Two-dimensional Diced Scintillator Array for Innovative, Fine-resolution Gamma Camera

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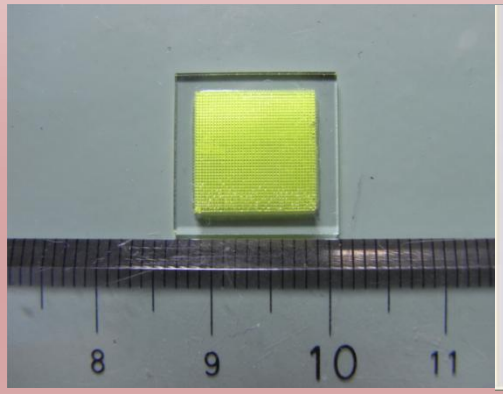

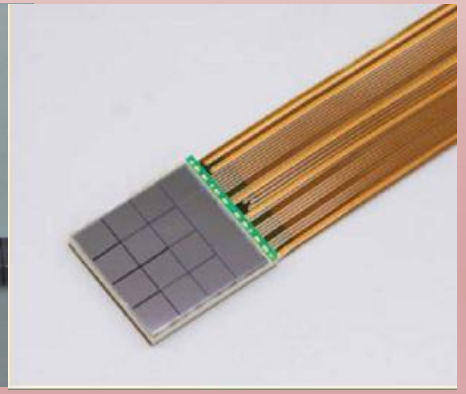

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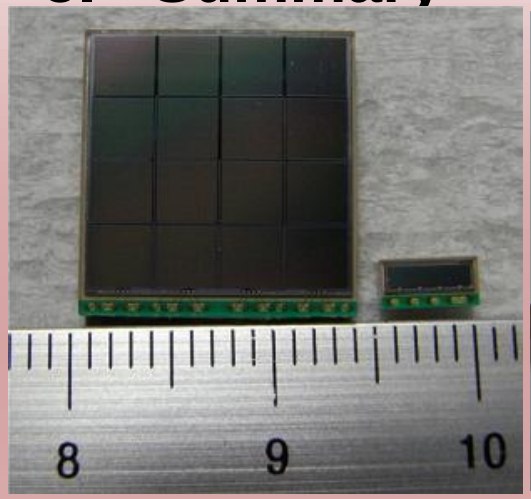
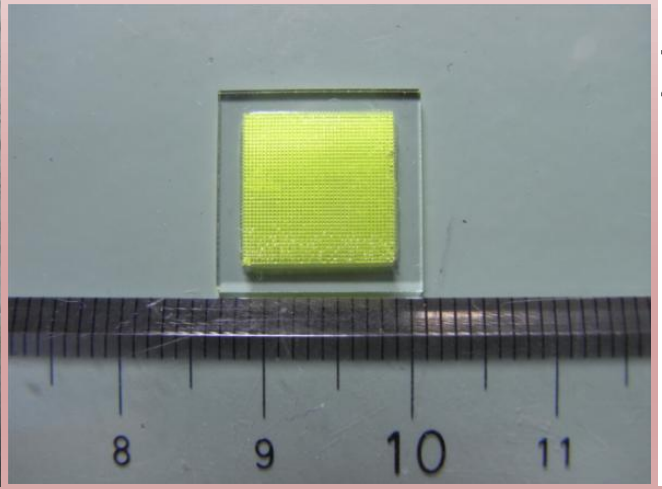
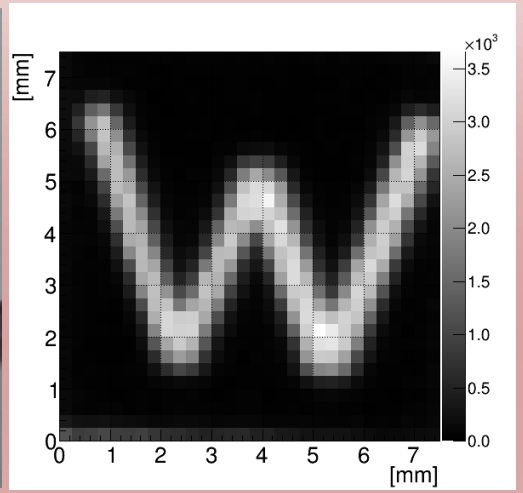






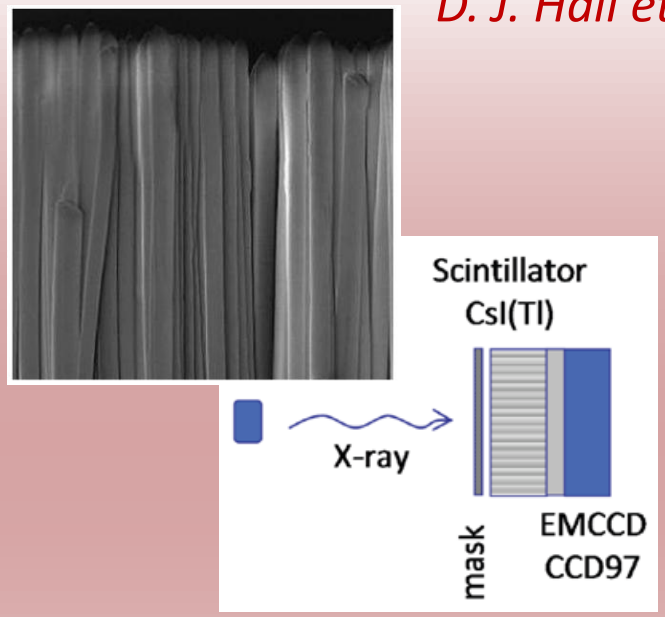
X-ray/gamma-ray imaging detectors

HAMAMATSU H8500

R. Pani et al. 2004

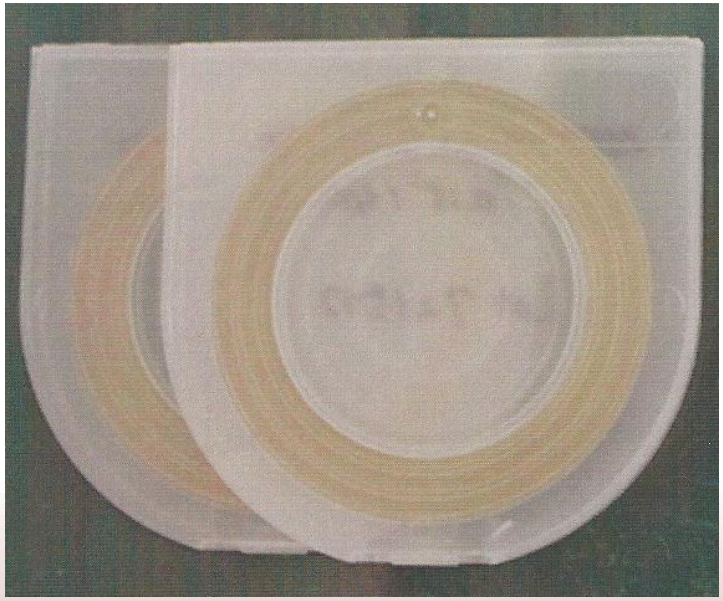
- NaI(Tl) scintillator array coupled to a flat panel photomultiplier tube.
- pixel resolution **400μm FWHM**(at 122keV)
- the light sampling is limited by too big anode size (**5. 5mm** pitch).

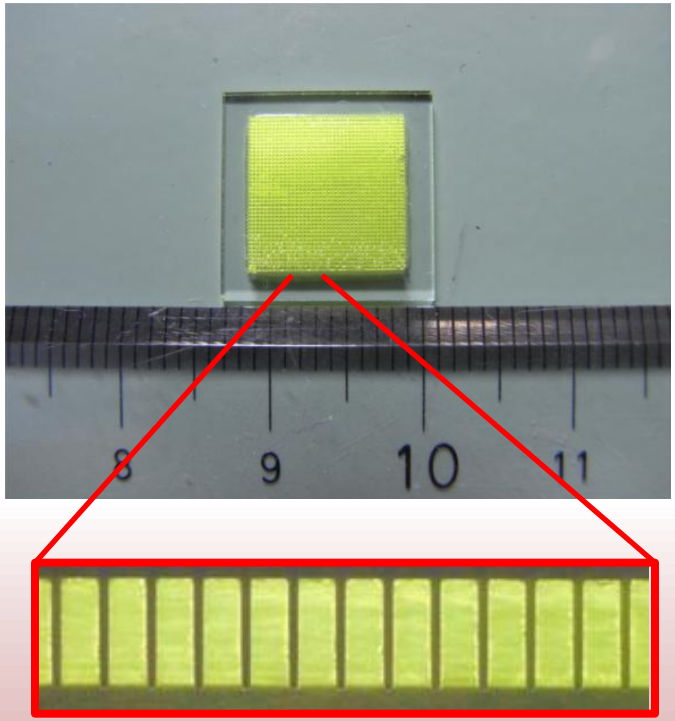
D. J. Hall et al. 2012



- A **5, 6μm** diameter columnar crystals of CsI(Tl) are formed on a fiber optic taper.
- Electron Multiplier CCD
- Photon counting technique
- **High** spatial resolution (**31μm** FWHM)
- **Low** sensitivity(~**70μm** thick)

Our approach



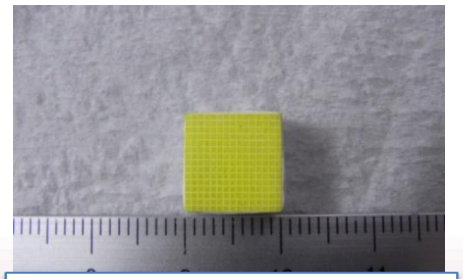


- Due to the development of machining in recent years, it have been enabled to cut micro-grooves into a scintillator.
- We fabricated fine-pitch scintillator array, by using dicing saw to cut micro-grooves **50μm** wide.

Ce:Gd3Ga2Al3O12 Scintillator Array

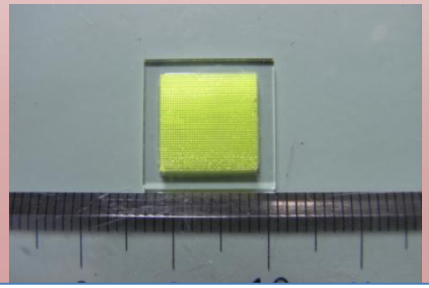
K. Kamada et al. 2011; I. G. Valaiset al. 2006

Scintillator	Ce:GAGG	Ce:LYSO	CsI(Tl)
Density(g/cm^3)	6.63	7.1	4.5
Light yield(ph/keV)	46	26	60
Decay time(ns)	52	40	1000



15x15 array,
0.5x0.5x5mm^3

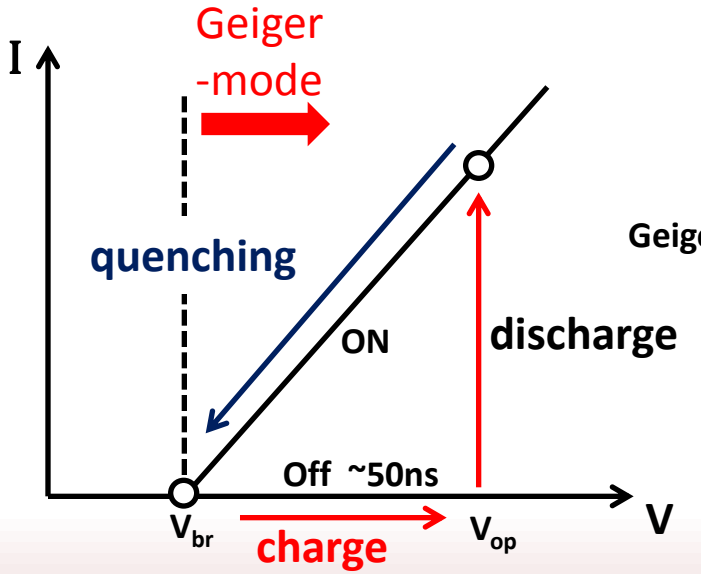
- A scintillator array fabricated by traditional way.
- Each pixel is separated 0.1mm thick BaSO4 layer.
- coupled to 1mm thick acrylic light guide with optical grease (OKEN6262A)

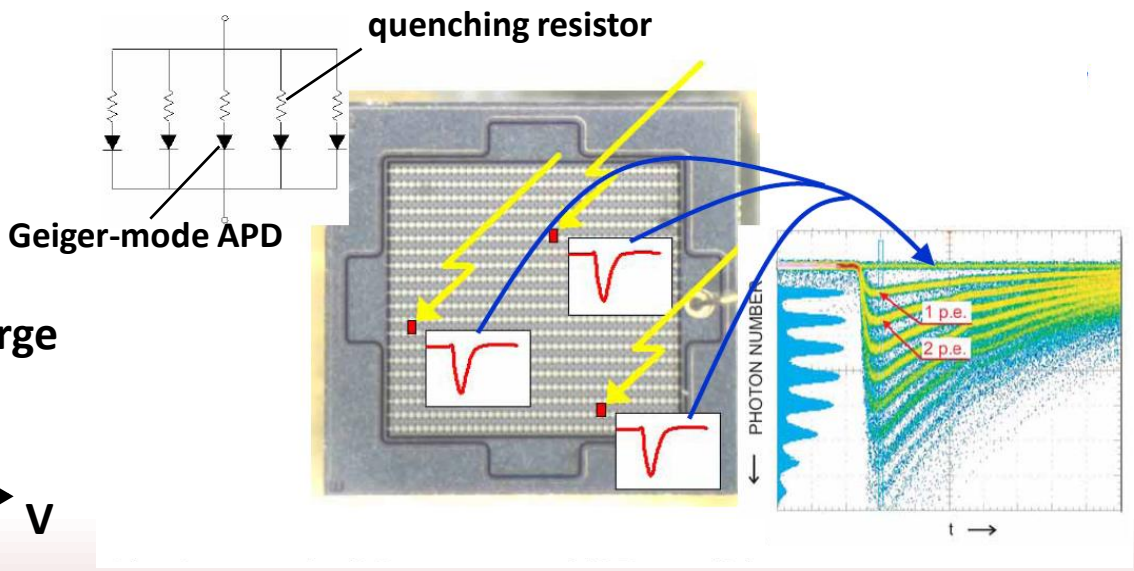


40x40 array,
0.2x0.2x1mm^3

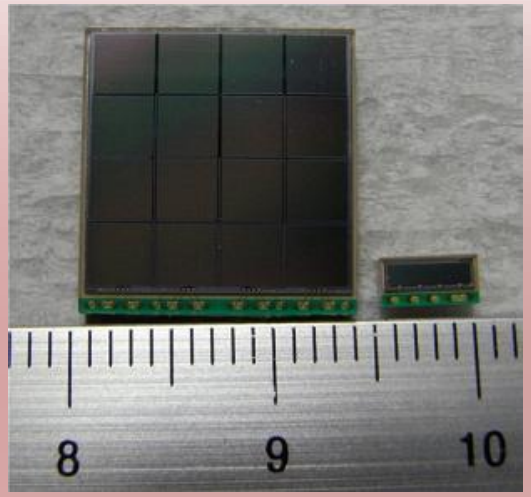
- A scintillator array fabricated by cutting grooves
- A 1mm thick Ce:GAGG plate (10mm square) glued to a 1mm thick glass plate(14mm square)
- Grooves: 0.25mm pitch, 0.05mm width, 0.95mm depth, coated with BaSO4.

Multi-Pixel Photon Counter(MPPC)

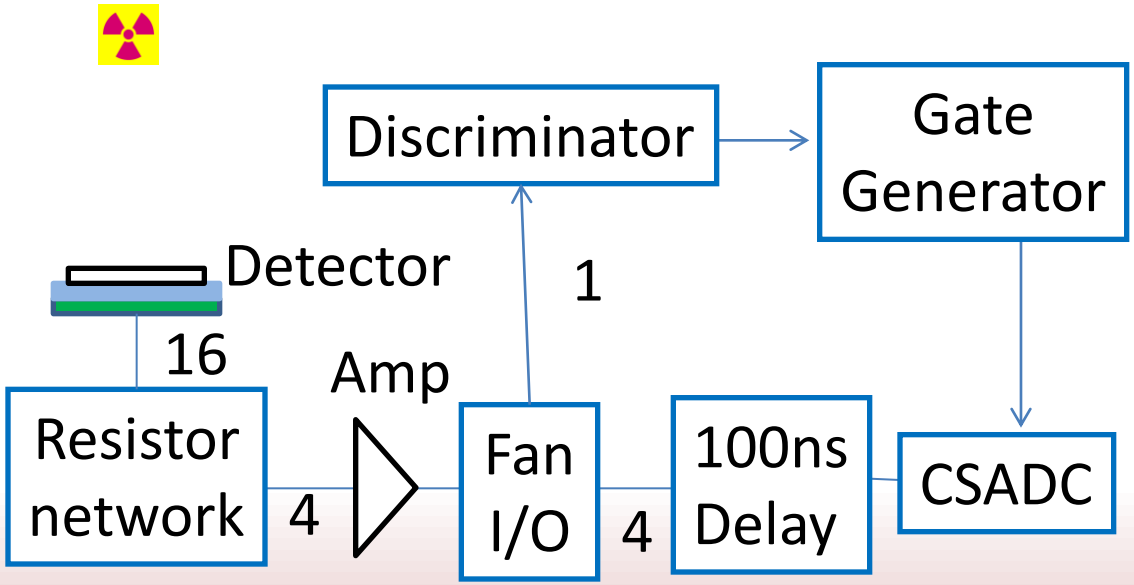


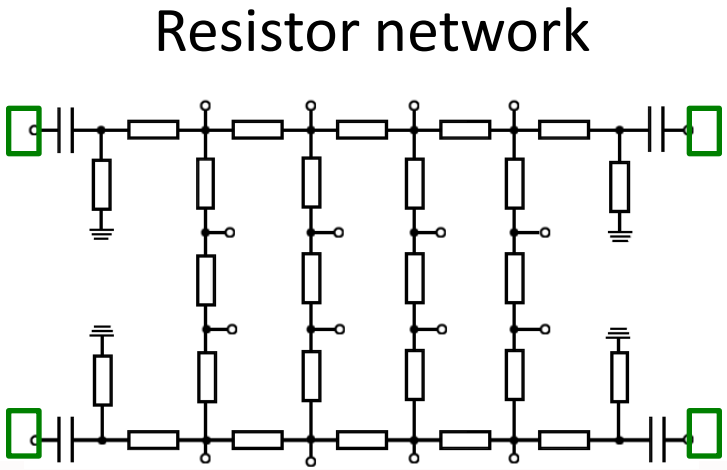


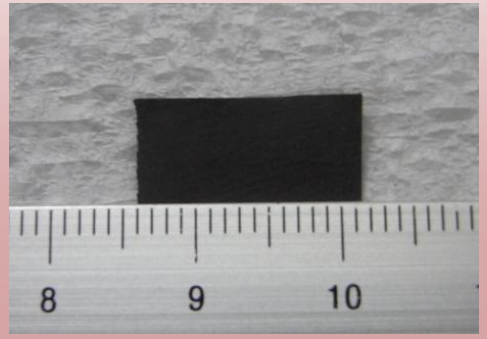
- A 2D-array of Geiger mode APD pixels
- charges proportional to the number of fired pixels
- compact
- low bias voltage (<100V)
- high gain (10^5~10^6)
- insensitive to B fields



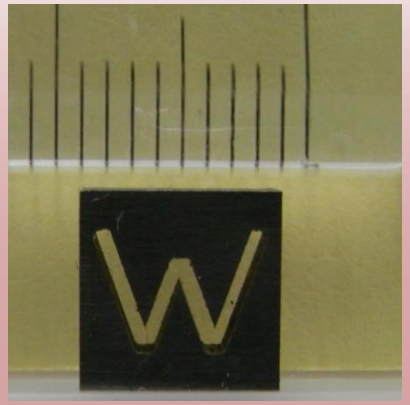
Experimental Setup







Tungsten sheet
(thickness:0.5mm)



Tungsten collimator
(thickness:3mm,Line width : 0.7mm)

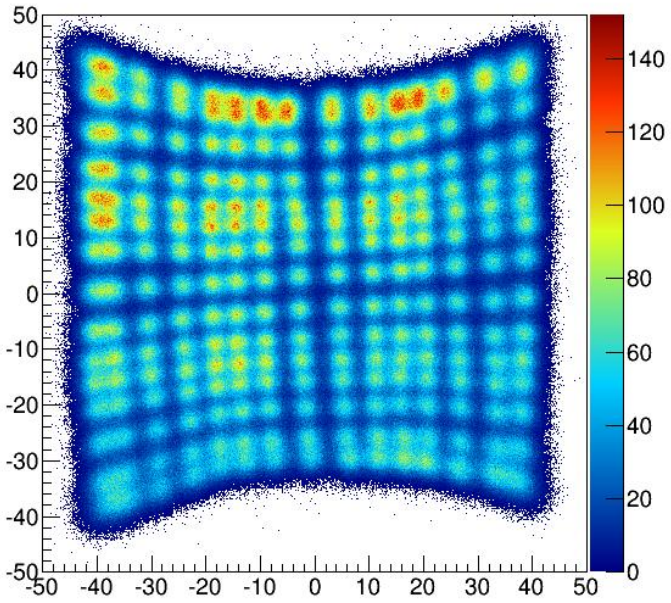
Flood map: nothing

Spatial resolution: Tungsten sheet

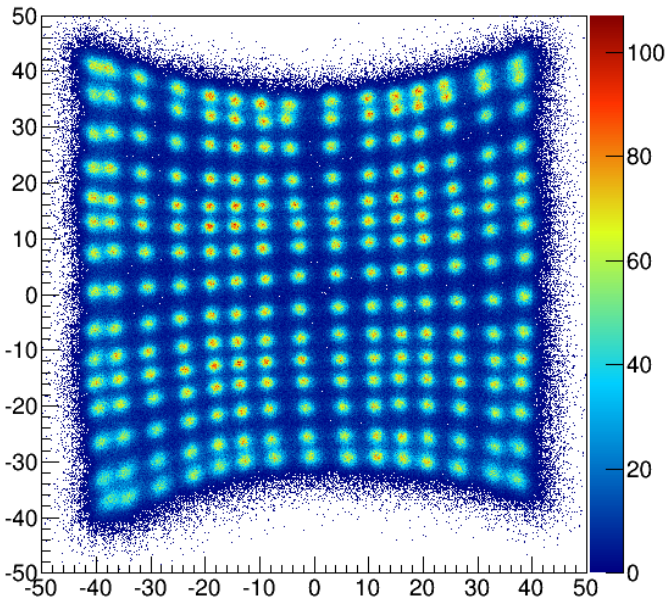
Imaging : Tungsten collimator

0.6mm pitch Ce:GAGG array

^{241}Am



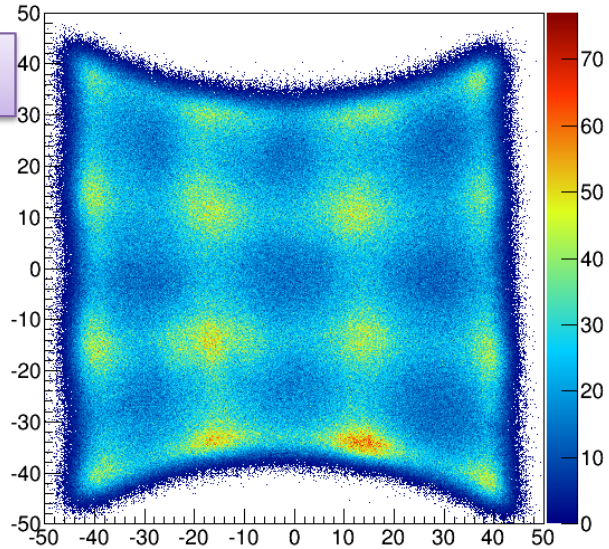
^{57}Co



- Each pixel is successfully resolved at 122keV,
  however, at 59.5keV some side pixels are overlaped.
- Pixel resolution is 0.25mm(FWHM)
  at the center of the scintillator arrayat 122 keV.

0.25mm pitch Ce:GAGG array

^{241}Am



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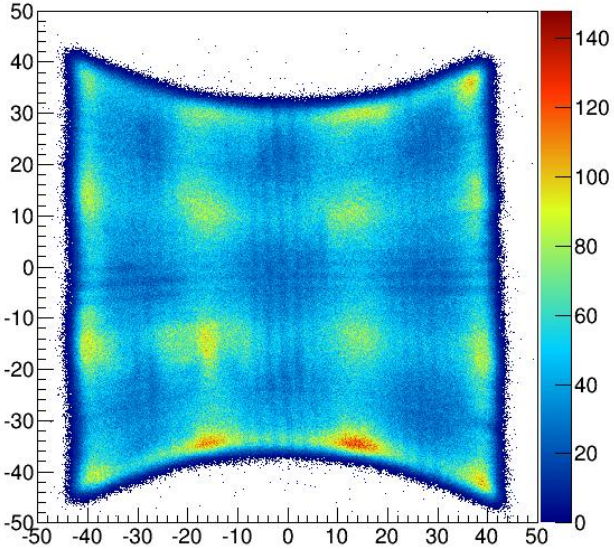
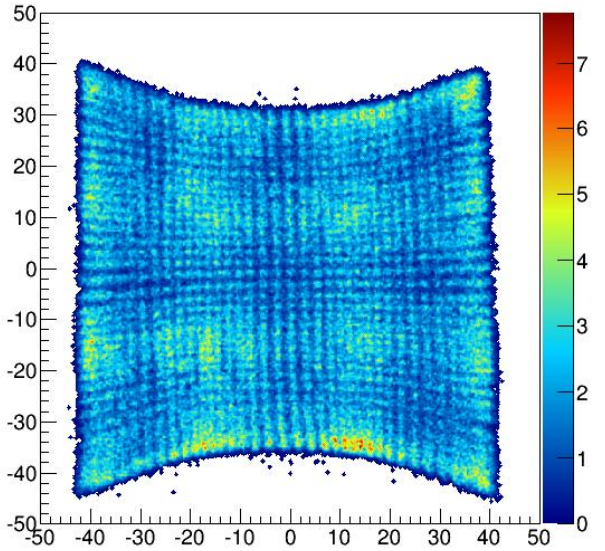
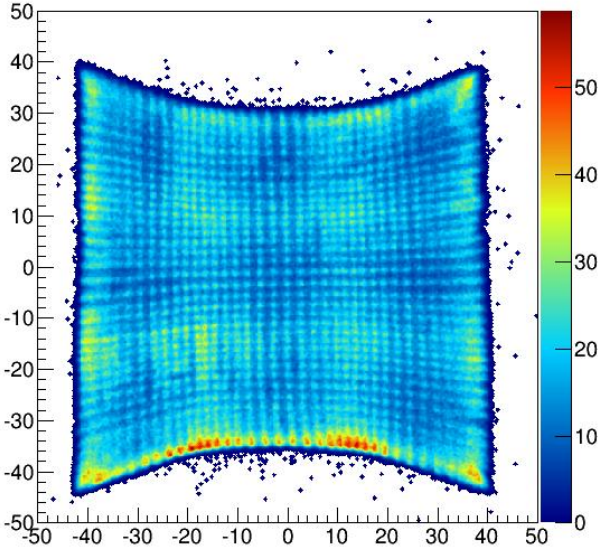


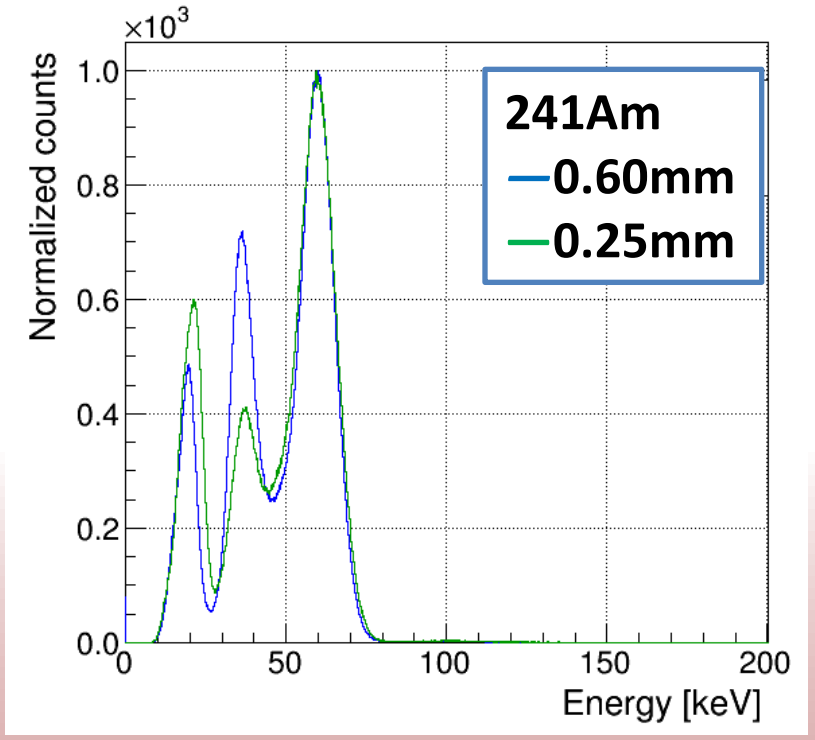
^{133}Ba

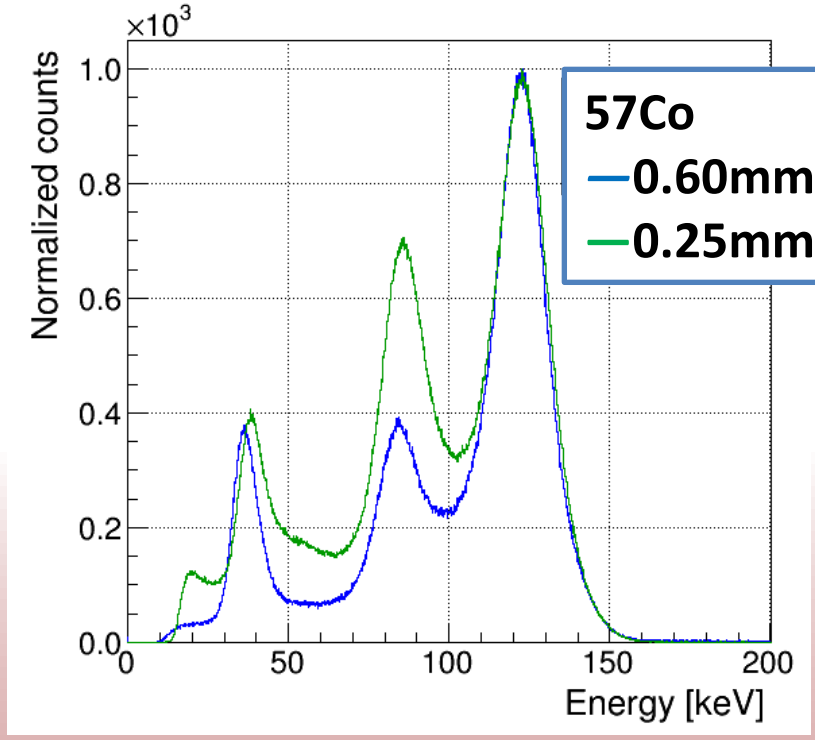


^{60}Co



Energy spectrum

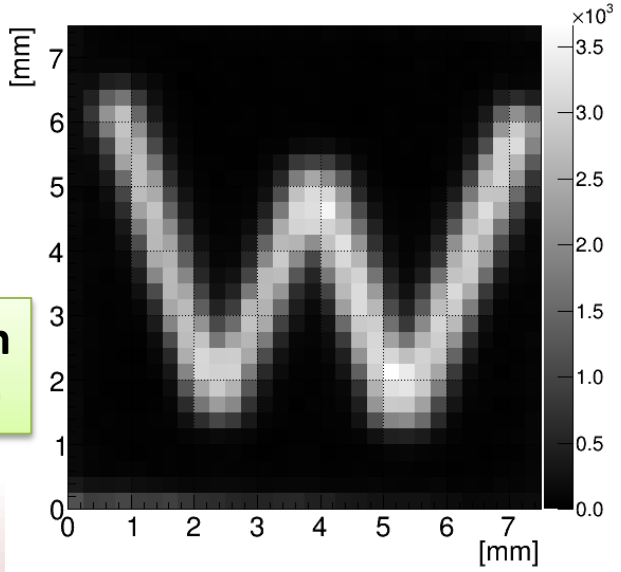




0.60mm pitch	21.8%(FWHM)@59.5keV	13.2%(FWHM)@122keV
0.25mm pitch	23.5%(FWHM)@59.5keV	14.4%(FWHM)@122keV

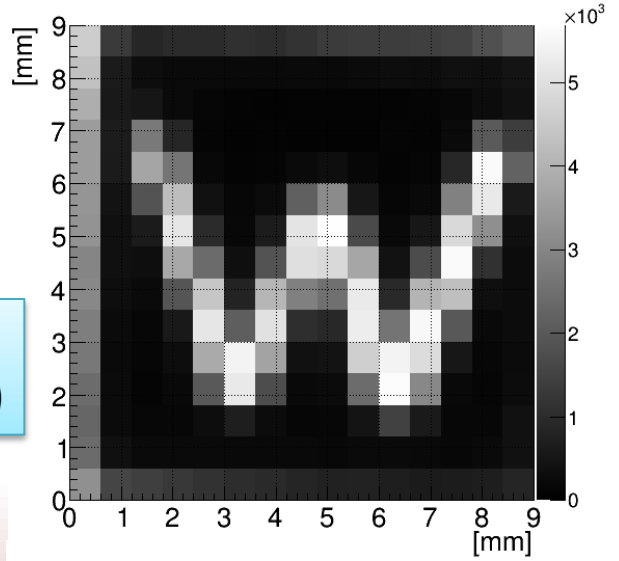
Results of imaging a collimator

0.25mm
122keV



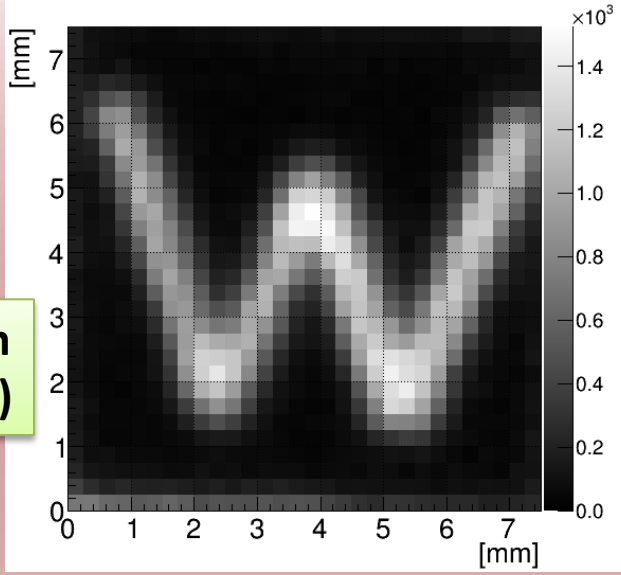
0.48±0.05 mm
(FWHM)

0.60mm
122keV



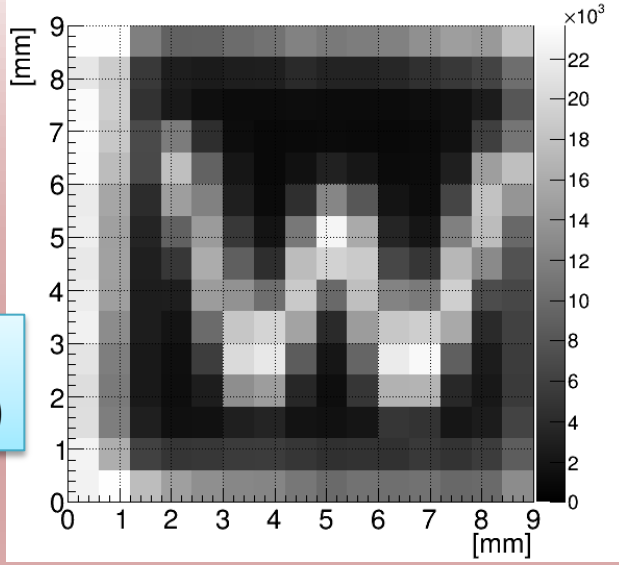
0.77±0.09 mm
(FWHM)

0.25mm
59.5keV



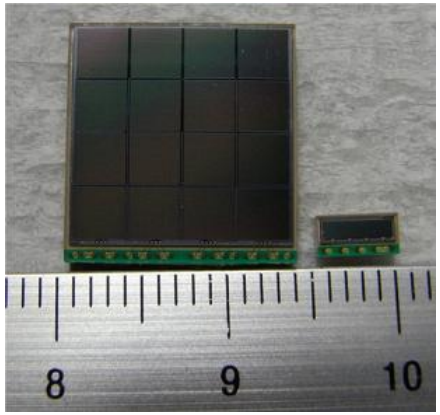
0.69±0.05 mm
(FWHM)

0.60mm
59.5keV

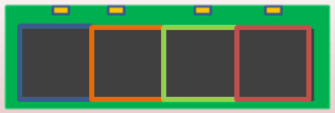


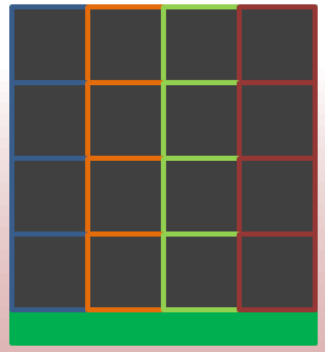
0.88±0.07 mm
(FWHM)

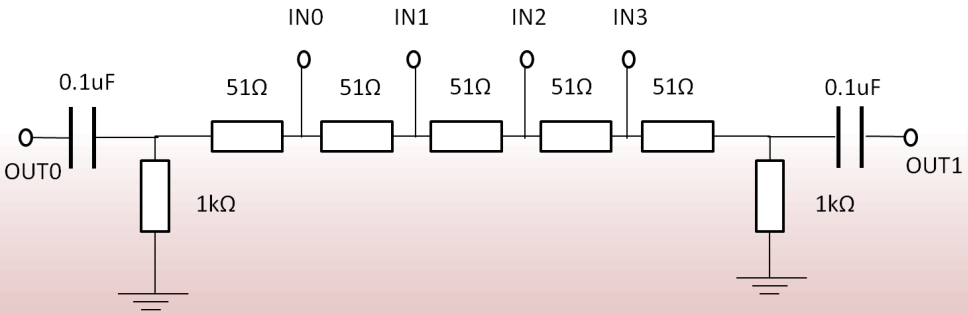
1mm square vs. 3mm square



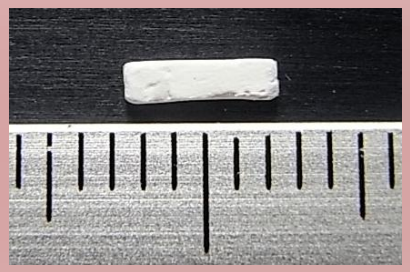
- It is expected that
  size of MPPC macro pixels limits pixel resolution.
- Hamamatsu S11830-33-44MB(3mm square, 4x4 pixels)
- Hamamatsu S10984 (1mm square, 1x4 pixels)





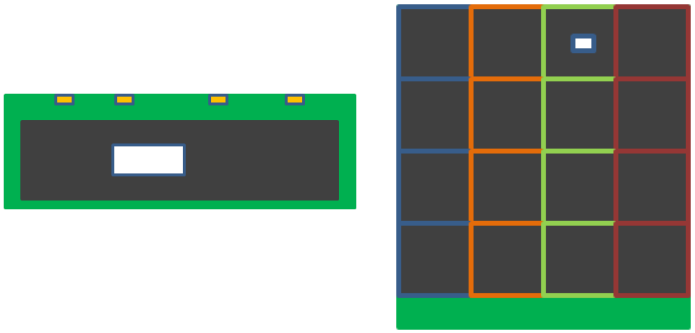


$$X = 100 * (OUT1-OUT0)/(OUT1+OUT0)$$



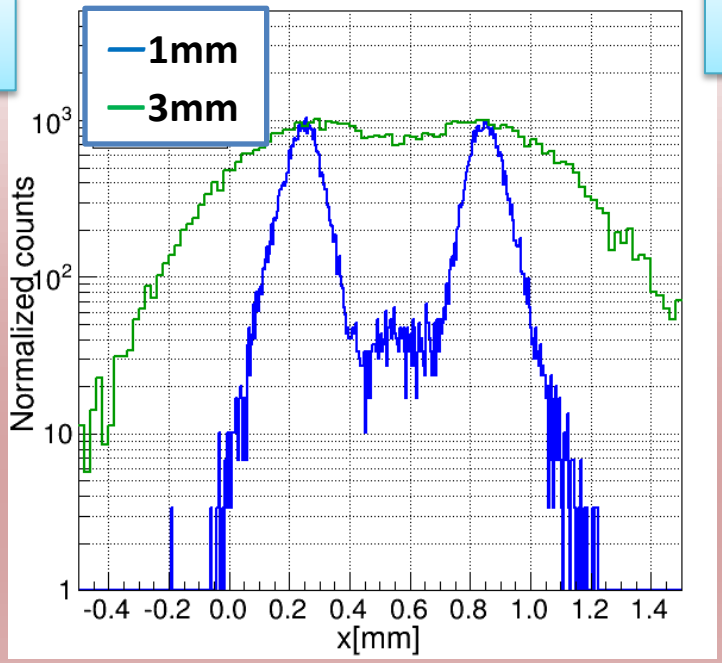
- An array of $0.5 \times 0.5 \times 5.0\,mm^3$ Ce:LYSO
- 1x2 pixels array
- Each pixel is separated by 0.1mm thick BaSO4 layers.

Comparison of pixel resolution

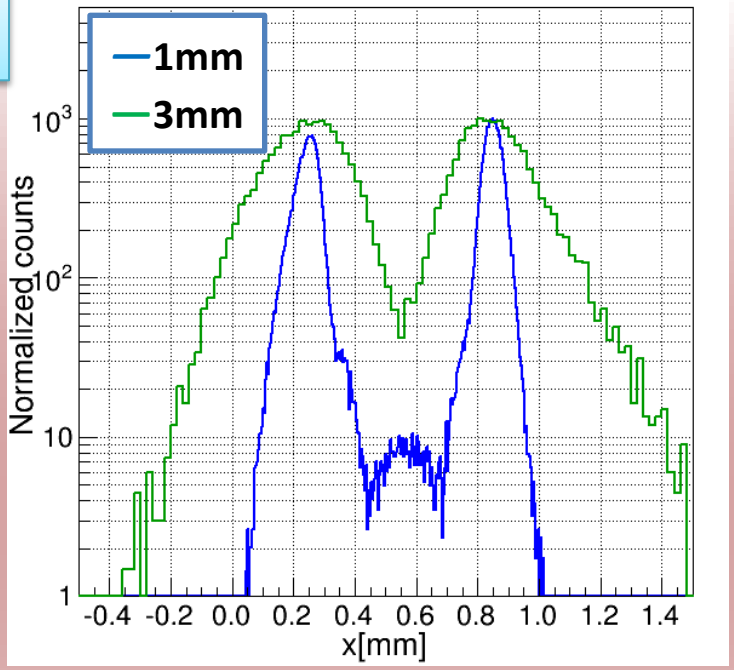


- 3mm square array is coupled to a 1mm thick acrylic light guide.
- 1mm square array is directly coupled to the LYSO array.
- Optical grease : OKEN 6262A
- The Scintillator is put on the center of a MPPC's macro pixel.

122keV

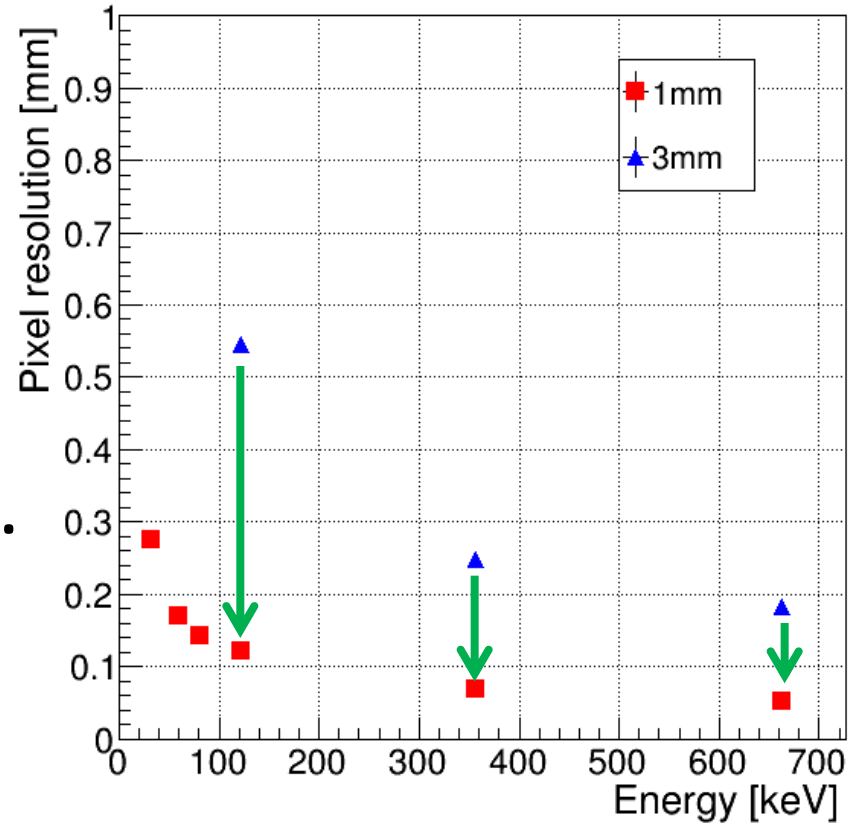


356keV



Comparison of pixel resolution

- The 1mm square MPPC array has higher pixel resolution than the 3mm square MPPC array.
- Even at the low energy of 59.5keV, the 1mm square MPPC array has high pixel resolution, 0.17mm FWHM.
- Since GAGG has higher light yield than LYSO, a GAGG array will show better performance than LYSO.



Summary

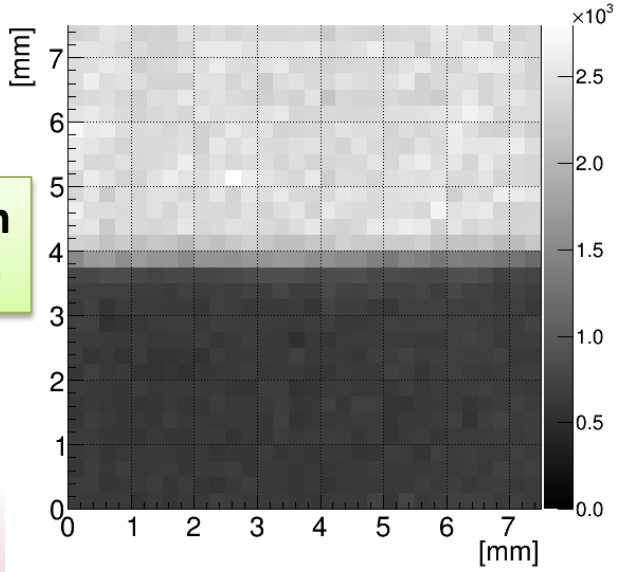
- We developed the detector coupling the 0.25 mm pitch Ce:GAGG array with 3mm square MPPC array. Spatial resolution was 0.48mm (FWHM) and energy resolution was 14.4% (FWHM) at 122keV.
- We compared pixel resolution of 1mm and 3mm square MPPC array. Even at the low energy of 59.5keV, 1mm square MPPC array showed high pixel resolution, 0.17mm (FWHM).
- We will develop a large area 1mm square MPPC array and develop a high stopping power and fine-resolution gamma camera in near future. The detector will be applied to X-ray/gamma-ray imaging and spectral CT.

Appendix

Edge Spread Function

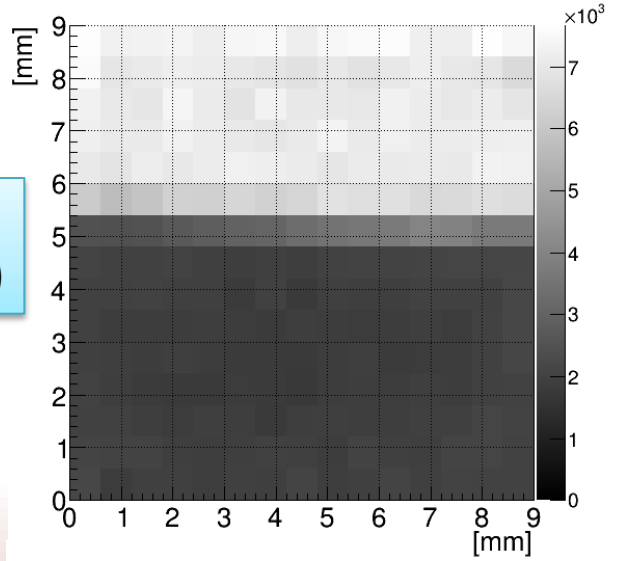
0.25mm
122keV

0.48±0.05 mm
(FWHM)



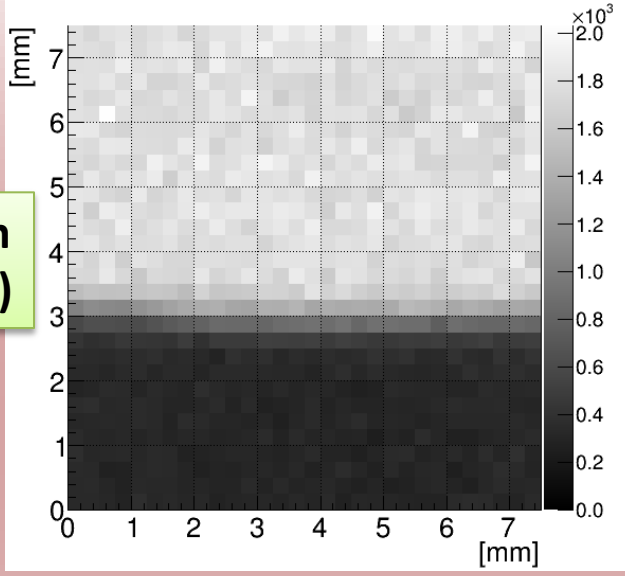
0.60mm
122keV

0.77±0.09 mm
(FWHM)



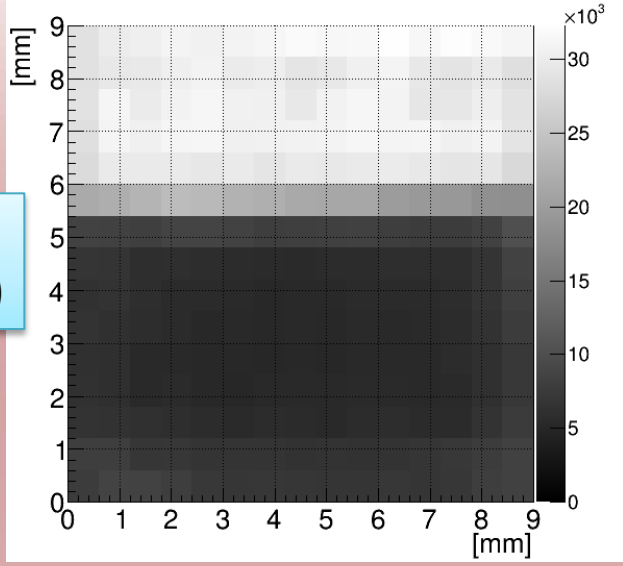
0.25mm
59.5keV

0.69±0.05 mm
(FWHM)

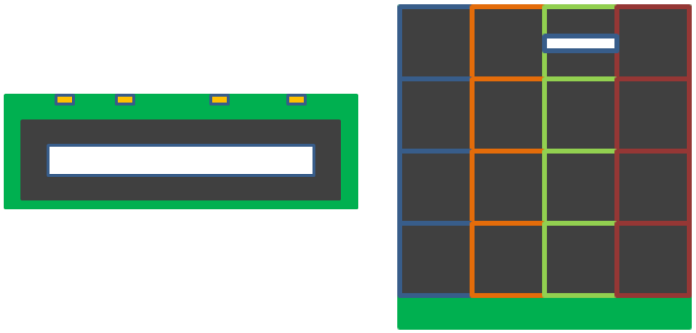


0.60mm
59.5keV

0.88±0.07 mm
(FWHM)



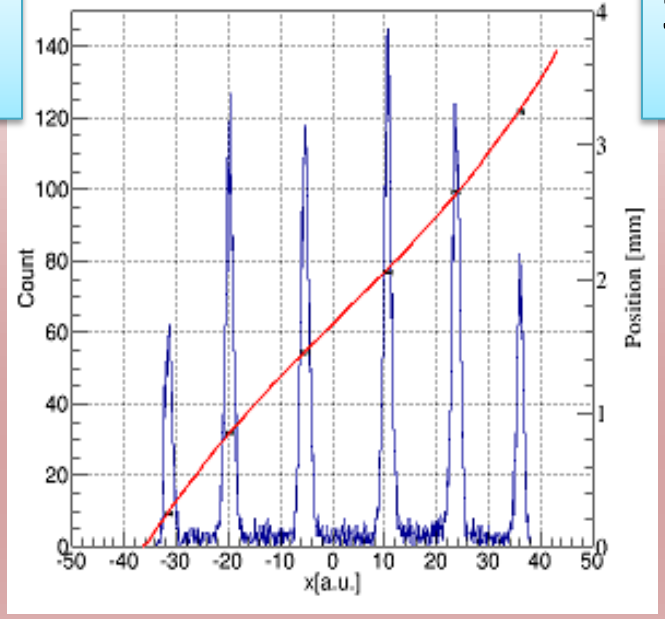
The linearity of coordinates



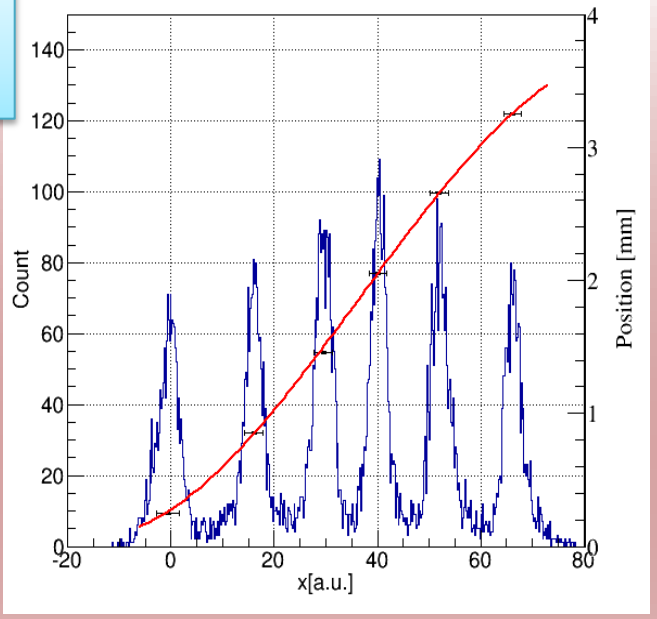
- 3mm square array is coupled to a 1mm thick acrylic light guide.
- 1mm square array is directly coupled to a 1x6 pixels LYSO scintillator array.
- Optical grease : OKEN 6262A

137Cs(662keV)

1mm square MPPC array



3mm square MPPC array



Detail about resistor network