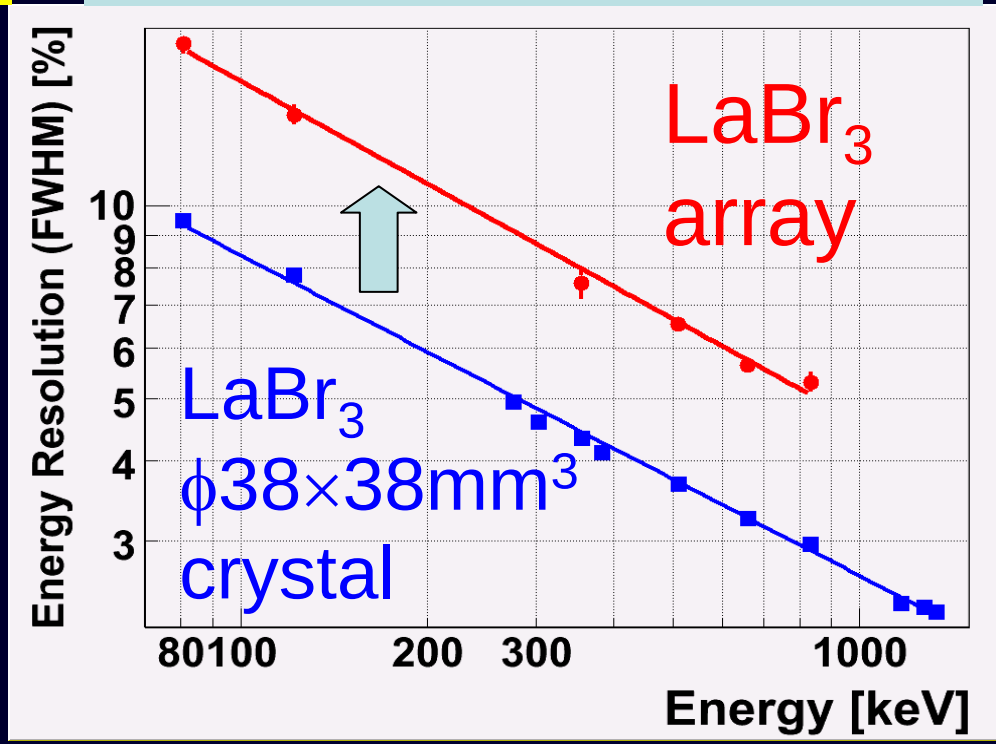
Energy Resolution (2)

Improved by factor ~2



GSO
6×6×13 mm³ 8×8 array:
FWHM(%)=(10.4±0.3)
×(E/662keV)$^{-0.51\pm0.01}$

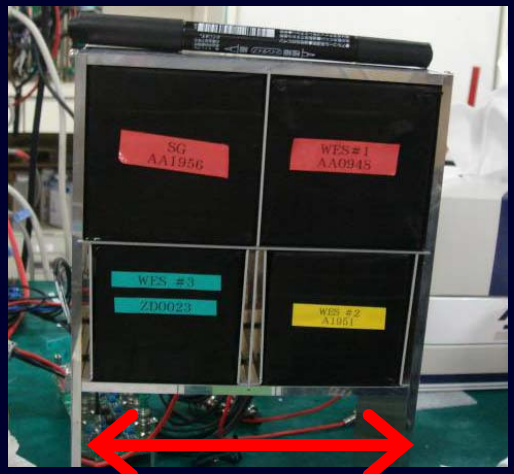
Worsened by factor ~2

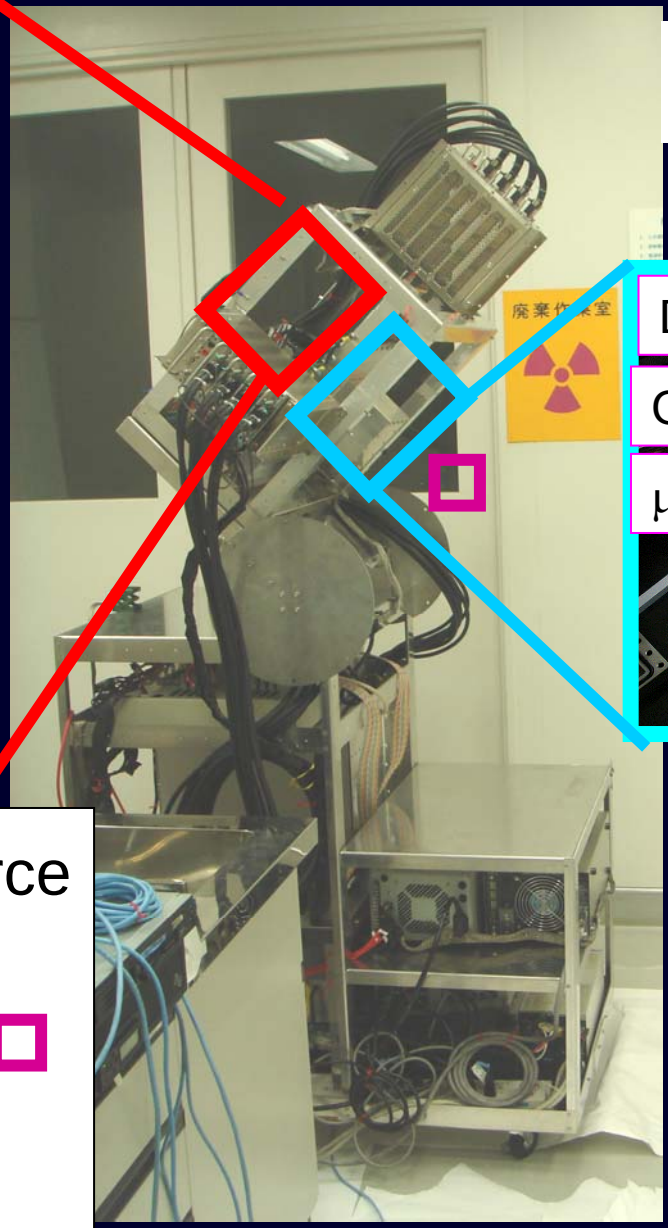


$LaBr_3$
6×6×15 mm³ 8×8 array:
FWHM(%)=(5.7±0.4)
×(E/662keV)$^{-0.53\pm0.01}$

Setup of Compton camera

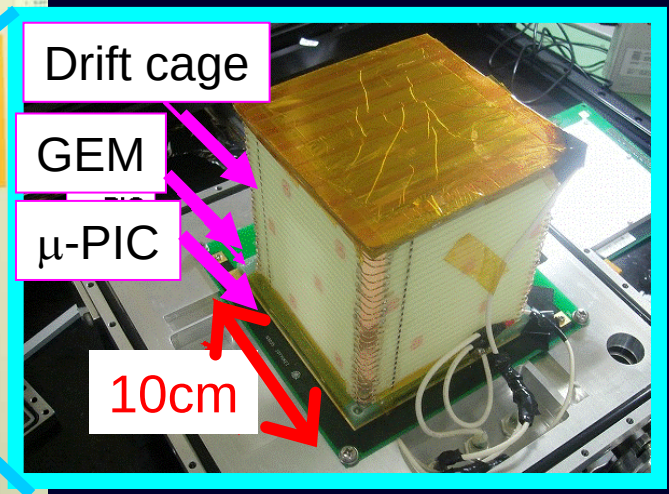
(8 × 8 $LaBr_3$ pixels) 2 × 2

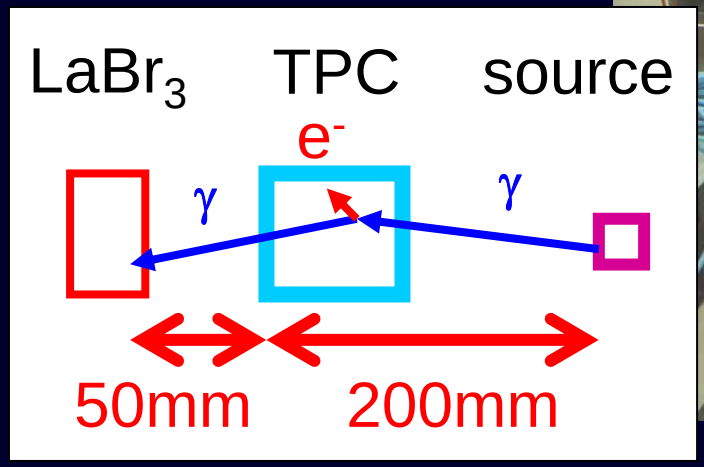


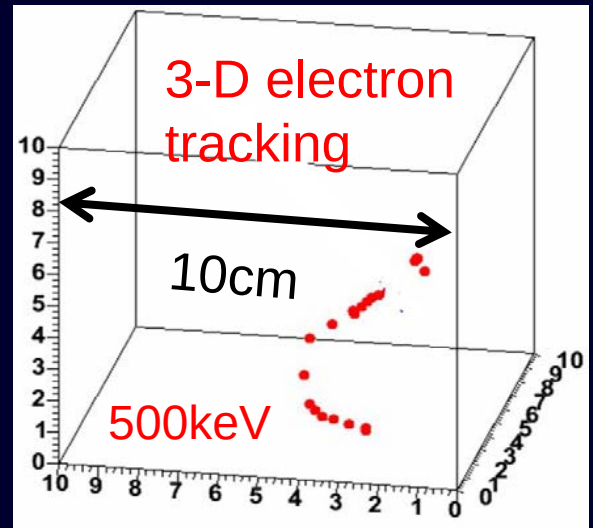


Gaseous TPC

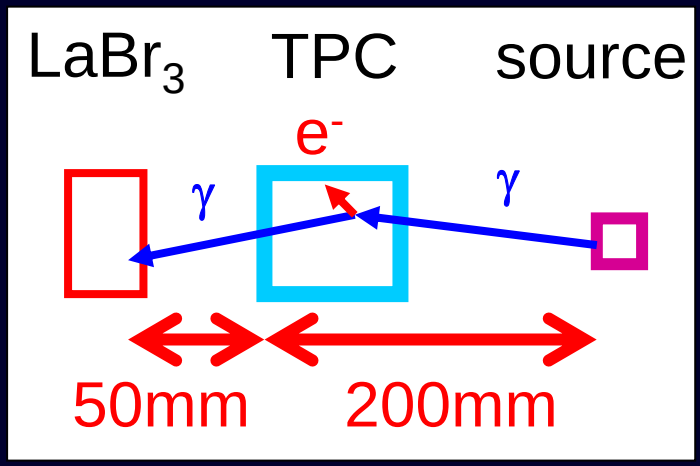
containing $Ar+C_2H_6$ 1atm



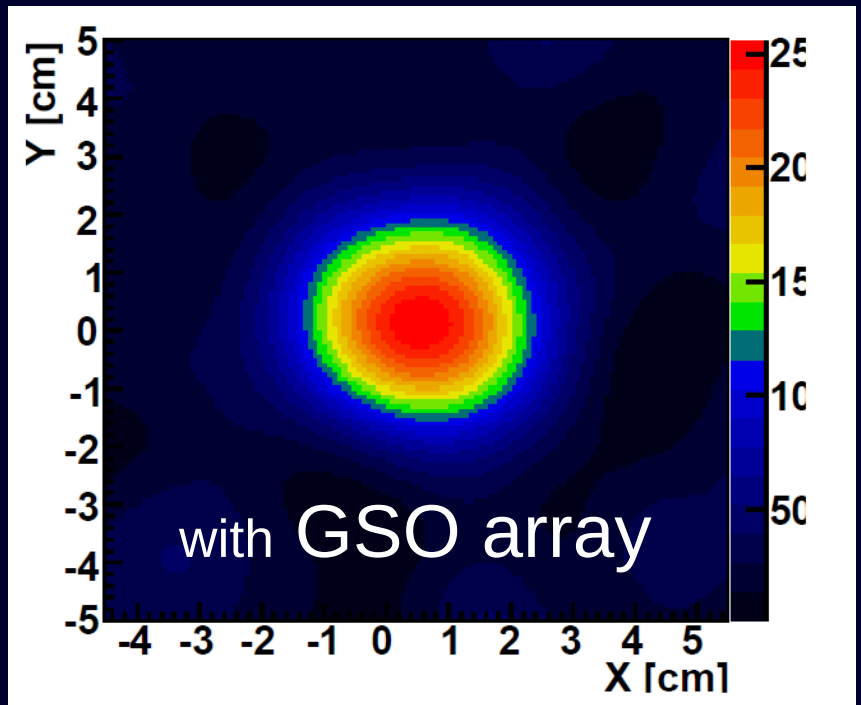


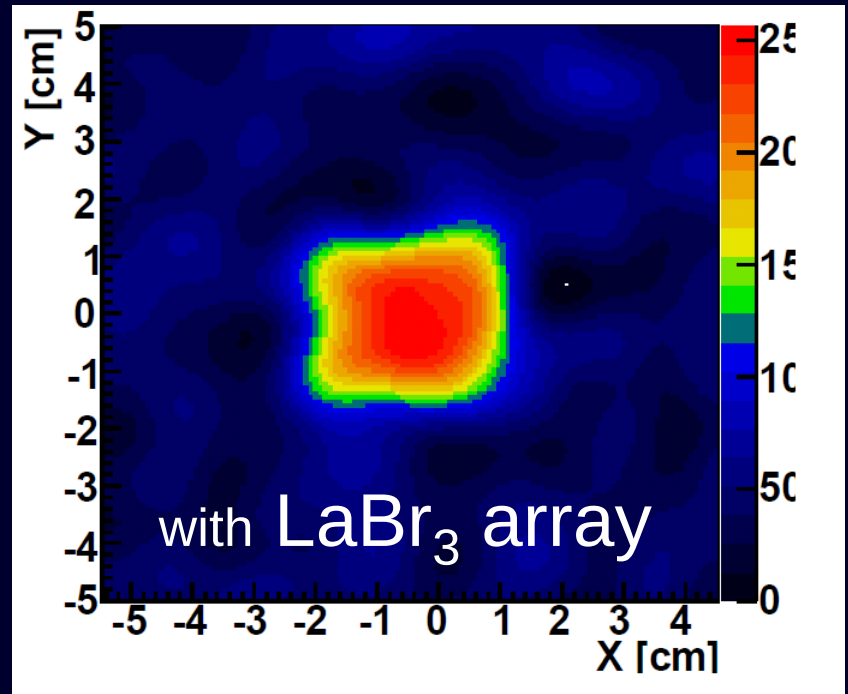


Performance of Compton camera

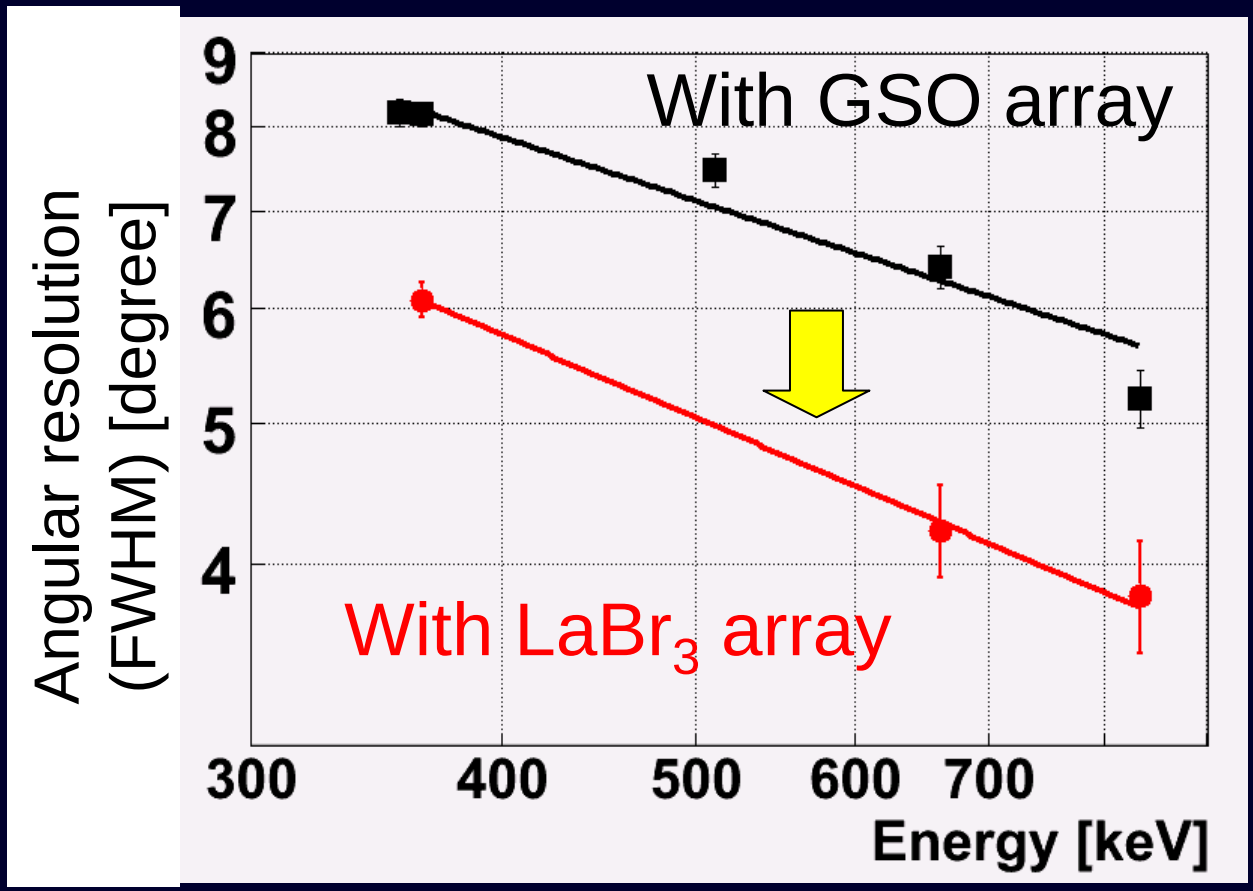


Source ^{131}I (364keV)





Improvement of the angular resolution



Angular resolution (FWHM) @662 keV [degree]

6.4±0.2 (GSO)

improved

4.2±0.3 ($LaBr_3$)

summary

- We assembled an 8×8 $LaBr_3$ pixel array in order to improve the angular resolution of Compton Camera.
  - Pixel size : 5.8 ×5.8 ×15 mm^3
  - Pixel pitch: 6.1mm (the same as that of MAPMT H8500)
  - Package size : 54 ×54 ×20 mm^3 (compact)
- Dynamic rage: 80 – 1000 keV
- Energy resolution of the array with MAPMT（FWHM、@662keV）
  - GSO array 10.7 ± 1.0 %
  - $LaBr_3$ array 5.8 ± 0.9 %
- Angular resolution of gamma camera (FWHM, @ 662 keV)
  - With GSO array 6.4±0.2 deg.
  - With $LaBr_3$ array 4.2±0.3 deg. (improved)
- Future works
  - We assemble more $LaBr_3$ arrays for expanding the effective area of Compton camera.
  - Individual readout system of all anode channels.


Fin