Studies of the performance of different Front-end systems for Flat-panel Multi-anode PMTs with CsI(Tl) Scintillator Arrays

IWORID-7

July 4, 2005, Grenoble, France

Hiroyuki Sekiya

Kyoto University

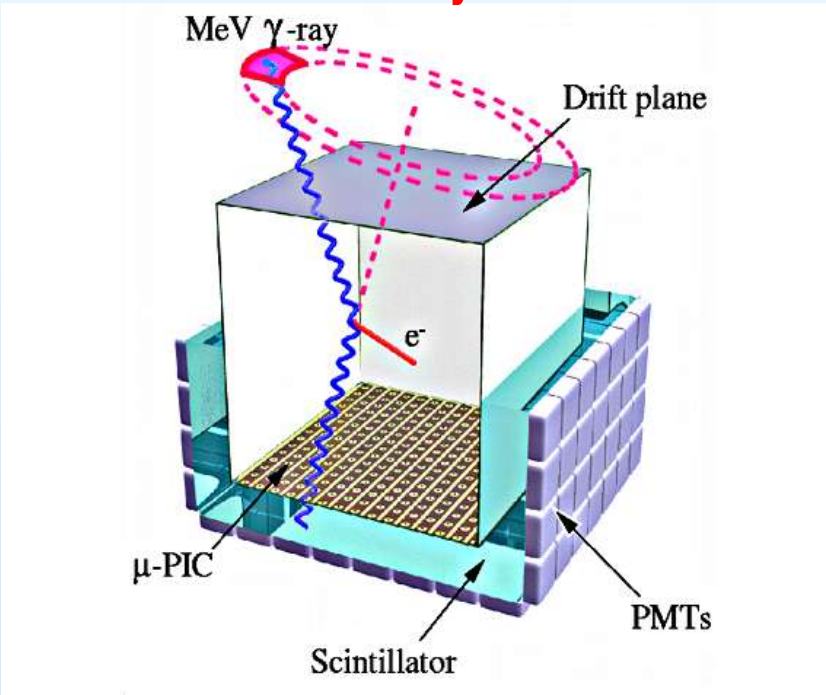
Direction Sensitive γ-ray Imaging Detector

sub MeV ～ MeV gamma-ray Imaging for...

- MeV gamma-ray Astronomy
- Medical Imaging (Post SPECT/PET)

Advanced Compton Imaging

Reconstruct Compton scattering event by event



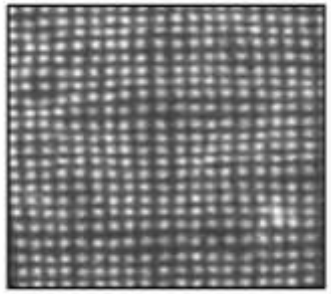
- μ-TPC (μ-PIC)
  track and energy of recoil electron
- Scintillator
  position and energy of scattered gamma

Multi Anode PMT
+
Pixelated Scintillator
Array

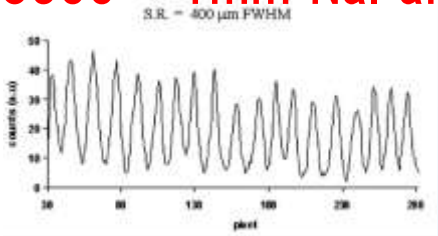
Motivation

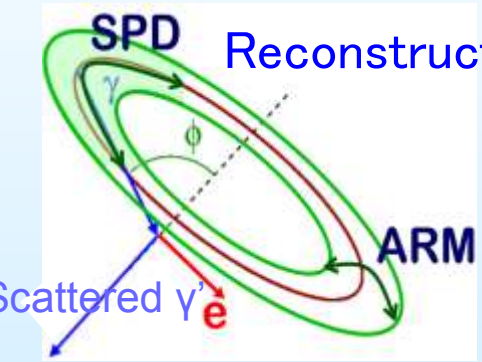
●Position resolution has been examined for PET applications.

R. Pani et. al.,
NIM A527(2004) 54

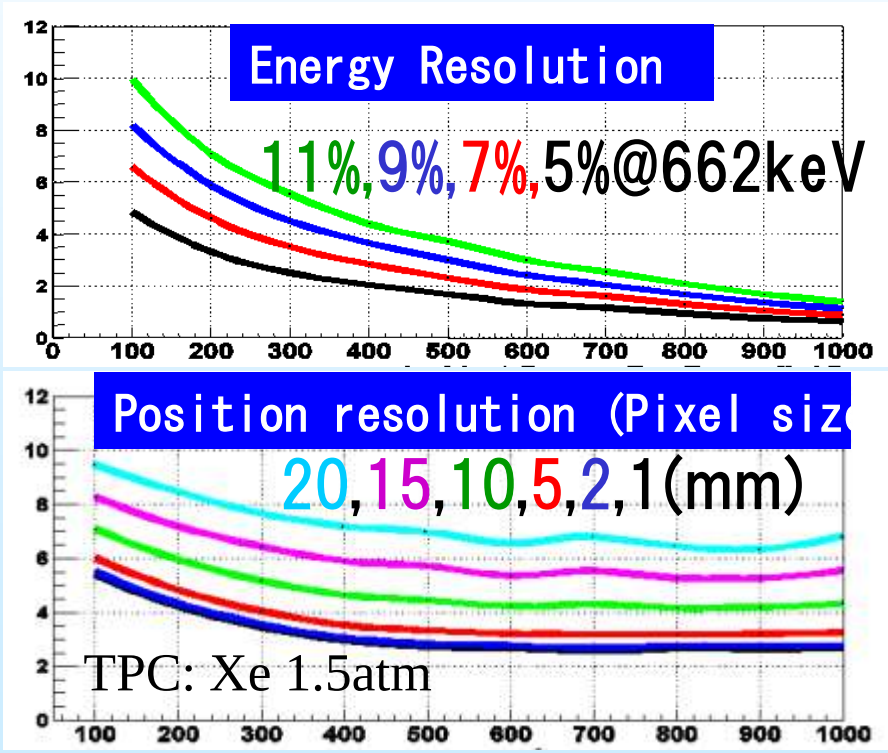


H8500 + 1mm NaI array



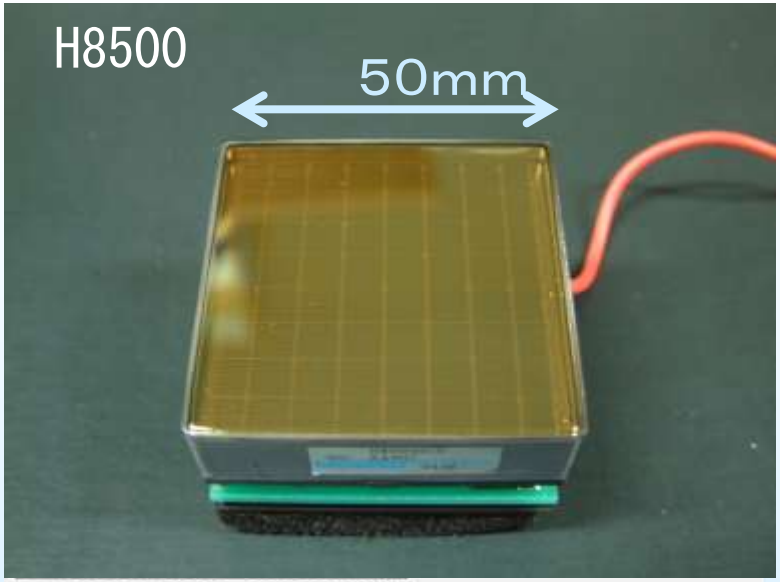


Reconstructed gamma direction are affected by both position and energy resolution of the scintillator



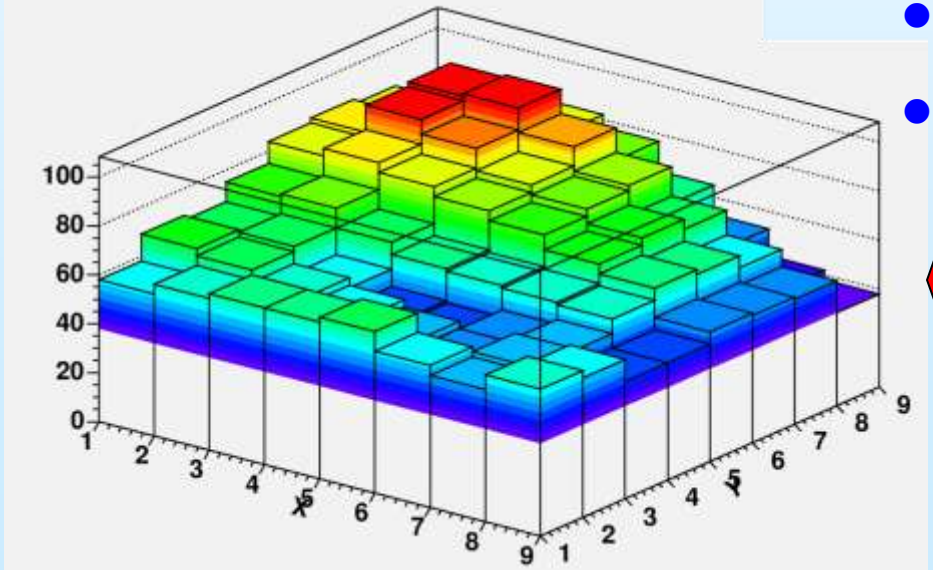
●We have examined not only position resolution but also dynamic range (100keV-1MeV) and energy resolution.

Hamamatsu H8500



Specifications

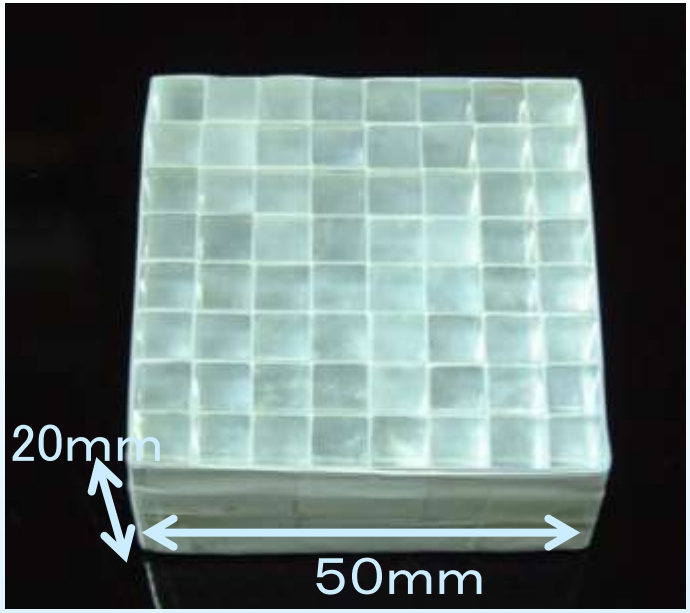
- 8×8 Multianode
- 6mm pixel pitches
- 12 stage metal channel dynode
- Gain ～10^6@-1000V
- Rise time 0.8 ns
- Photo Cathode Coverage 89%
- Cross talk (w/o optical) 3%

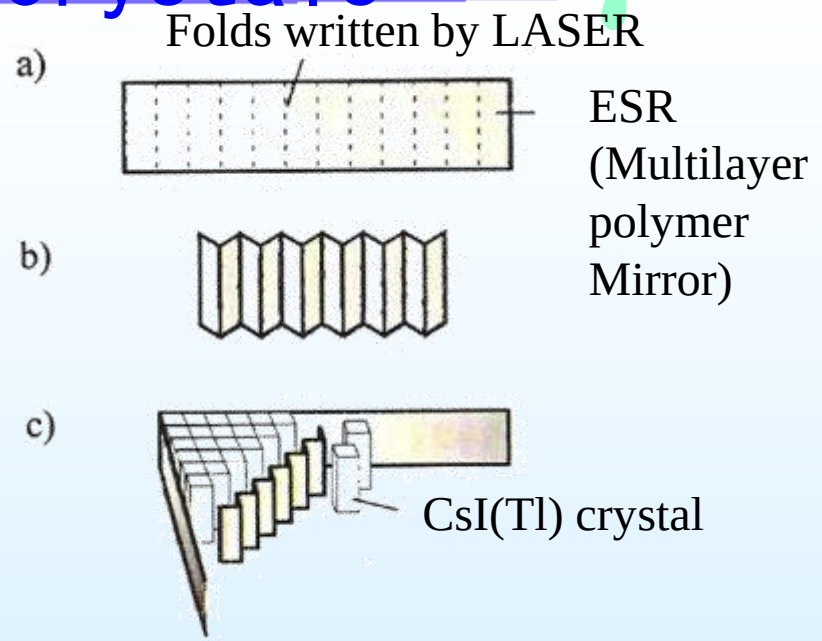


Anode Gain Map (S/N ZA3115)

Anode uniformity
min : max = 1 : 2.6

Array of pixelated CsI(Tl) crystals

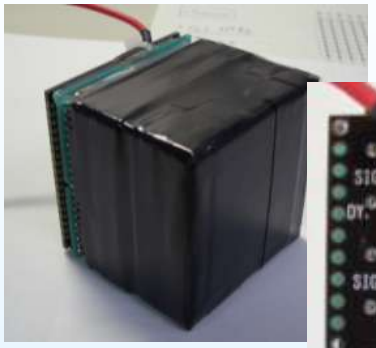




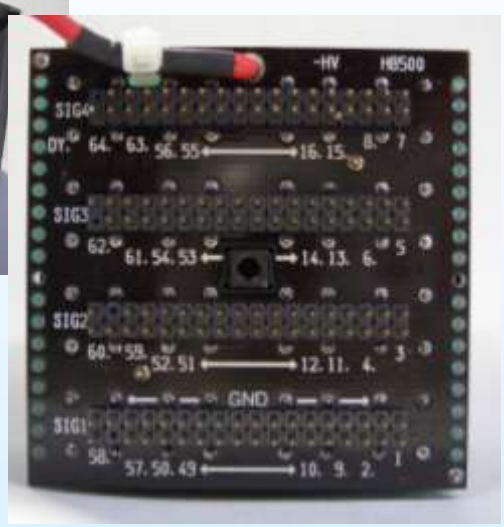
- 6mm × 6mm × 20mm CsI(Tl) pixel (Hamamatsu)
- 8 × 8 array fits to anodes of H8500
- Pixels are optically isolated by the ESR (3M)
- Glued to H8500 with OKEN-6262A grease.

Read-out Methods and Experimental Setup

Front View



Rear View



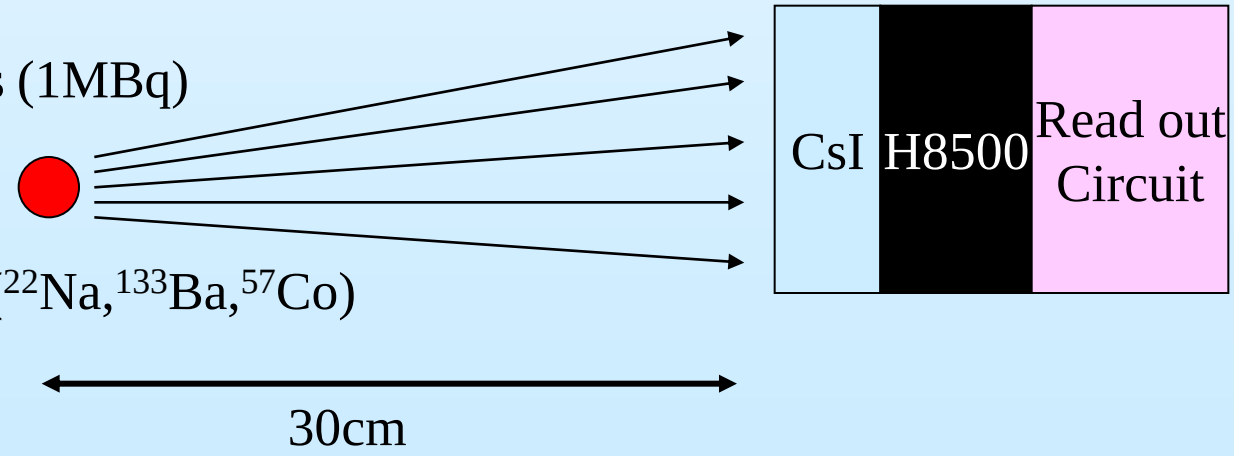
In order to deal with 64 anodes .....

Comparatively evaluate
the following read-out systems.

- 64ch readout with ASIC
- 16ch Resistive charge division
- 4ch Resistive charge division

Experimental Setup

662keV γ-rays are uniformly irradiated to the array.



Every 64ch read-out with ASICs

Head Amp+FADC module CP80068 (by Clear Pulse Co. Ltd.)

32ch 0.8um CMOS ASICs (by IDEAS ASA)

VA32_HDR14

pre-amplifier (dynamic range ～15pC)
shaper (gain 118mV/pC, peaking time 2us)
sample & hold
multiplex

TA32CG2

Fast shaper (peaking time 75 ns)
discriminator
wired OR

self trigger

FADC

164usec/64ch to read out

Every 64ch read out with ASIC

VME sequence module
for 4 head amp

Head Amplifier
with H8500 and CsI(Tl) Array

- The dimension is designed for 2D array

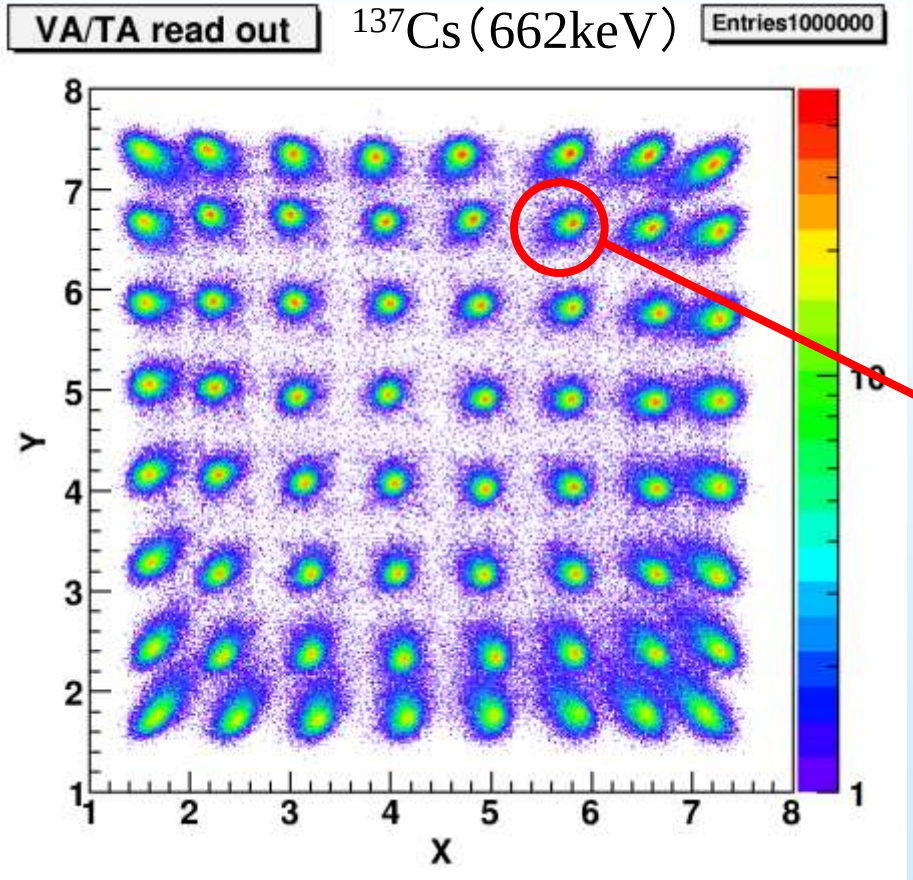
RJ45
Serial
cable

HV ～ -600V

- Input dynamic range of VA32_HDR14 is as small as -15pC,
H8500 has to be operated with the gain of 10^4 for CsI(Tl).

VA 64ch read out

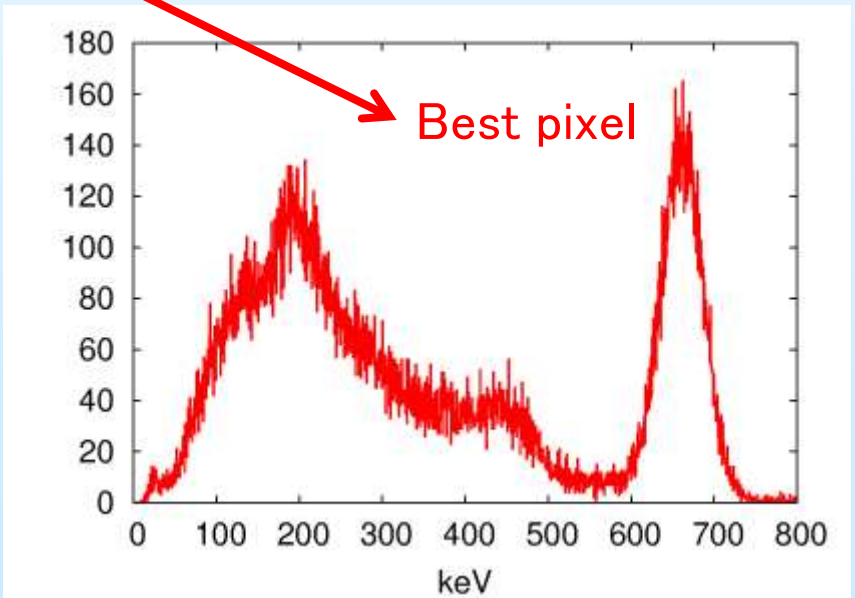
Position image map



$$P_i = \text{ADC output of } i\text{th ch}$$

$$x = \frac{\sum_{i=1}^{64} P_i(i \bmod 8)}{\sum_{i=1}^{64} P_i}$$

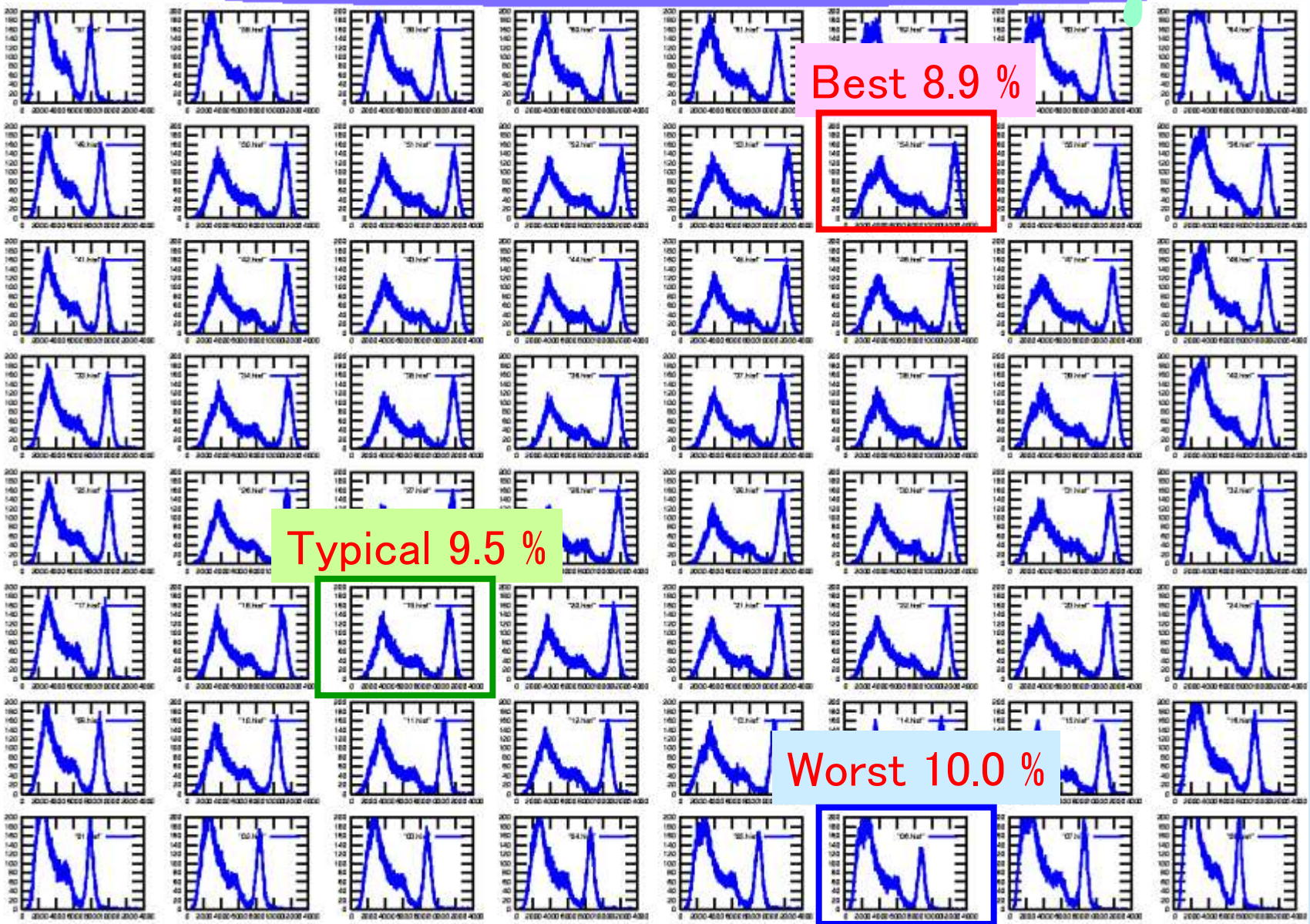
$$y = \frac{\sum_{i=1}^{64} P_i(i \mathrm{div} 8)}{\sum_{i=1}^{64} P_i}$$



Energy resolution
8.9%@662keV(FWHM)

HV=630V, gain=3×10^4

VA 64ch read out

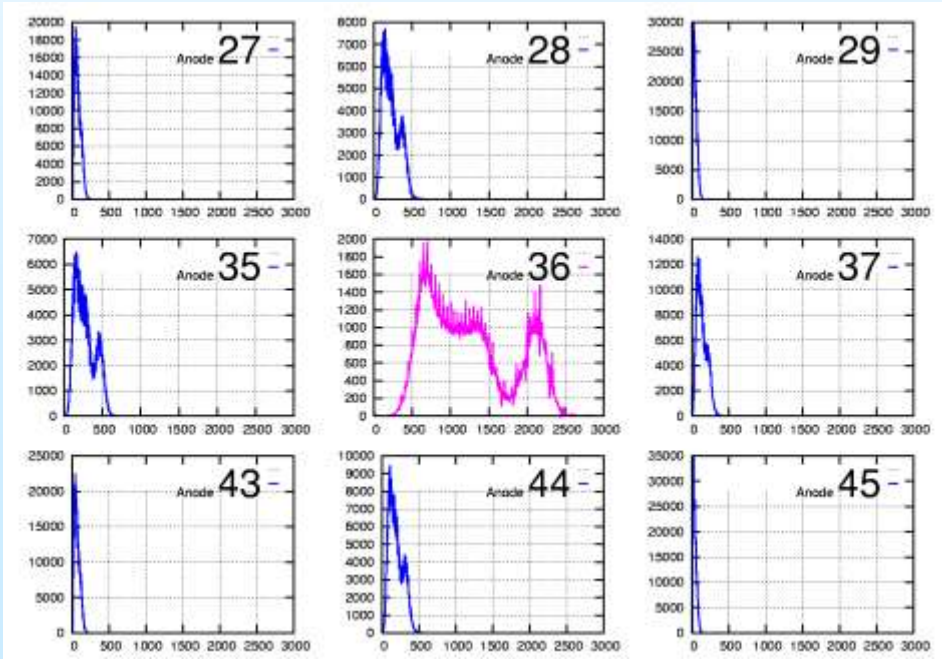


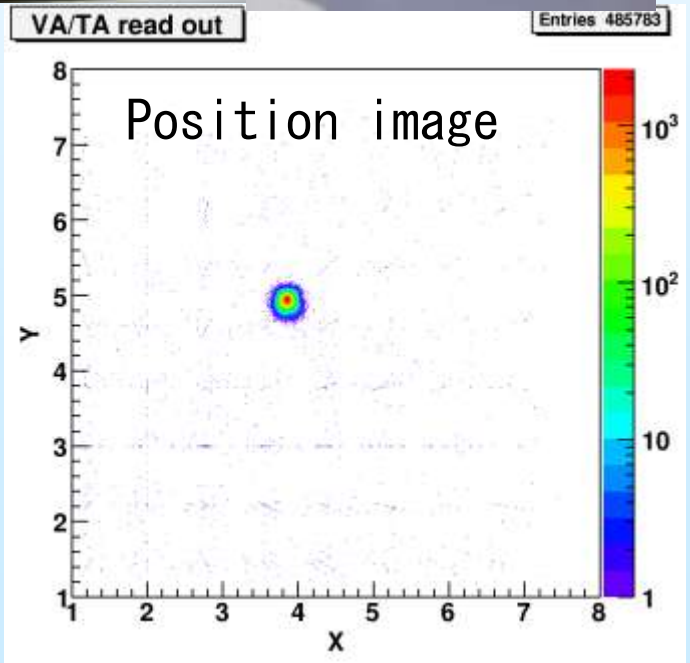
Optical Leakage/Cross Talk

- One CsI(Tl) pixel is attached to anode 36 area.
- Others are masked.

We observed the response of neighbor anodes.

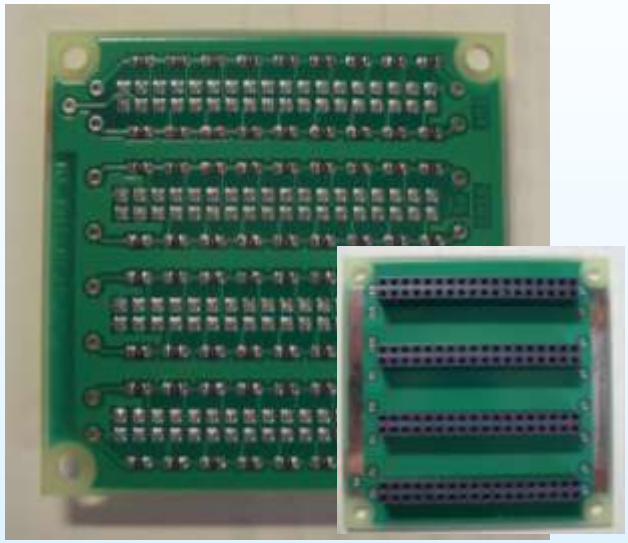
25% cross talk { 1.5mm glass / cathode to 1st dynode

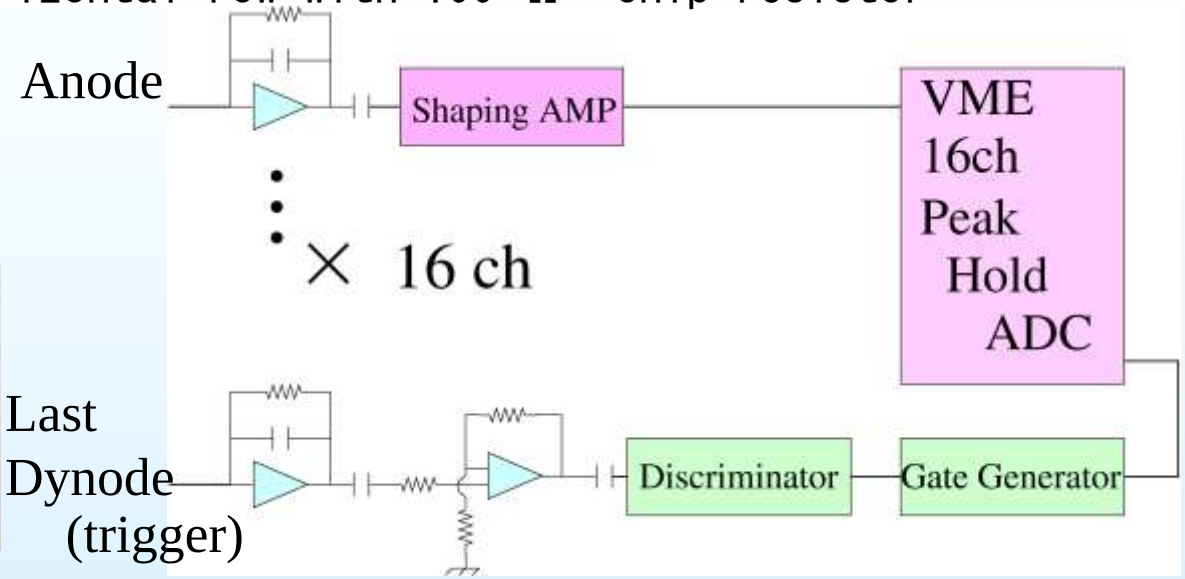




Reduce to 16ch read-out with Resistive Charge division!

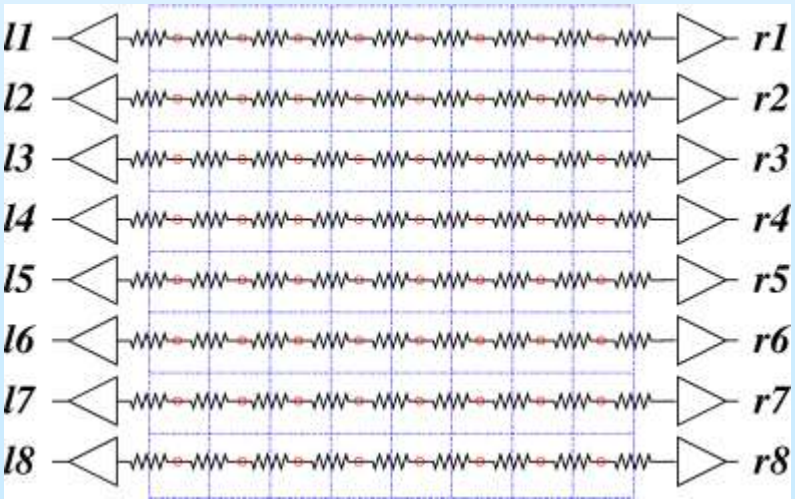
Connect the anodes in horizontal row with 100 Ω chip resistor





X

Y



$$P_i = l_i + r_i$$

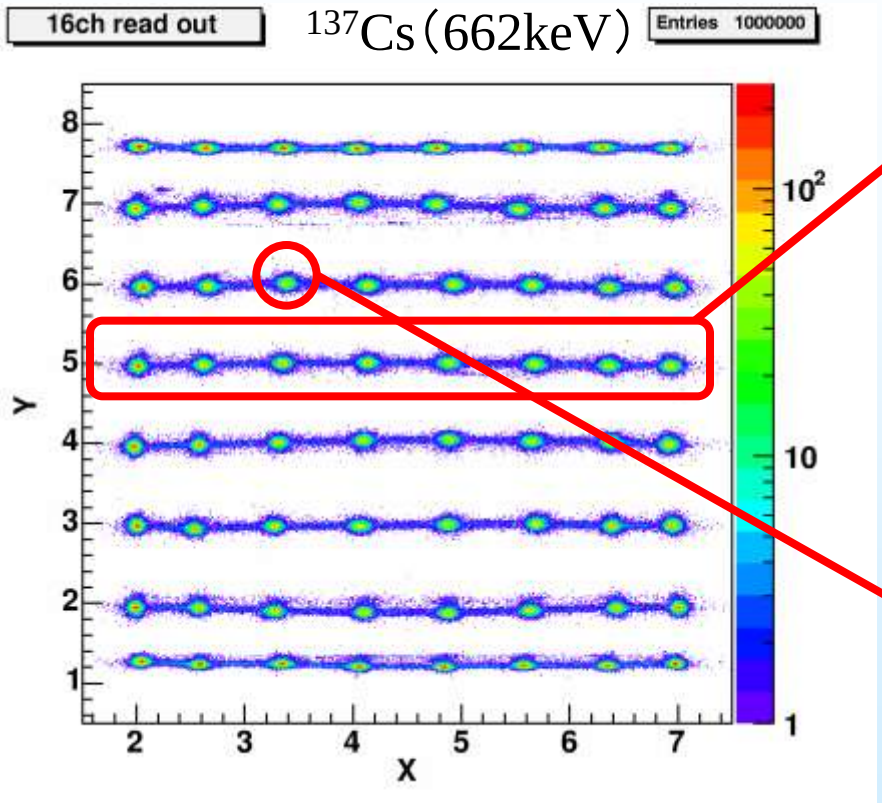
$$P_{\max} = \max(P_i)$$

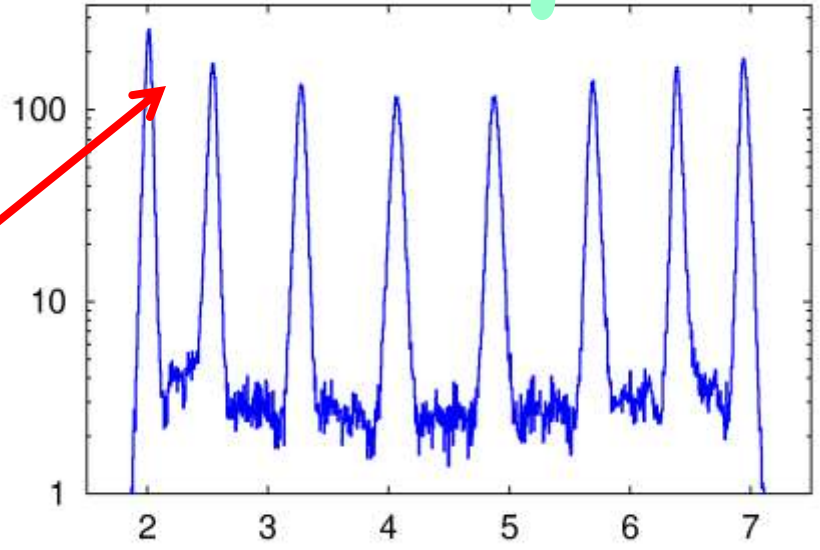
$$y = \frac{\sum_{\max-1<i<\max+1} P_i \cdot i}{\sum_{\max-1<i<\max+1} P_i}$$

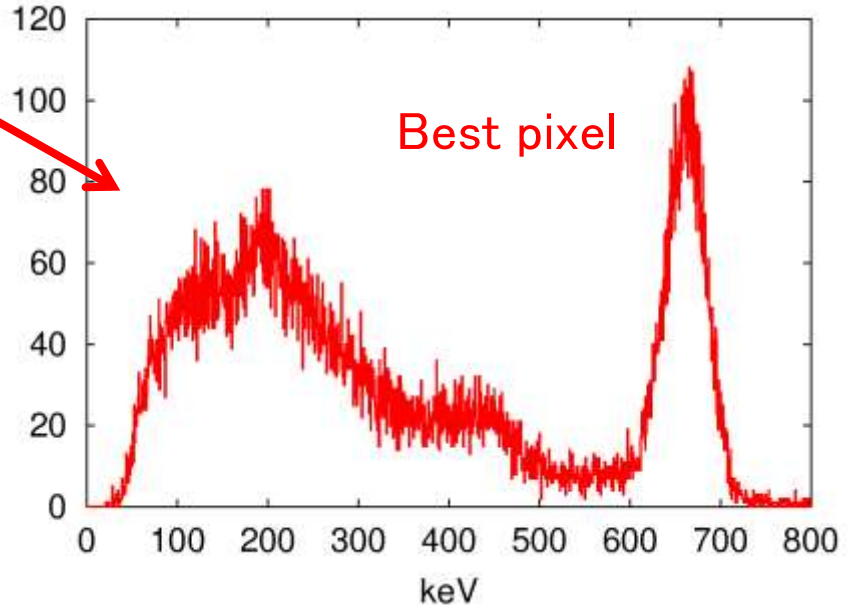
$$x = \frac{l_{\max}}{P_{\max}}$$

Reduce to 16ch read-out with Resistive Charge division

Position image map

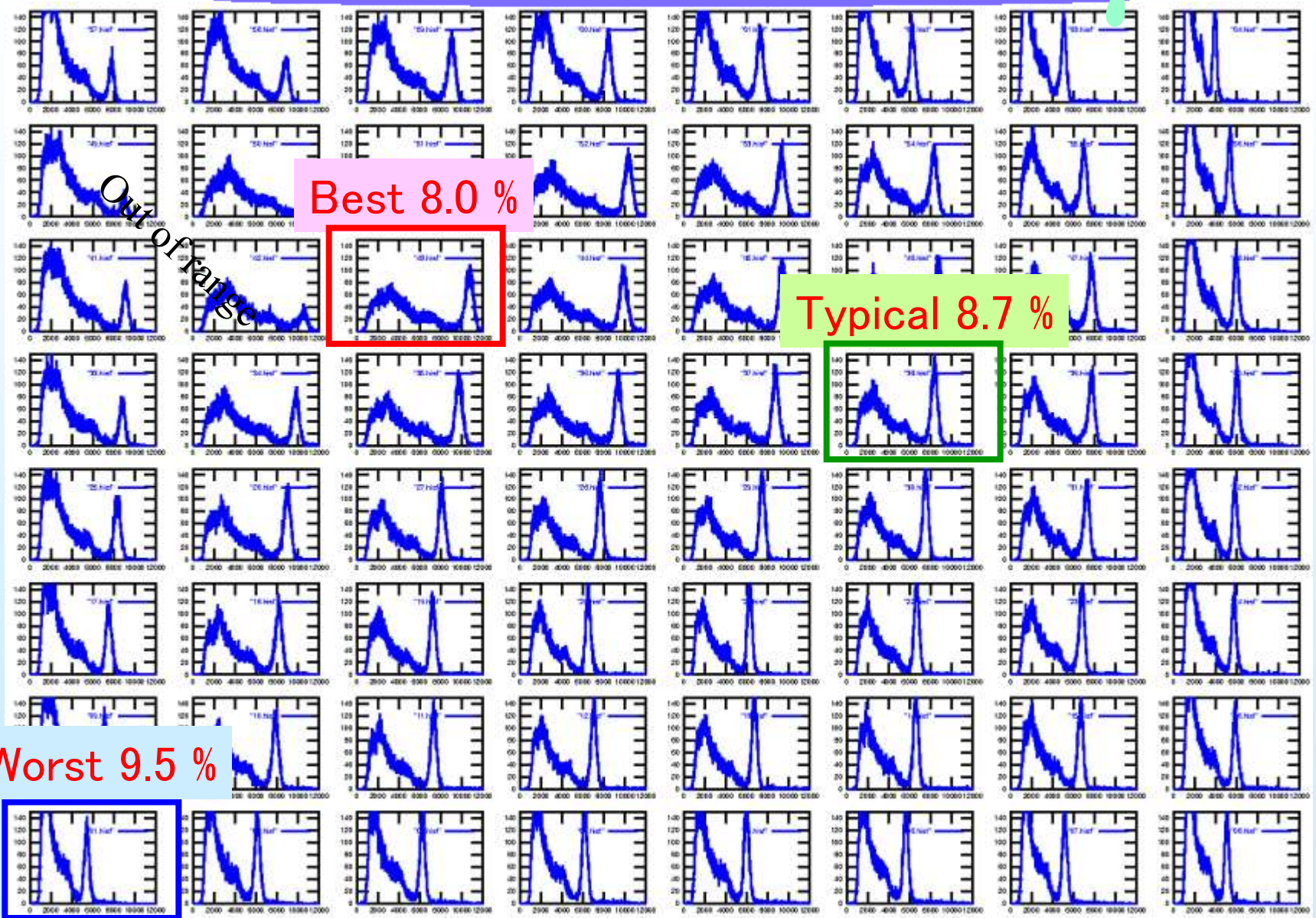






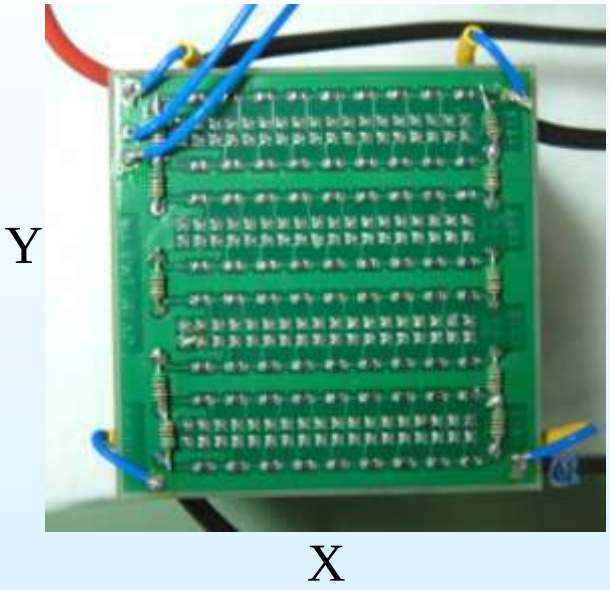
Energy resolution
8.0%@662keV(FWHM)

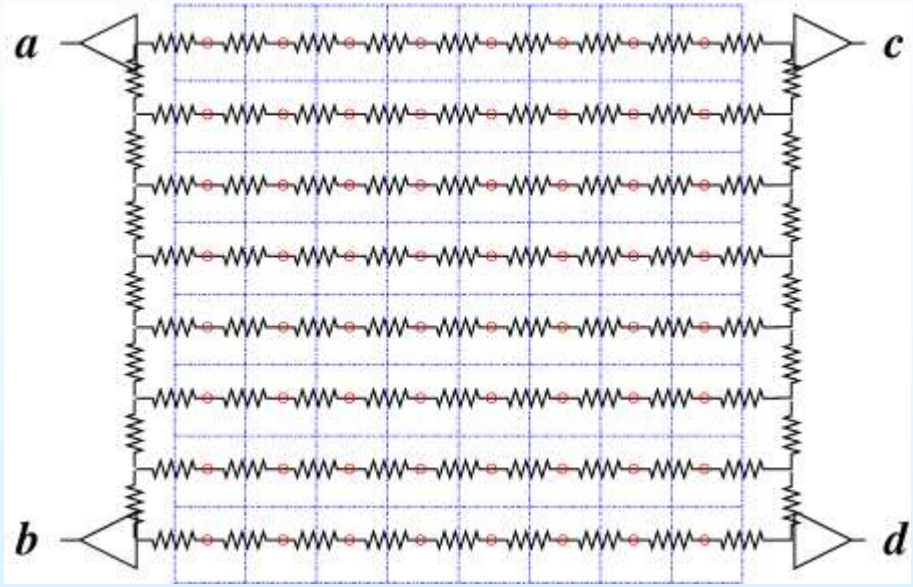
Reduce to 16ch read-out with Resistive Charge division



Further Reduction to 4ch Read-out

Connect the both edges of the horizontal chains





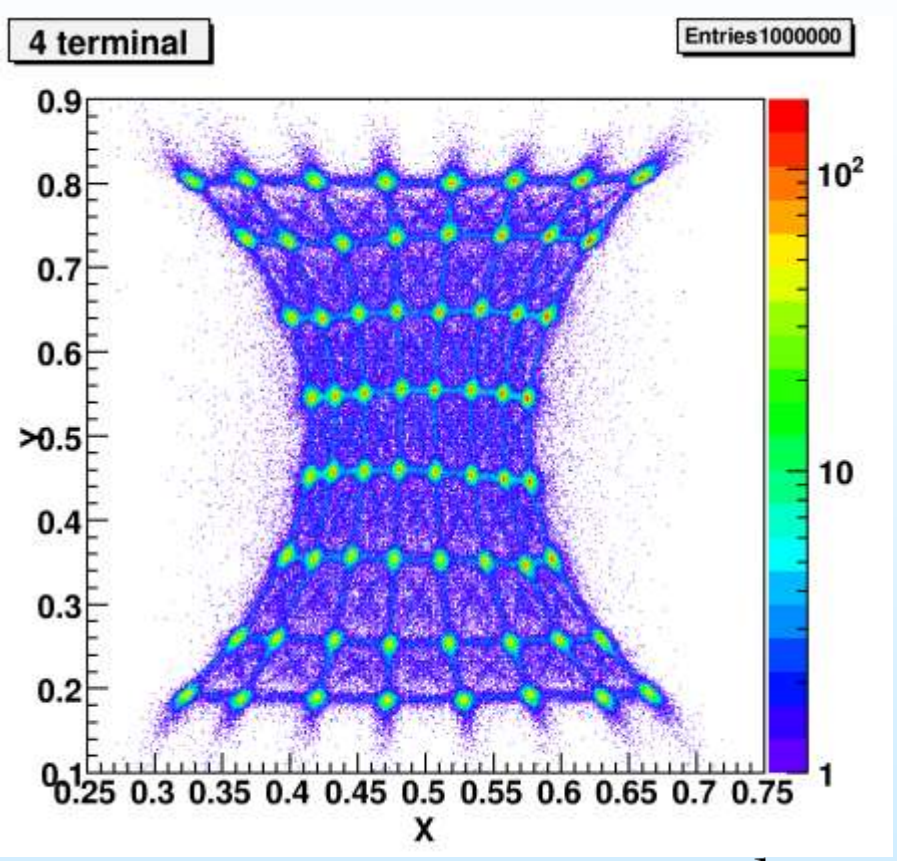
Position reconstruction

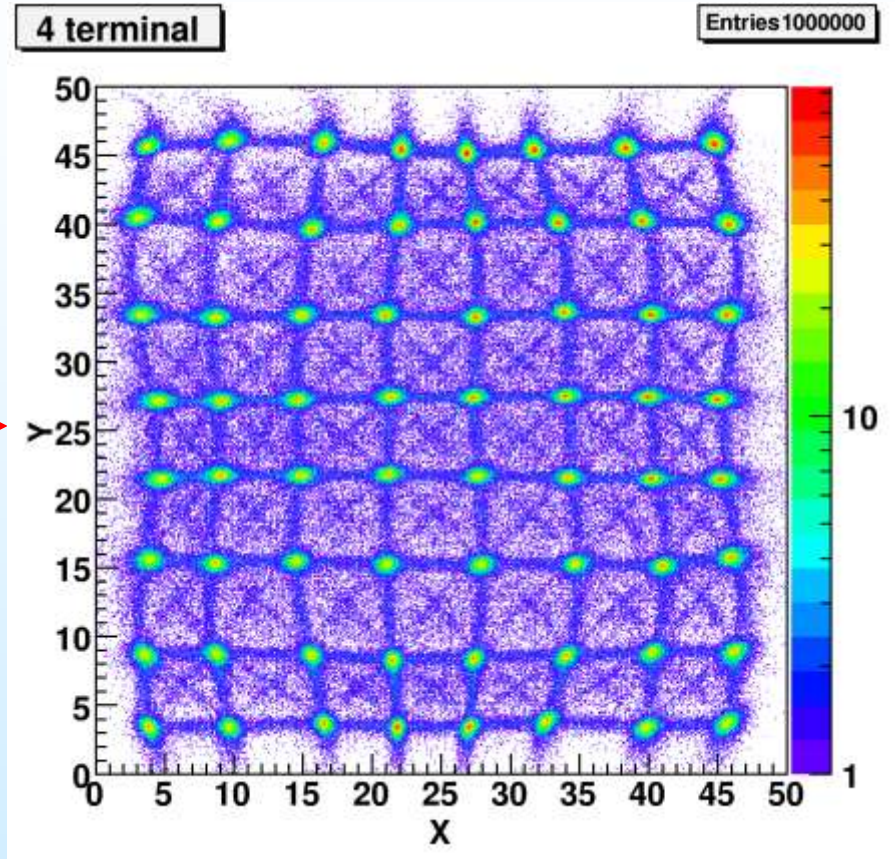
Simply calculate the center of gravity of the 4 outputs

$$x = \frac{c+d}{a+b+c+d}$$

$$y = \frac{b+d}{a+b+c+d}$$

Further Reduction to 4ch Read-out





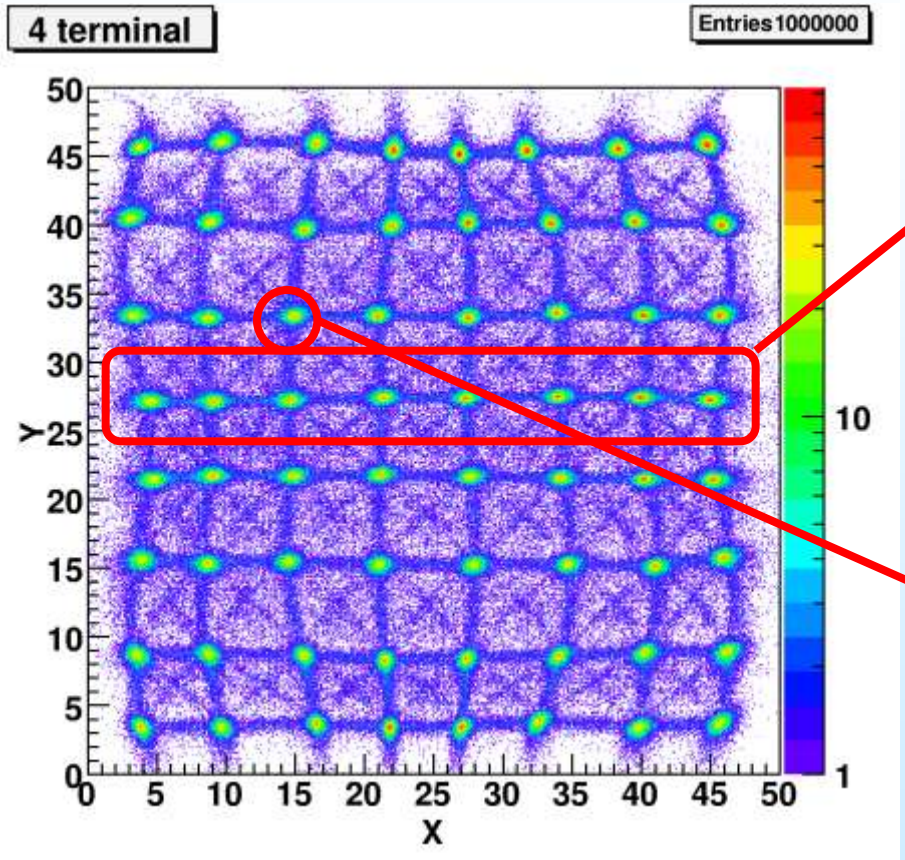
$$\text{real } x = f(x, y)$$

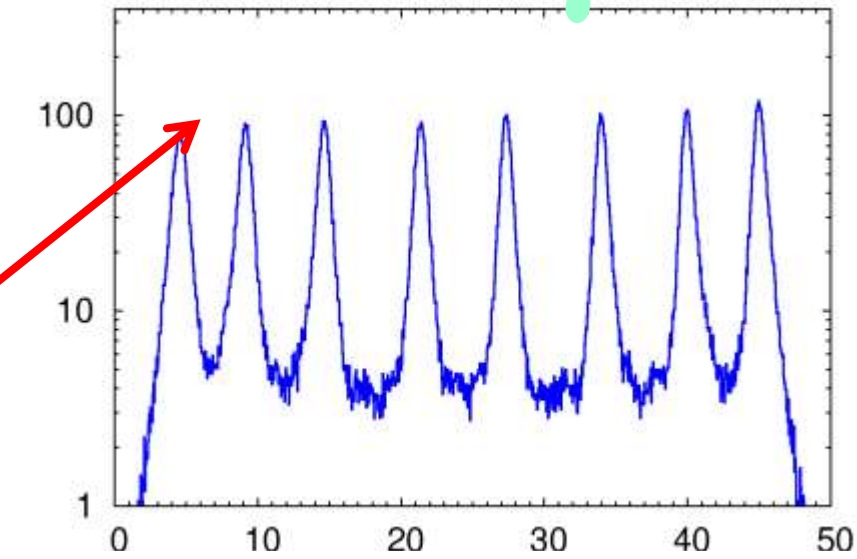
$$\text{real } y = g(x, y)$$

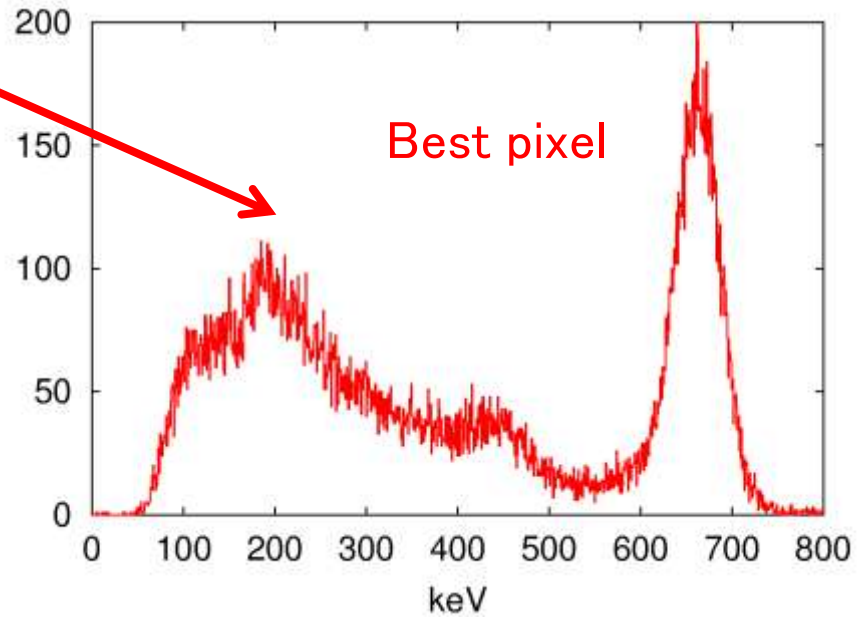
f, g are given by ROOT's TMultiDimFit class.

Further Reduction to 4ch Read-out

Position image map

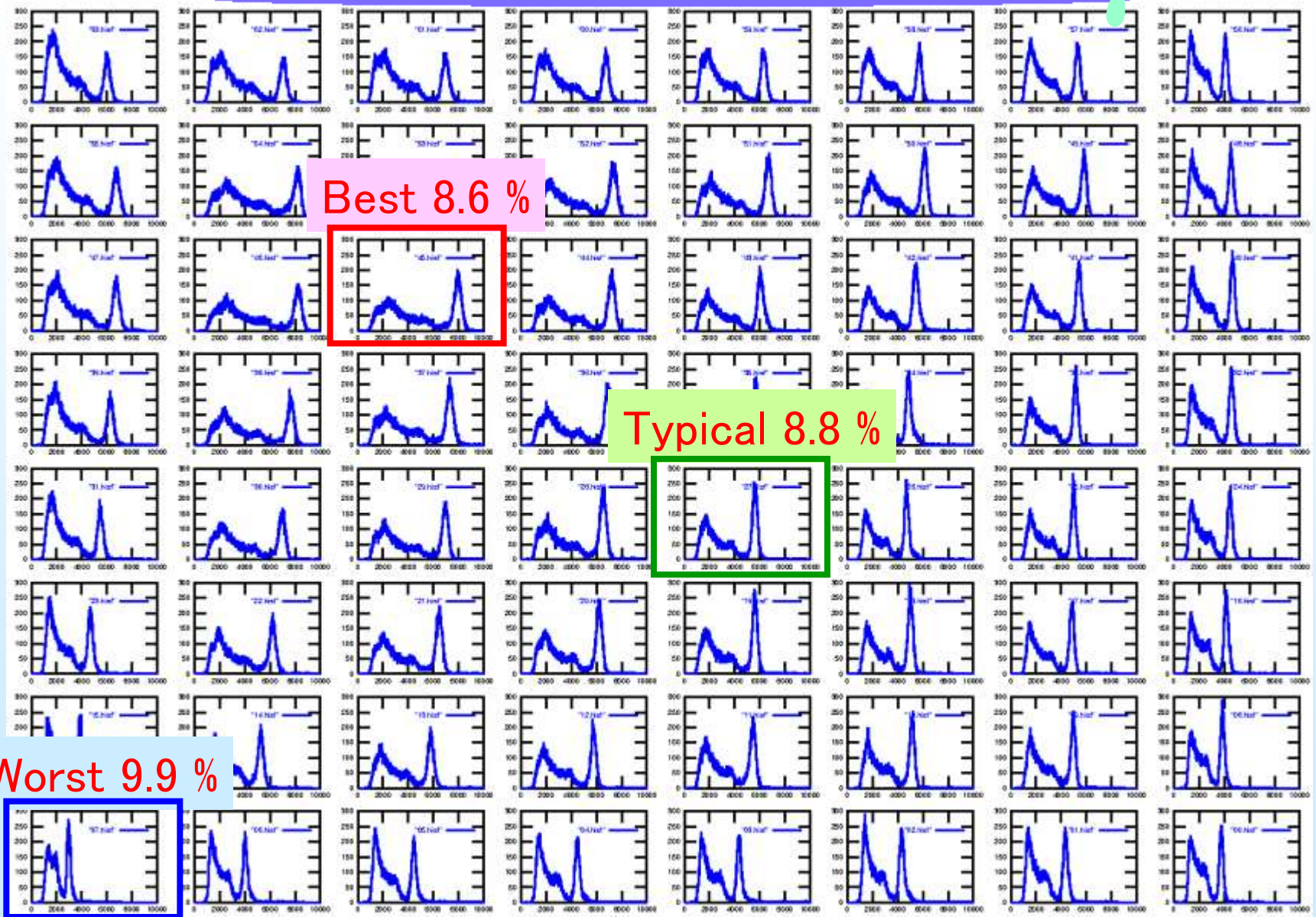






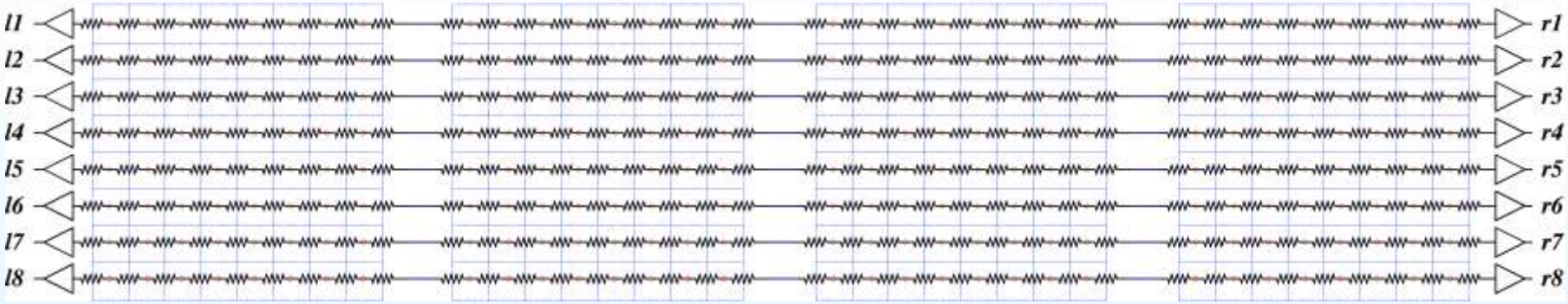
Energy resolution
8.6%@662keV(FWHM)

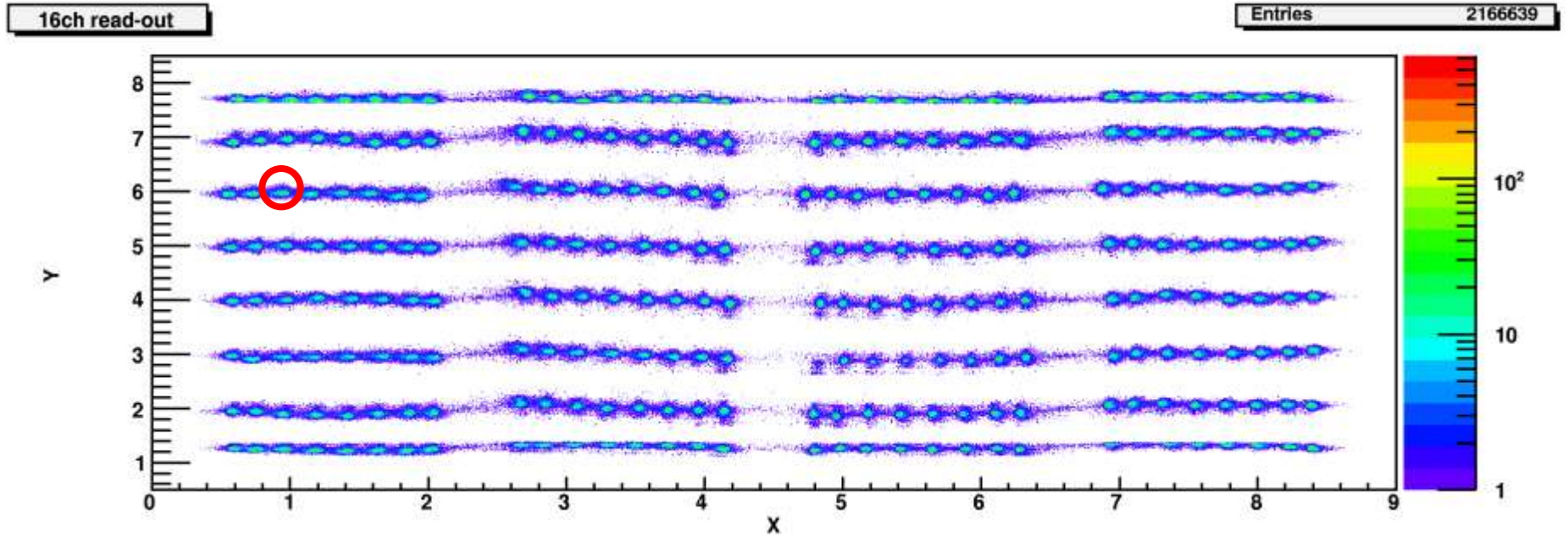
Further Reduction to 4ch Read-out



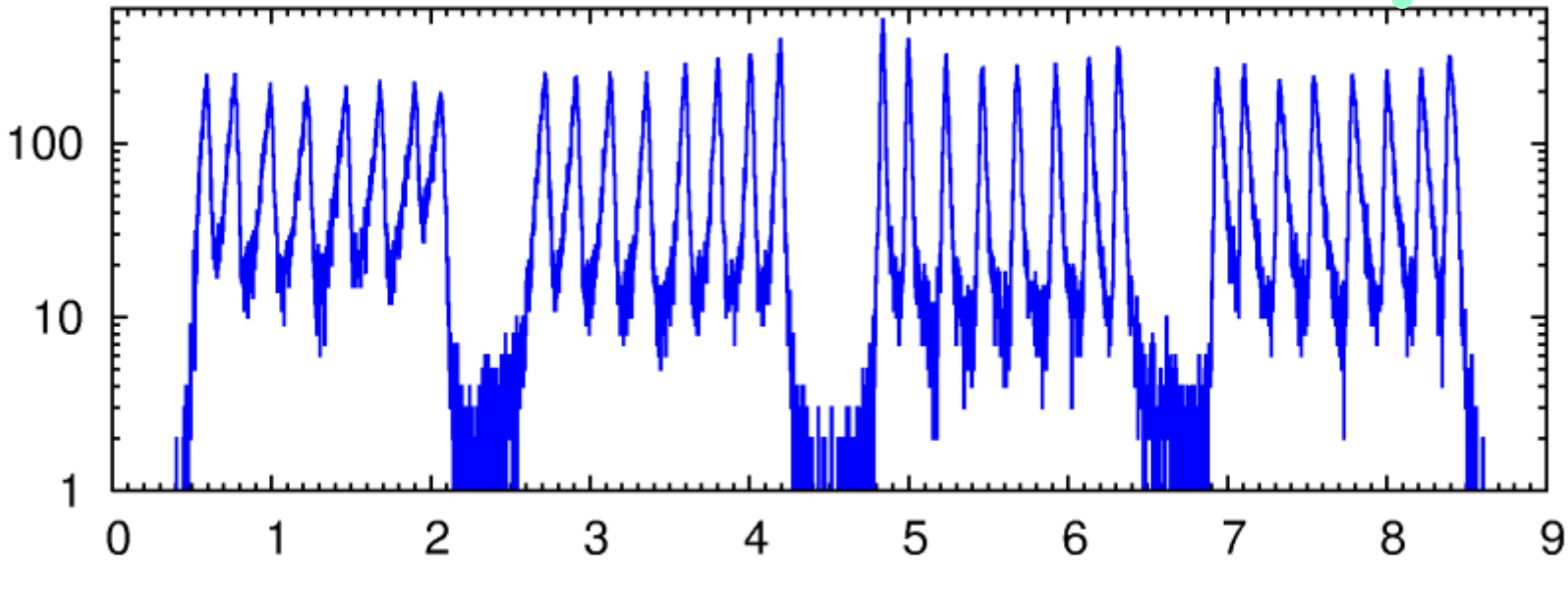
Another 4ch/1PMT Read-out

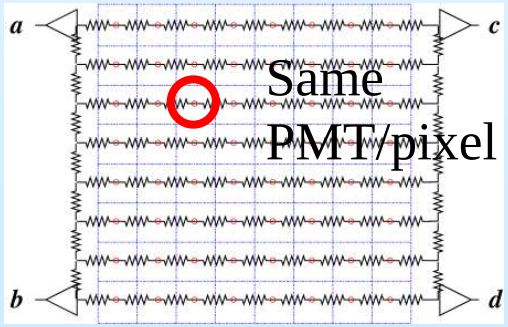
Connect the 4PMTs with horizontal chains

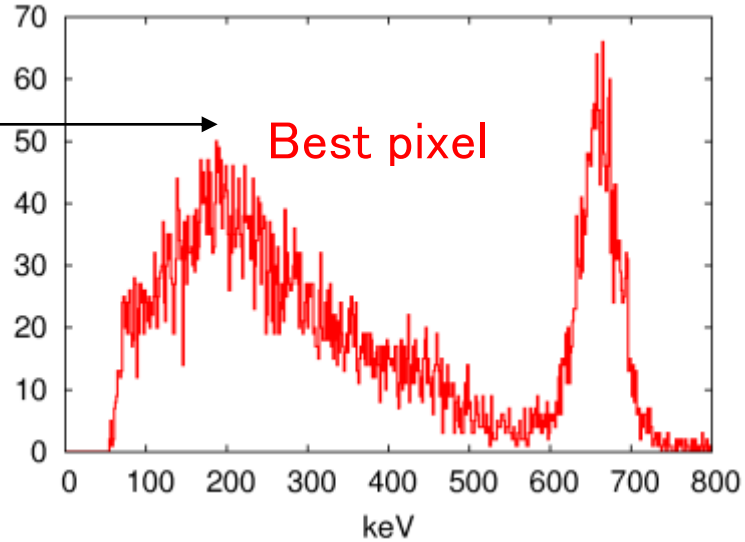




Another 4ch/1PMT Read-out

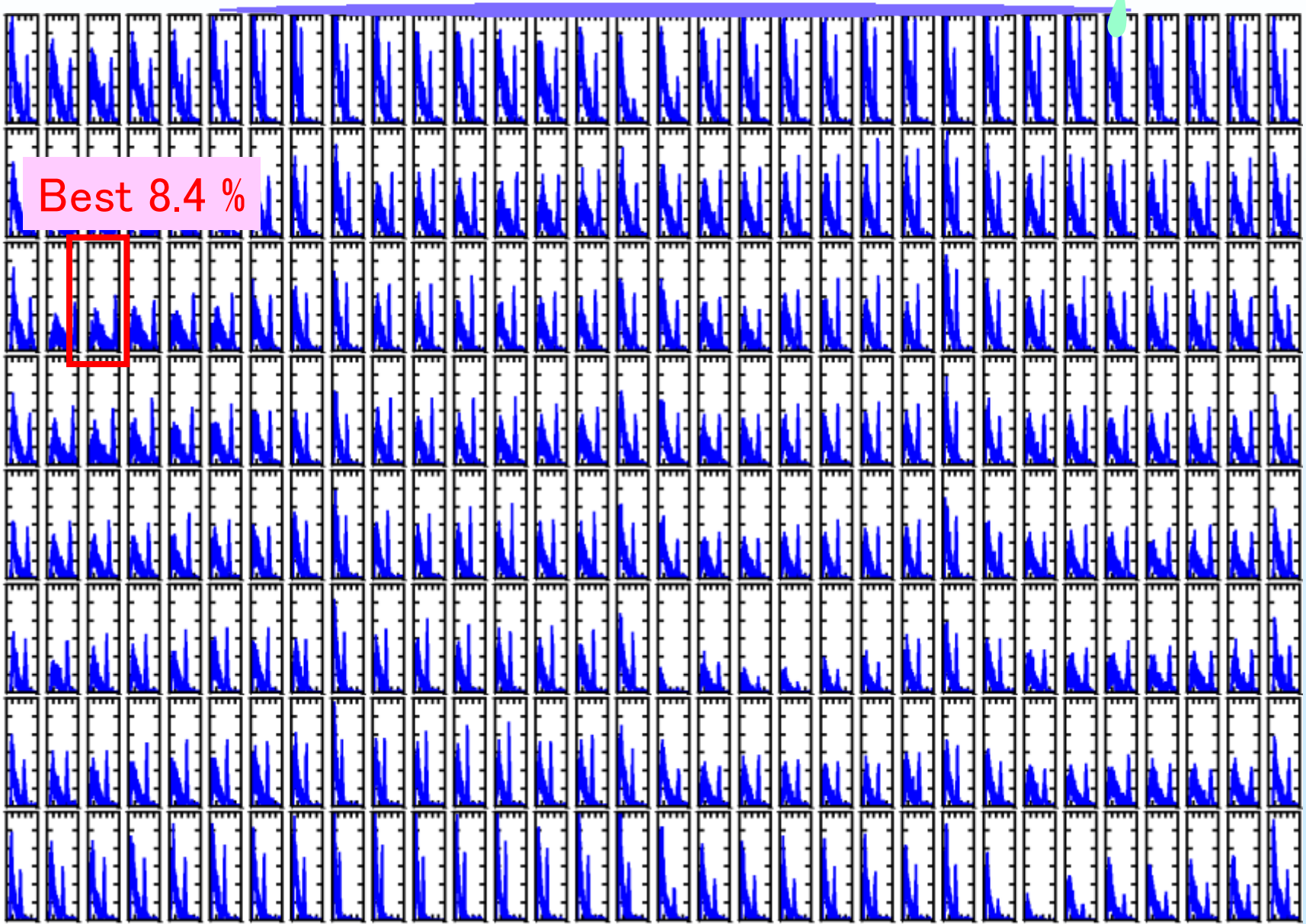




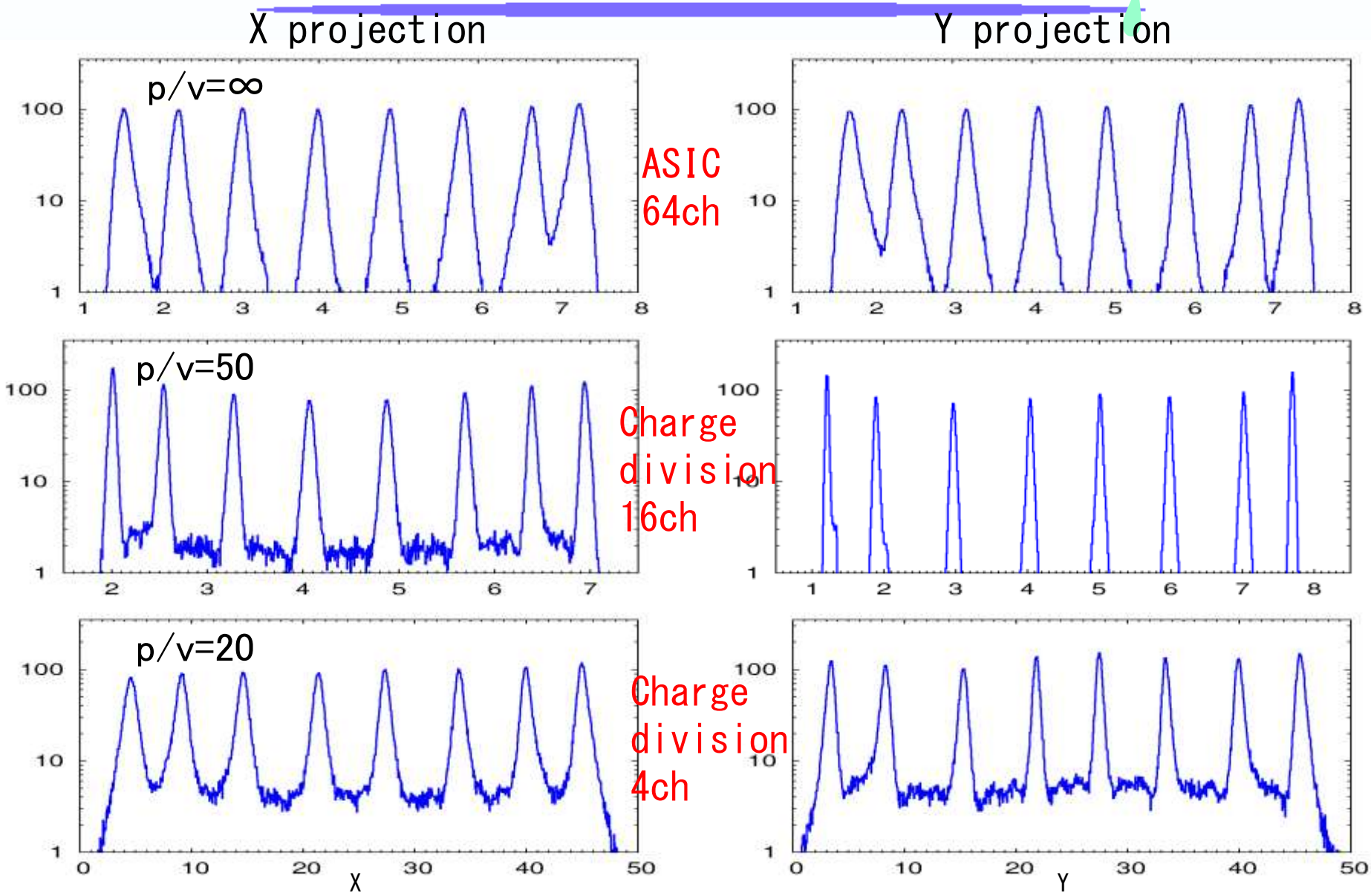


Energy resolution
8.4%@662keV(FWHM)

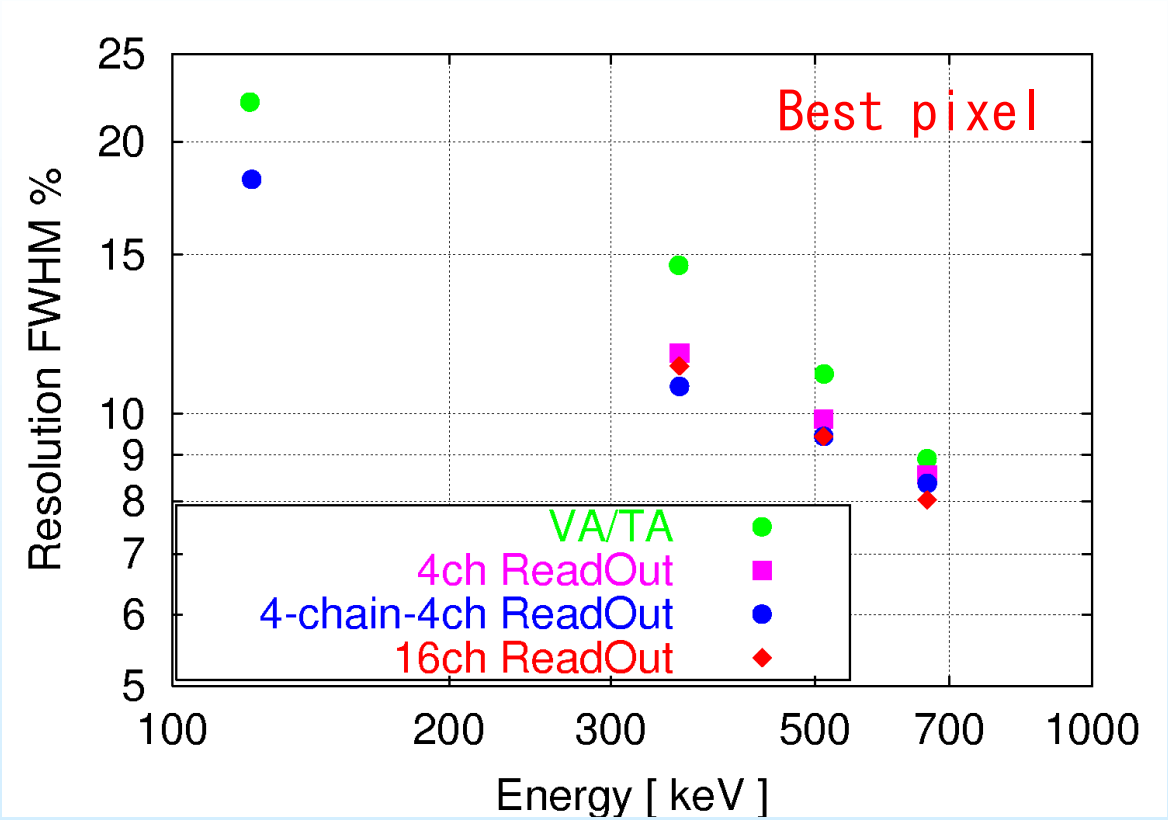
Another 4ch/1PMT Read-out



Summary Position Resolution



Summary Energy Resolution

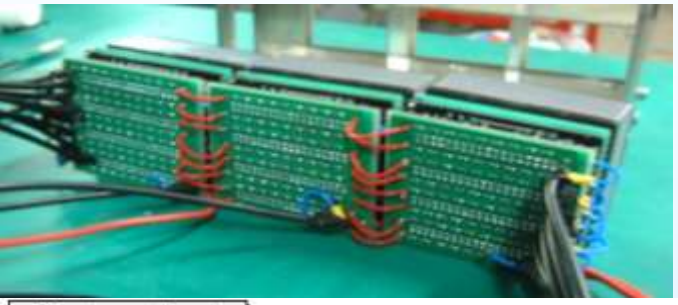


- VA system has good position resolution, however, its dynamic range is too small and it is inferior to the resistive charge division systems in energy resolution.

Resistive charge division for large area gamma camera

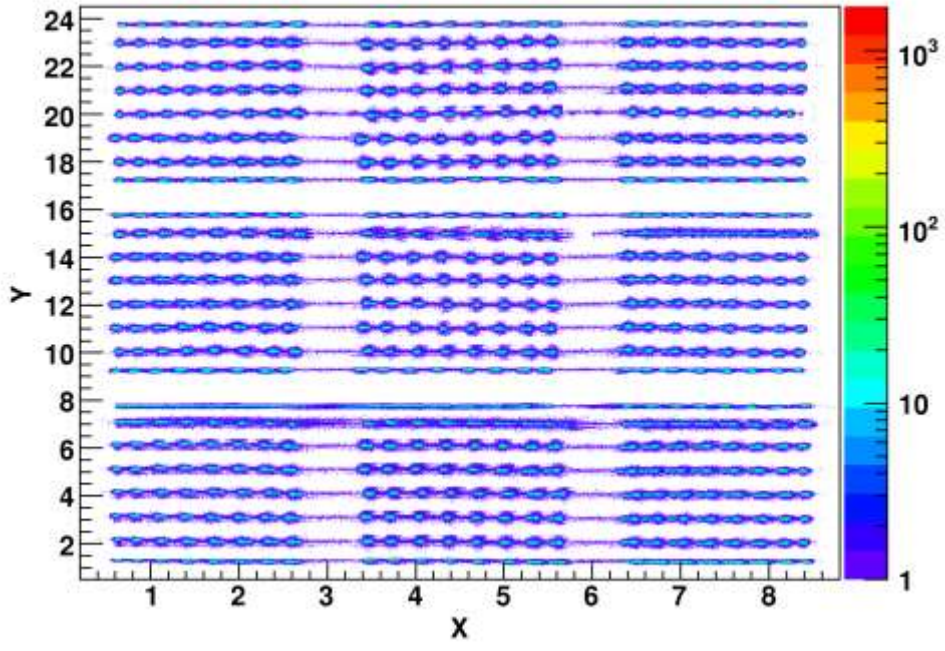
Large Area Detector

- 16cm × 16cm
- 8×8×3×3 GSO array

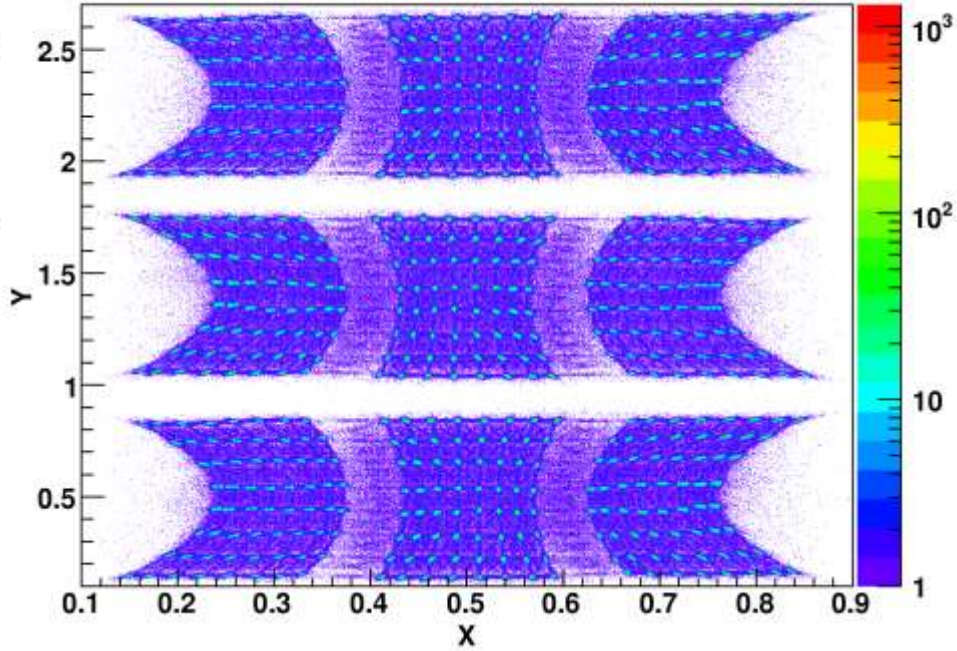


Coverage
81%

48ch read-out

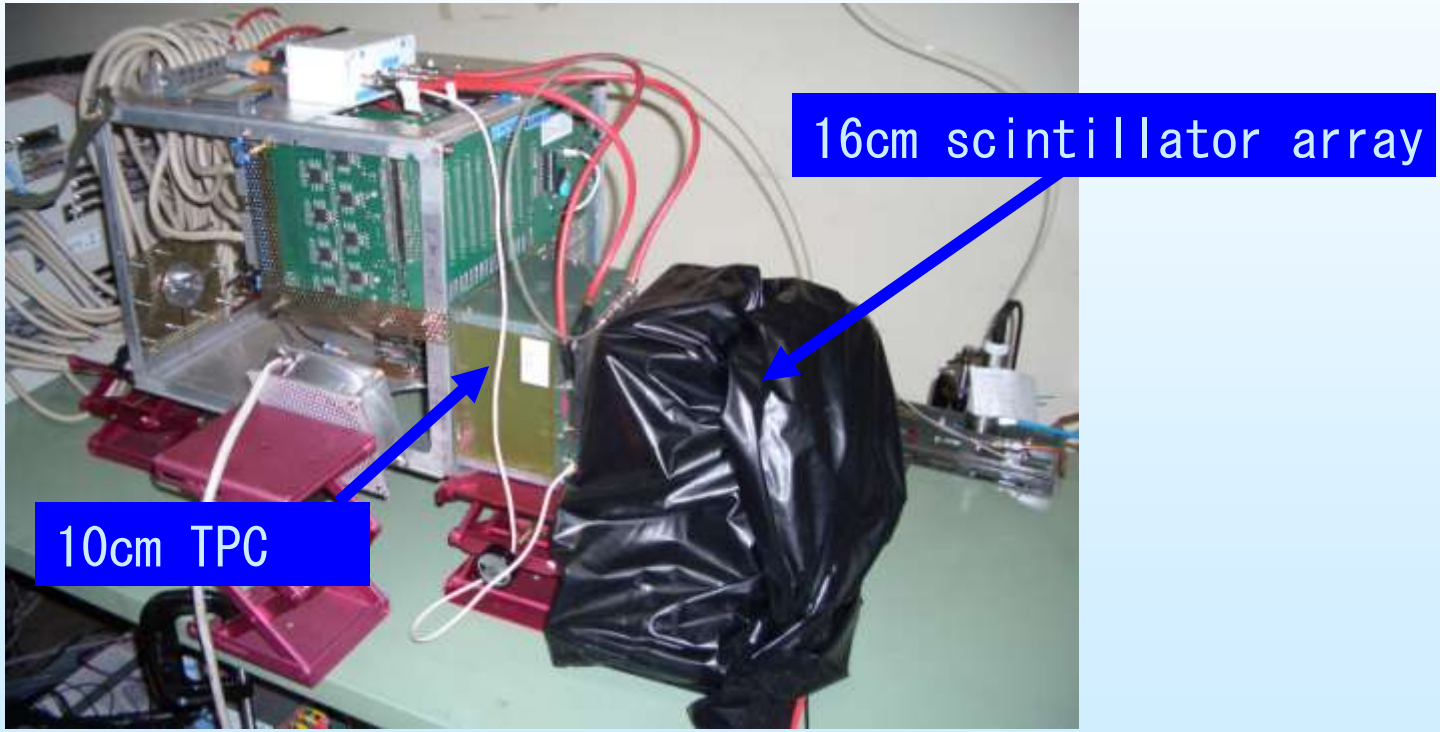


12ch read-out



Prospects

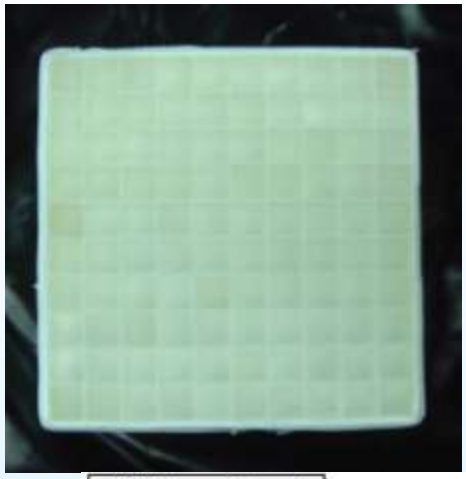
- We are testing gamma ray imaging detector
  (TPC+large area gamma camera



Results will be presented at PSD7 in Sep. @ Liverpool

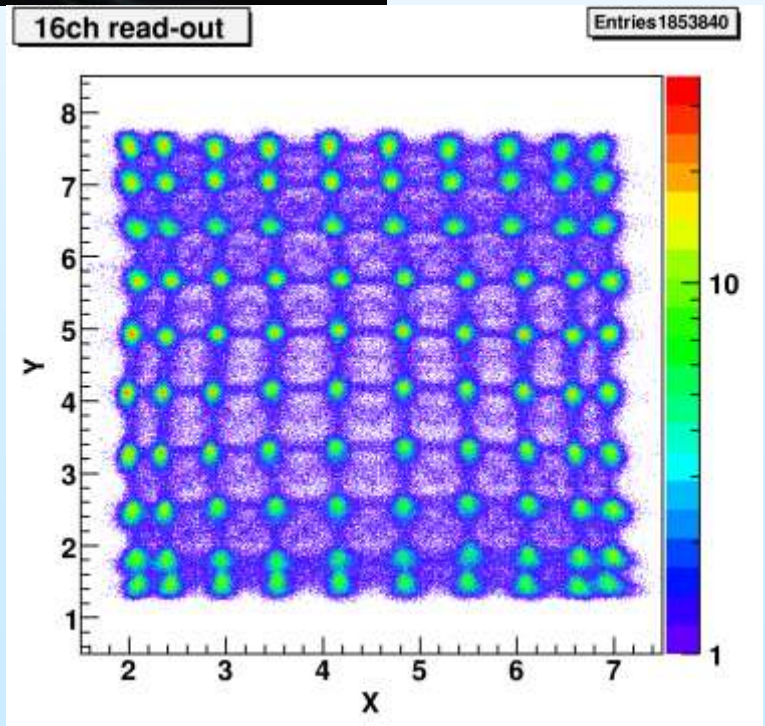
Thank you !

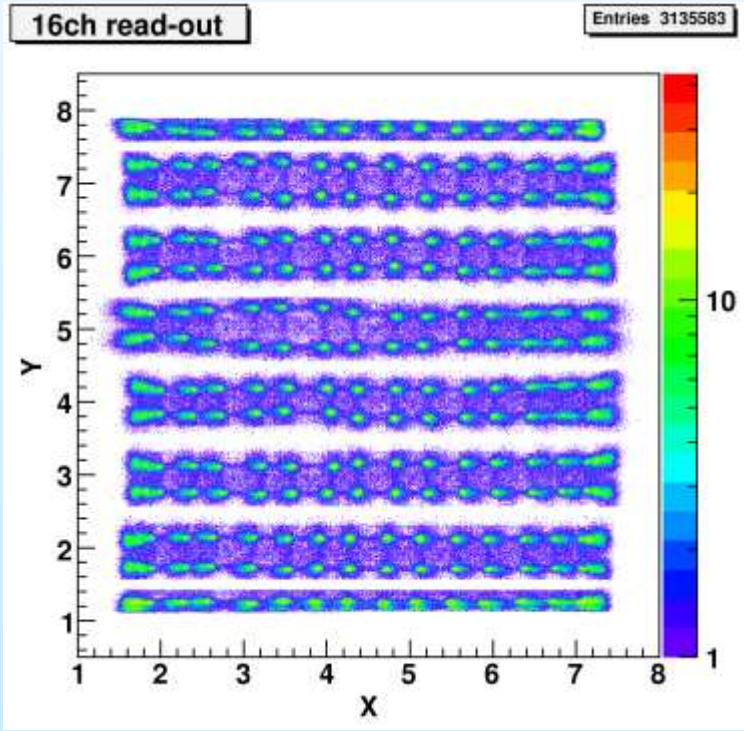
Smaller pixels via 16ch read out



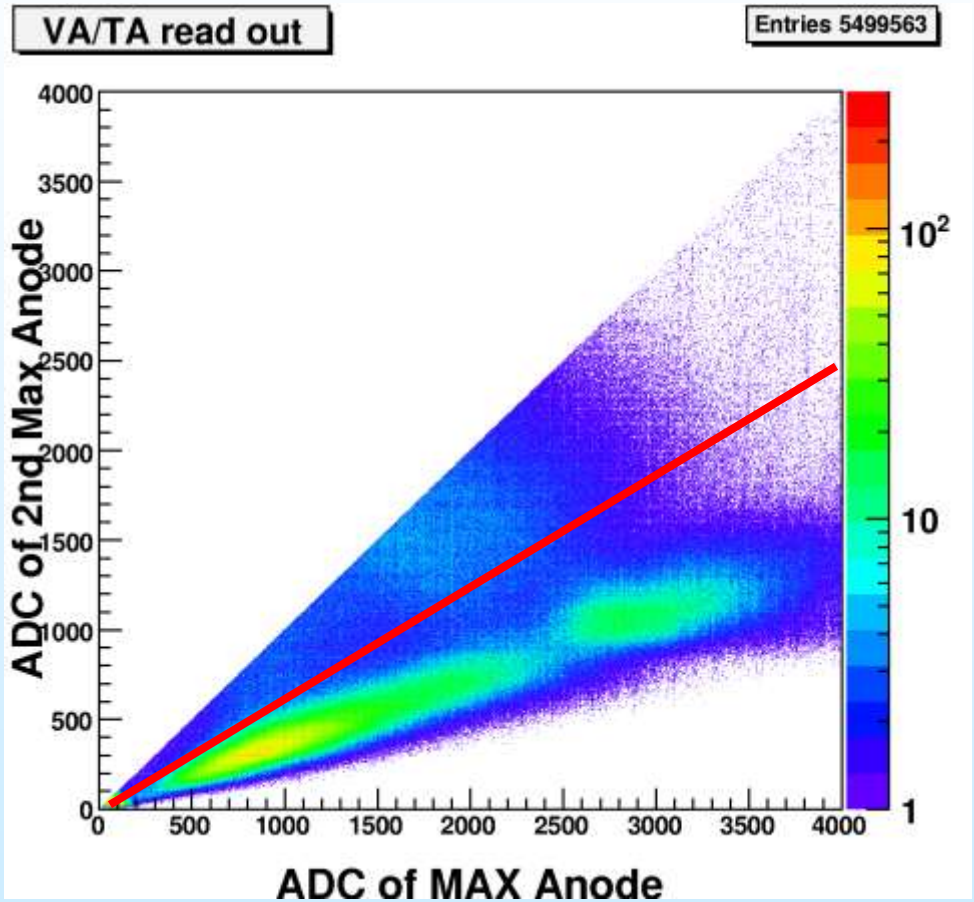
CsI(Tl)
5mm × 5mm × 20mm
10 × 10 array
GORETEX

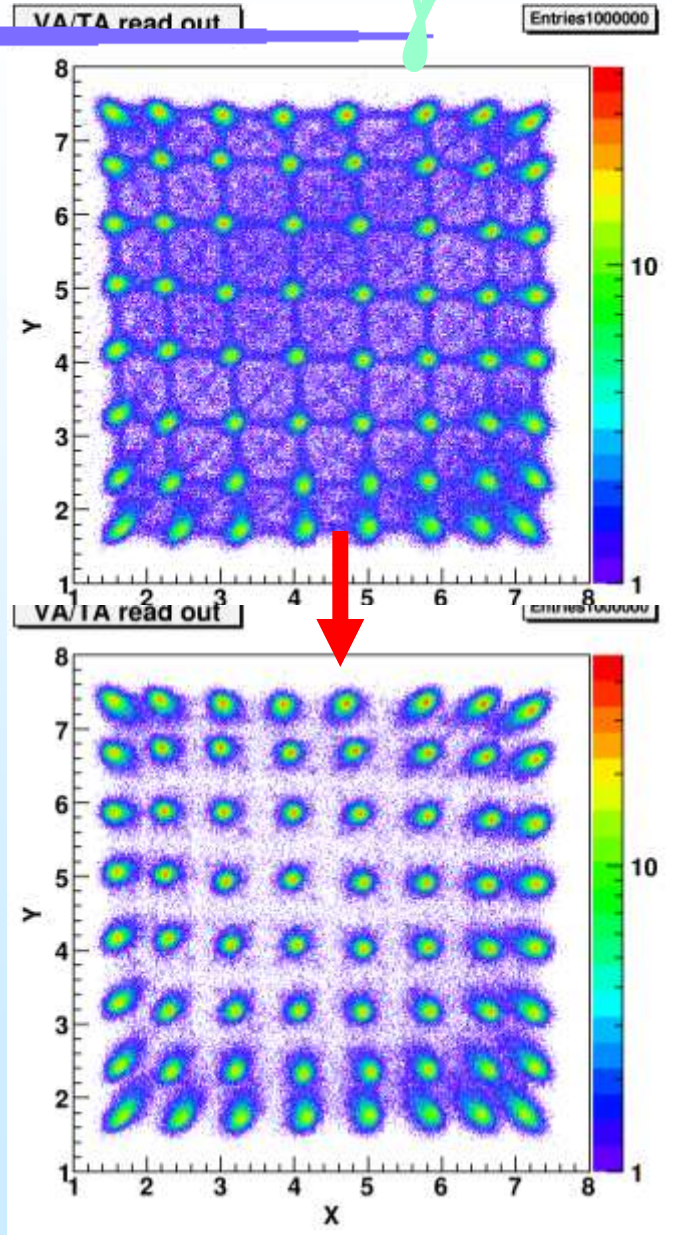
GSO
3mm × 3mm × 10mm
16 × 16 array
ESR



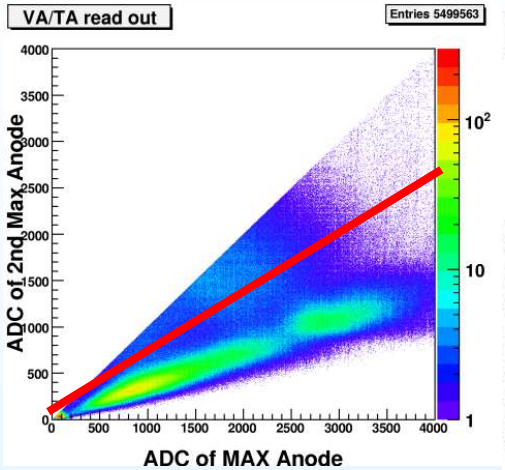


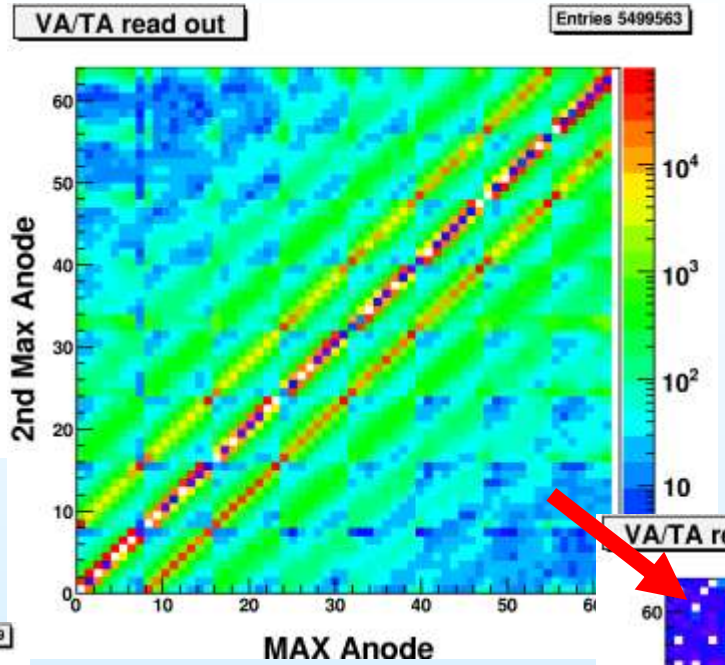
VA 64ch read out



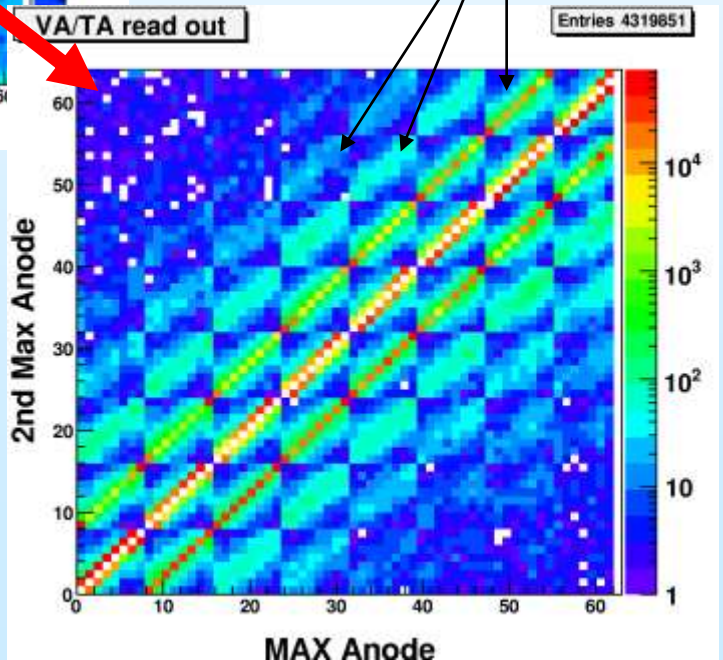


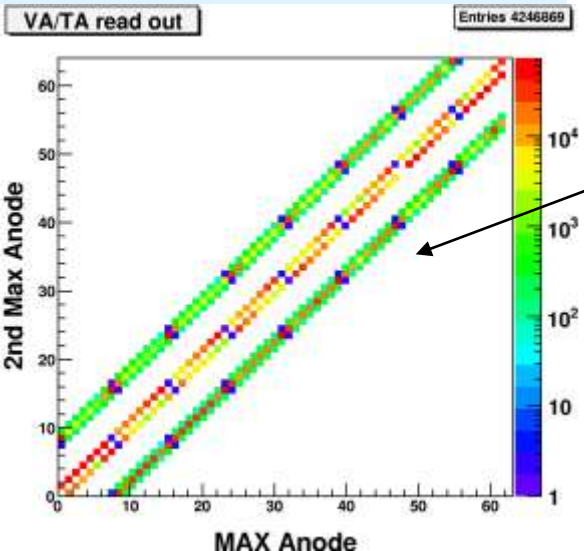
VA 64ch read out





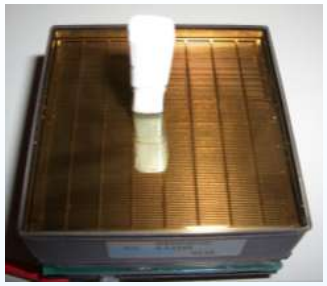
Multiple Compton

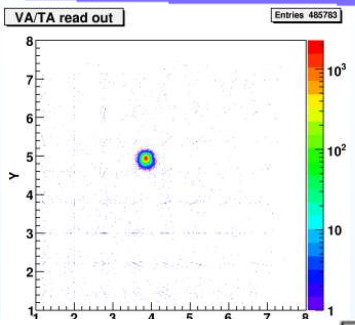


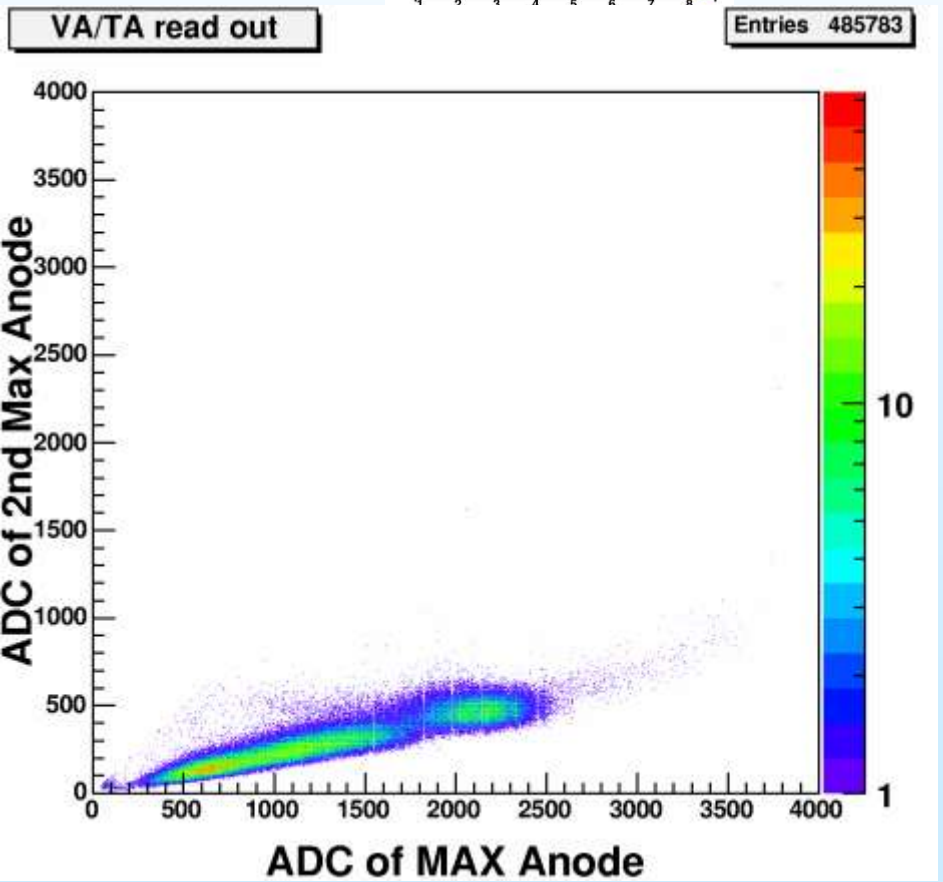


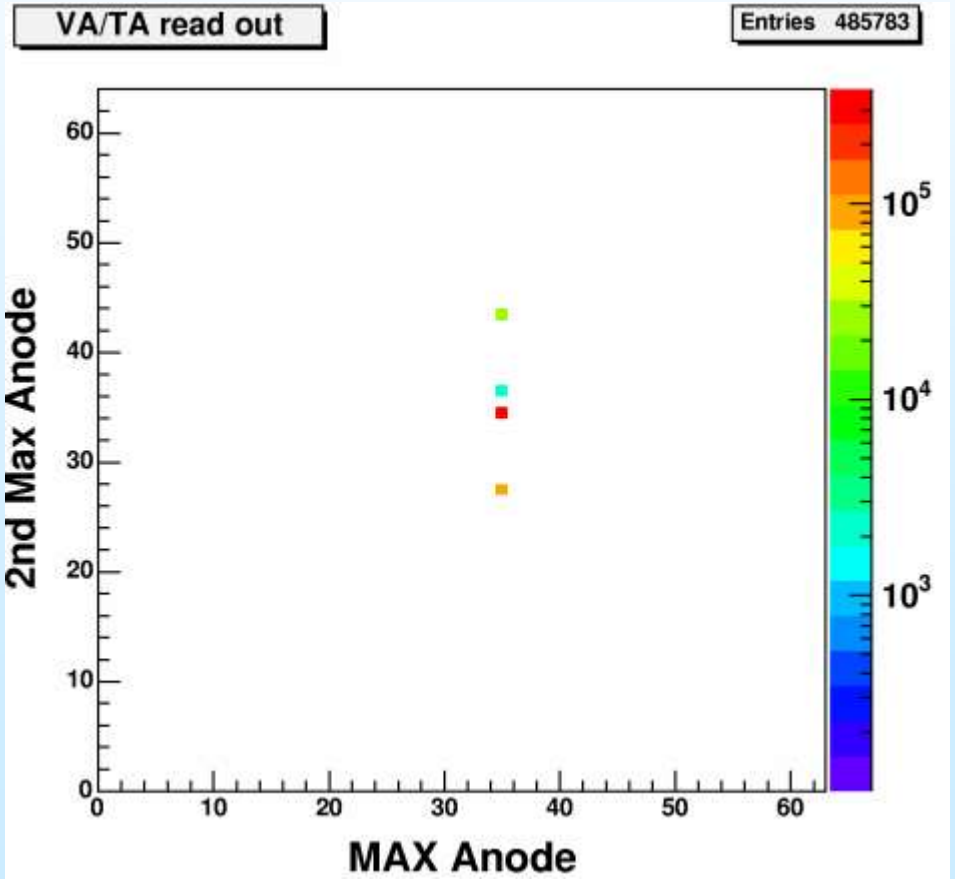
Light leakage

VA 64ch read out

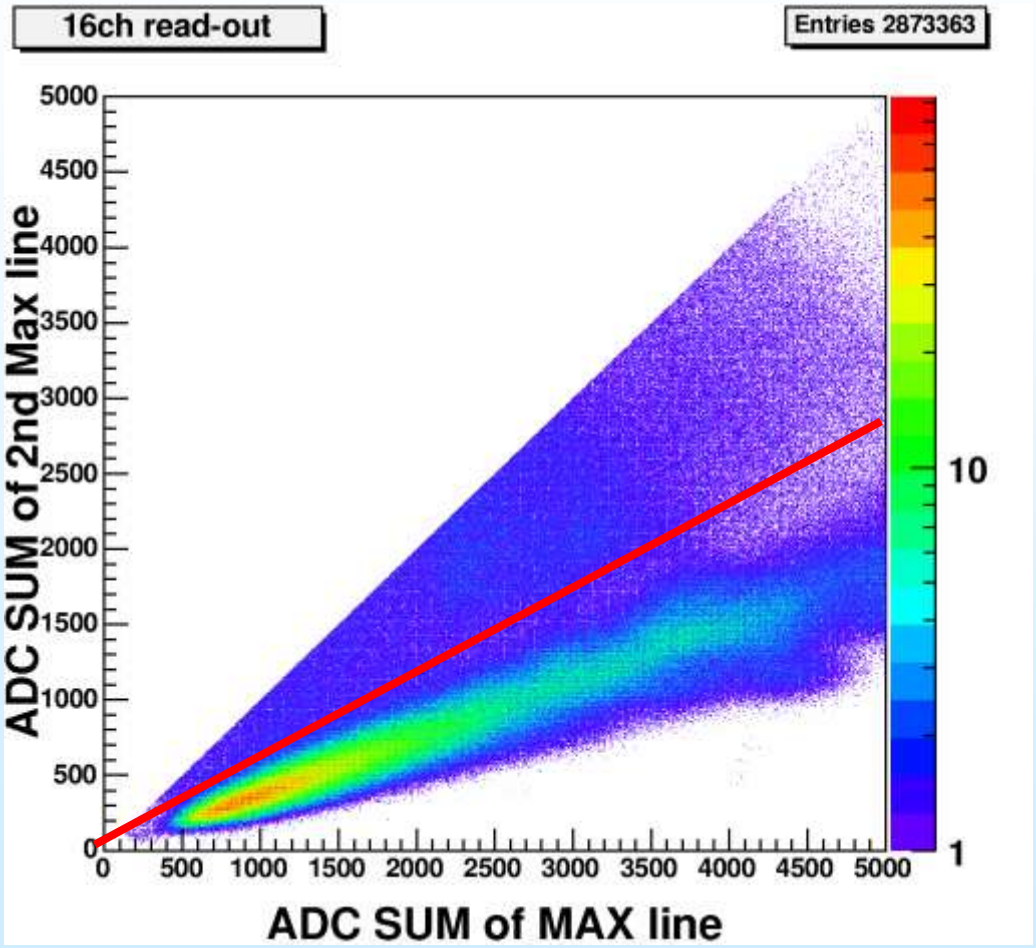


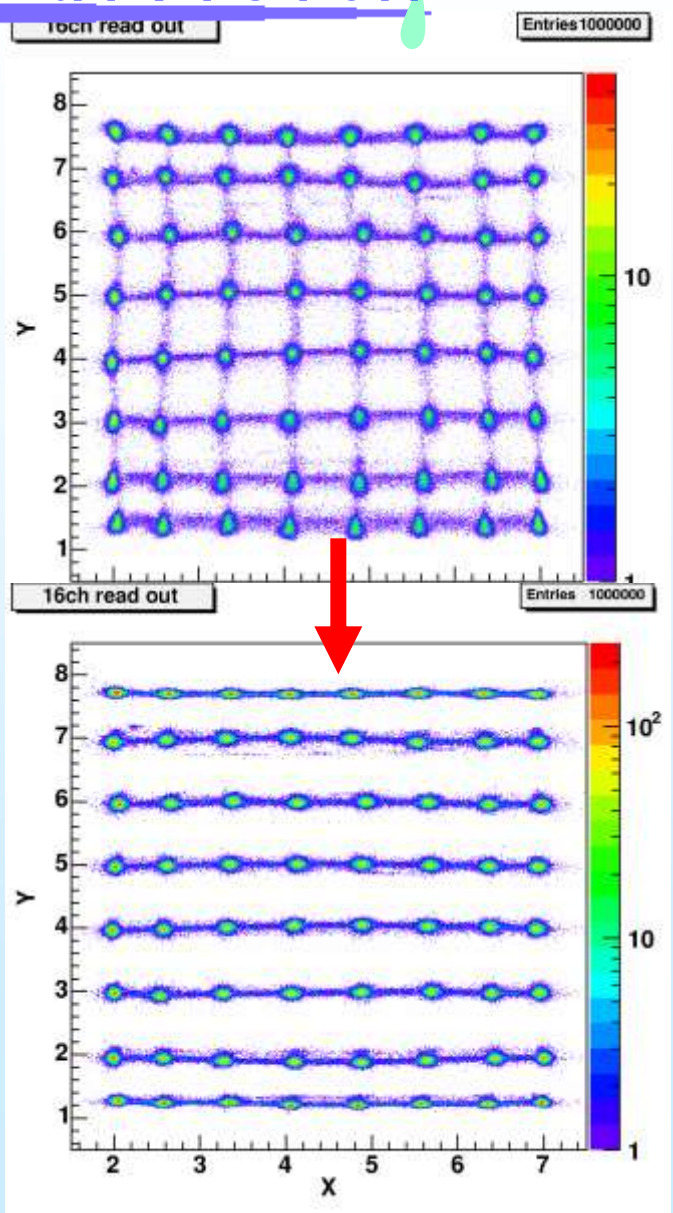






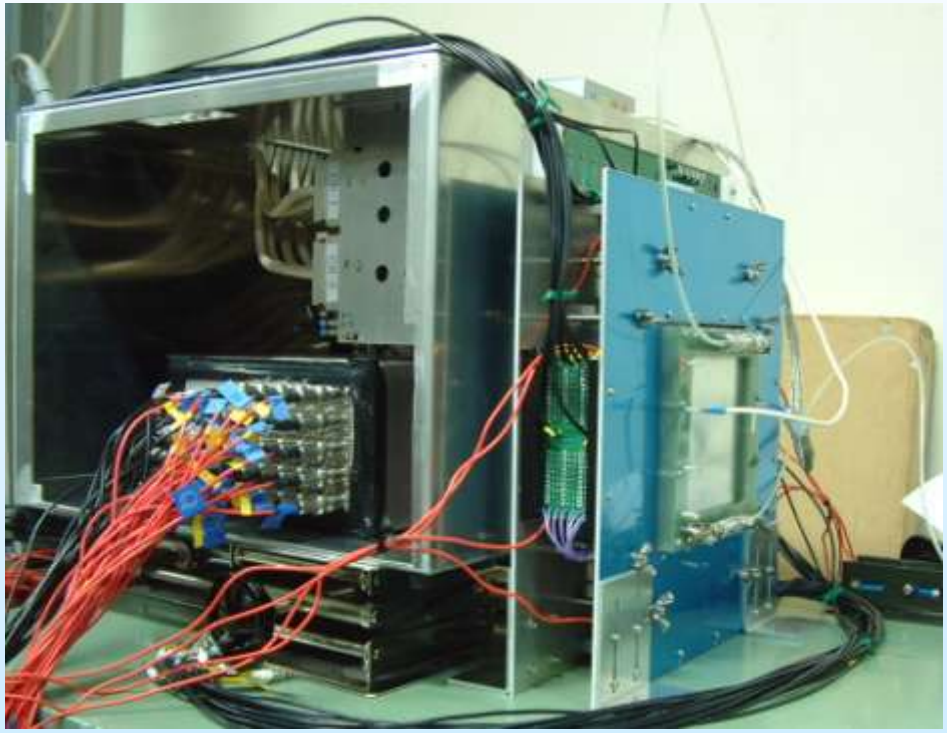
Reduce to 16ch read-out with Resistive Charge division





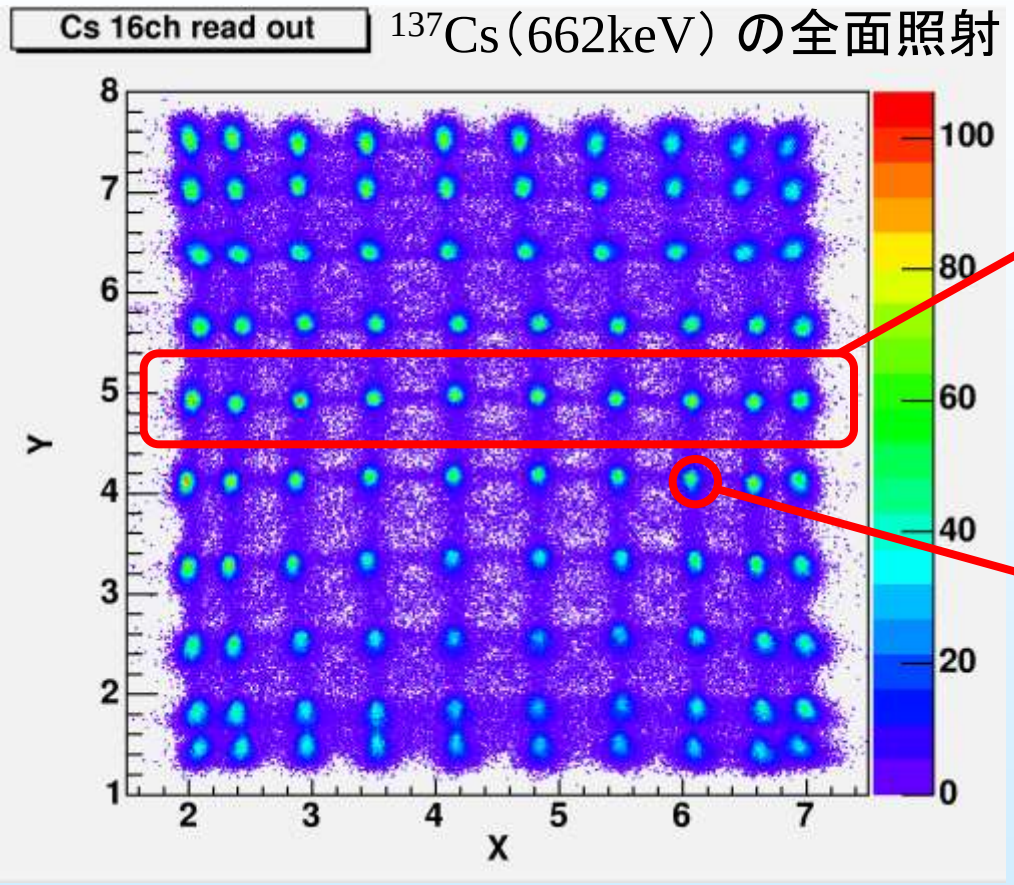
今後

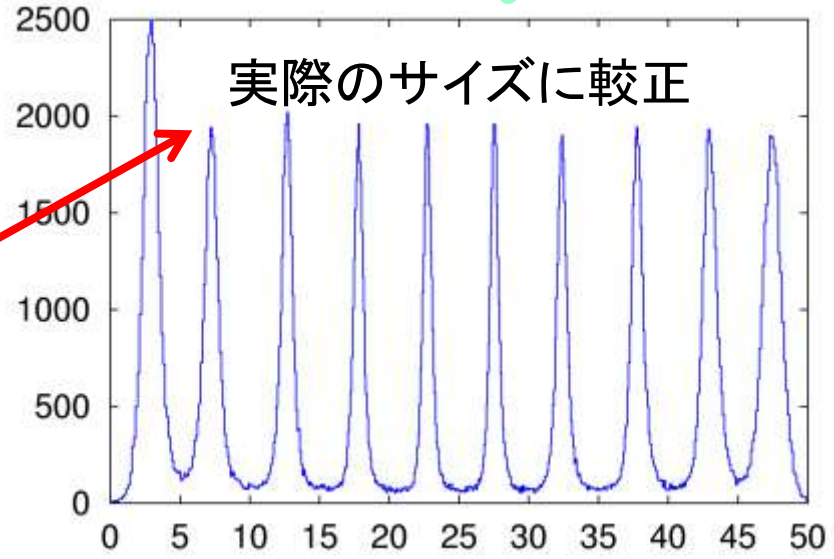
- 抵抗チェーンでH8500をつなぎμ-TPCを囲い
  ガンマ線カメラとしての性能評価を行う。

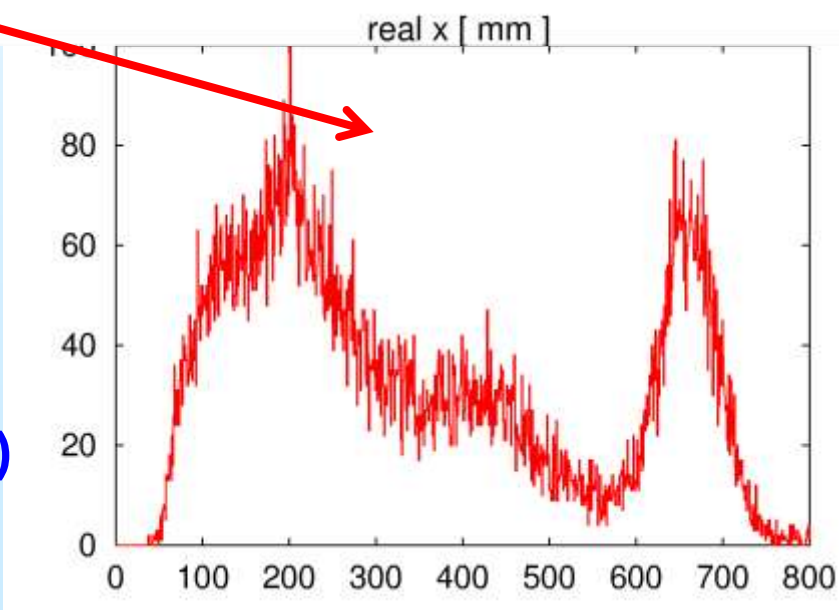


- ダイナミックレンジの大きな新たなASIC開発を行う。

Anode pitchと異なるピクセルの場合
5mm×5mm（抵抗チェーン　16ch）

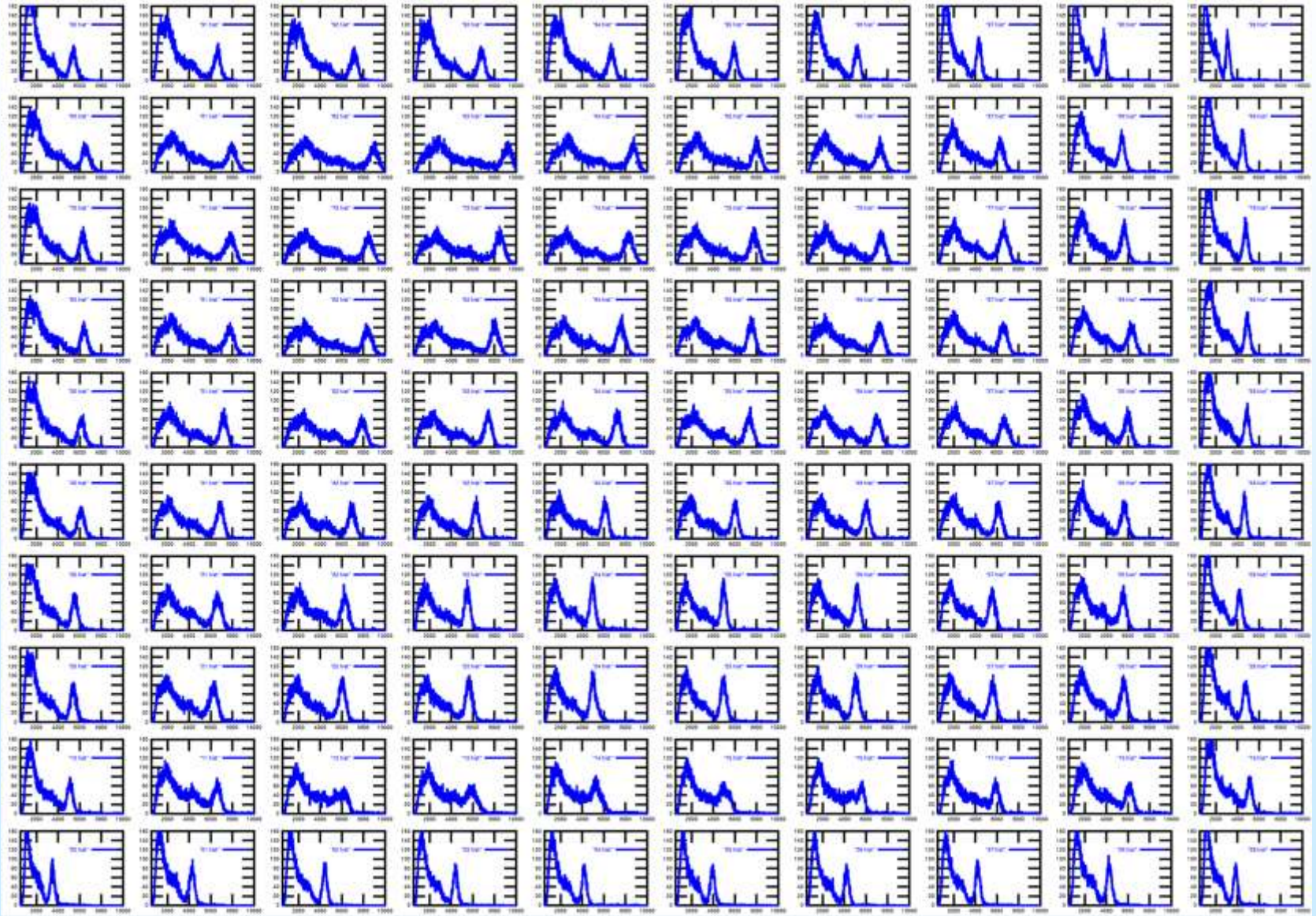




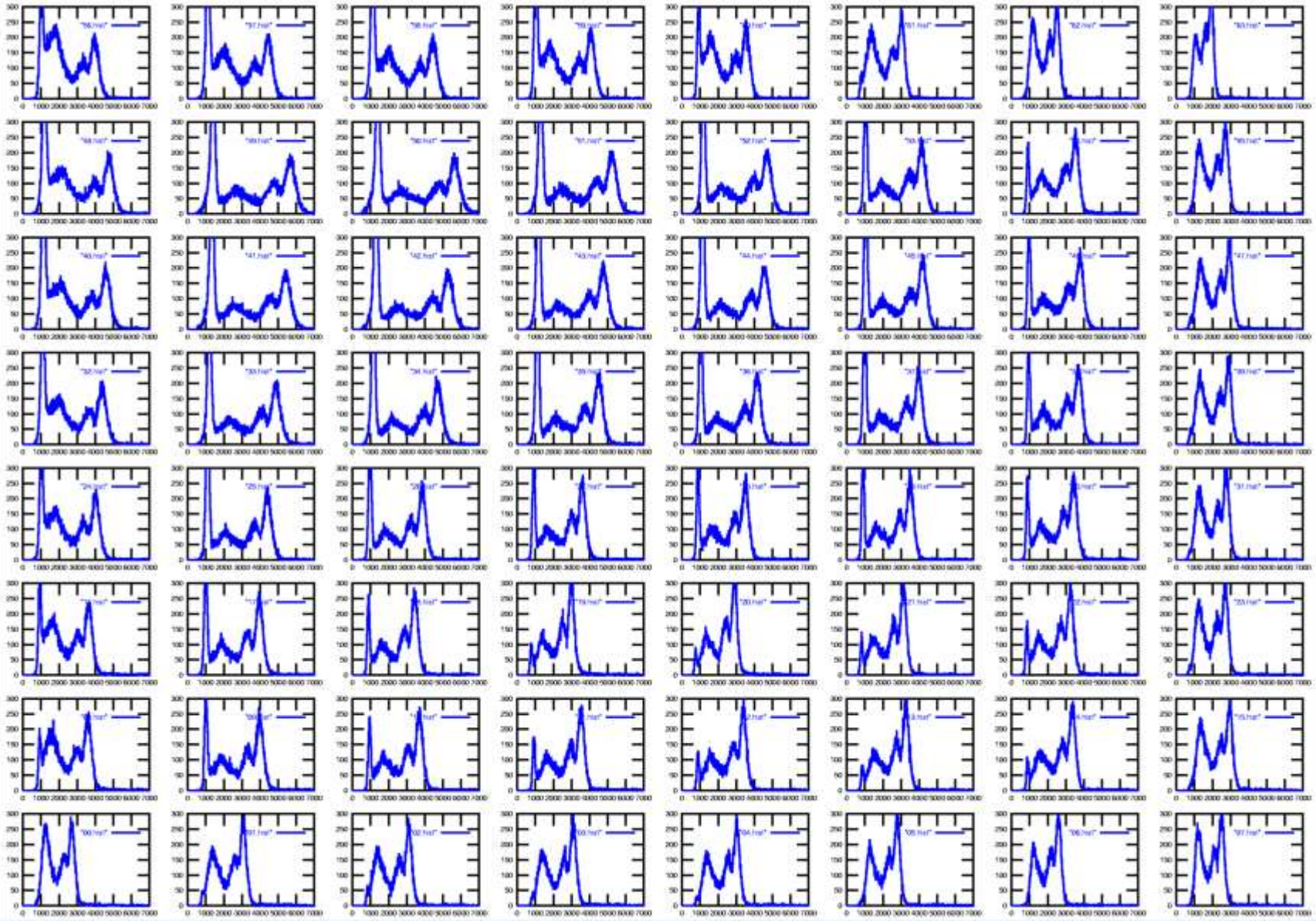


Energy resolution
11.4%@662keV(FWHM)

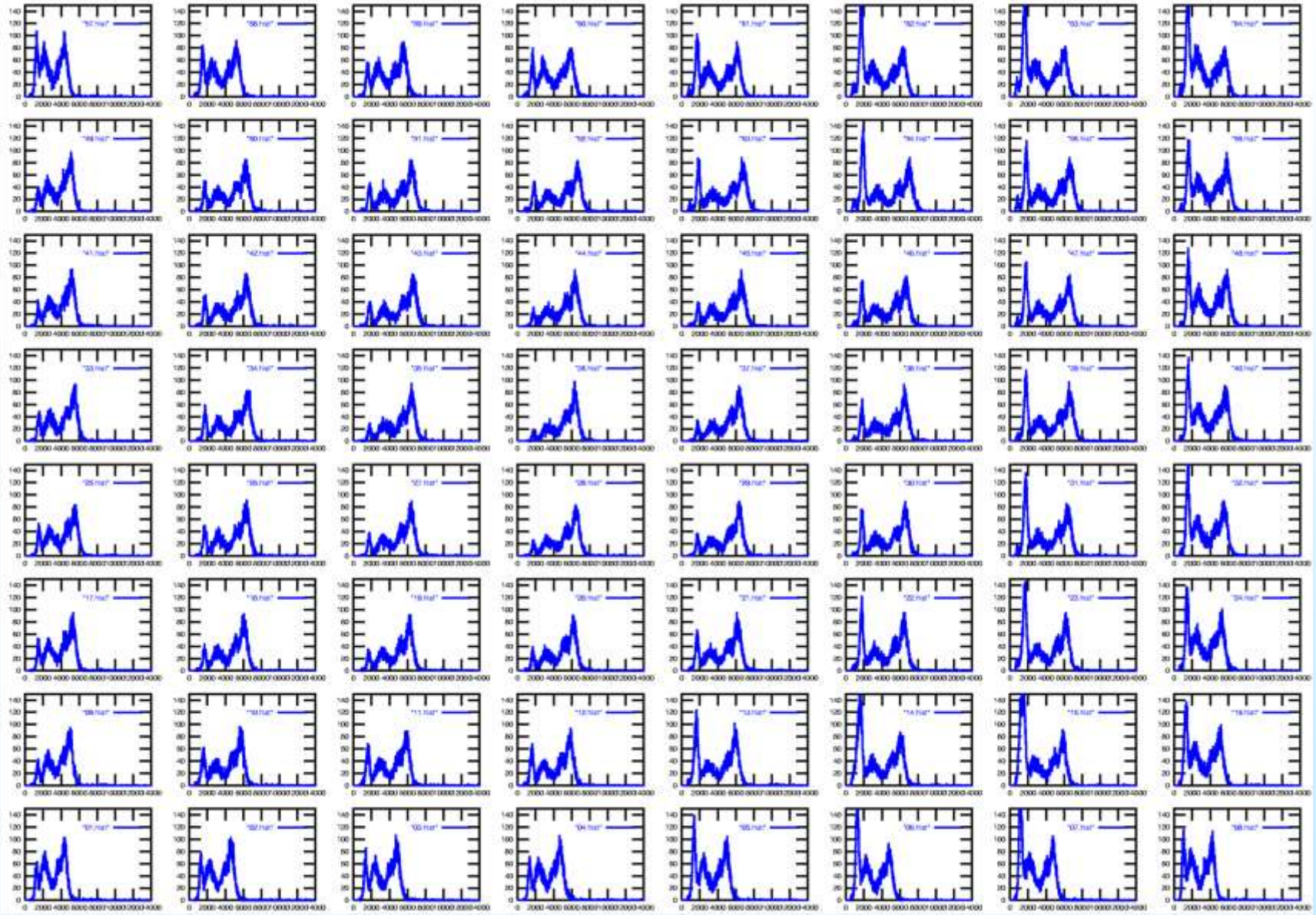
Anode pitchと異なるピクセルの場合
5mm×5mm（抵抗チェーン　16ch）



抵抗chain 16ch ^{133}Ba γ



VA 64ch ^{133}Ba γ



Anode Gainの補正