Low-power Wide-dynamic-range Readout System for a 64-channel Multi-anode PMT of a Scintillation Gamma Camera

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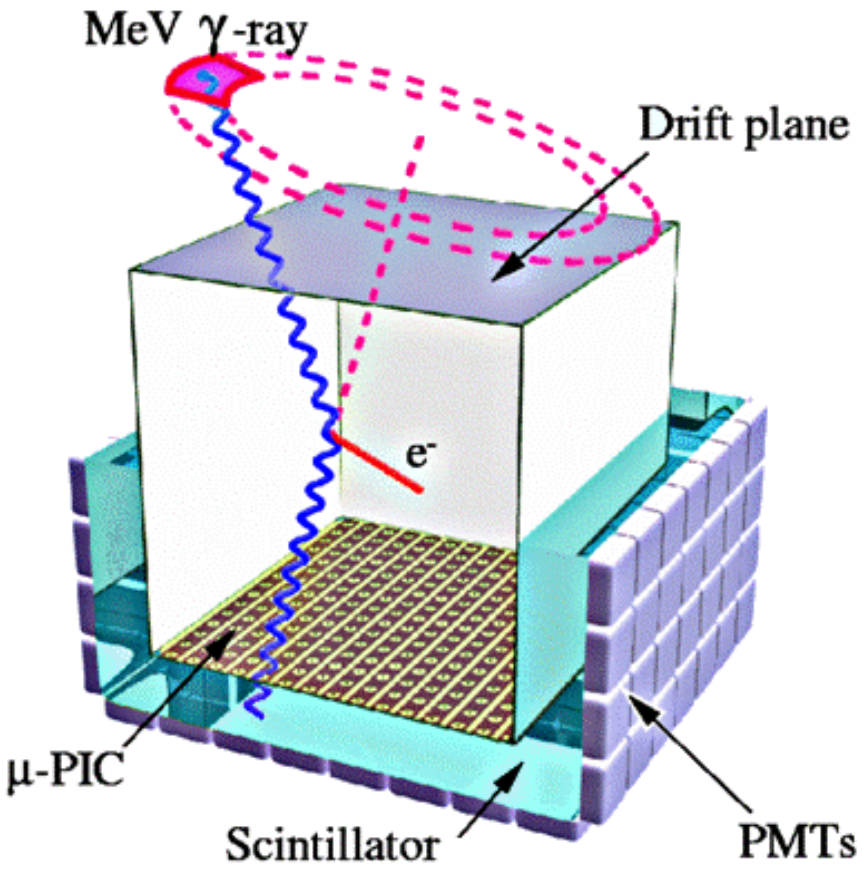
Electron Tracking Compton Camera (ETCC)

Sub MeV~ MeV gamma-ray imaging for …

- Astronomy (balloon experiment, SMILE)
- Medical Imaging

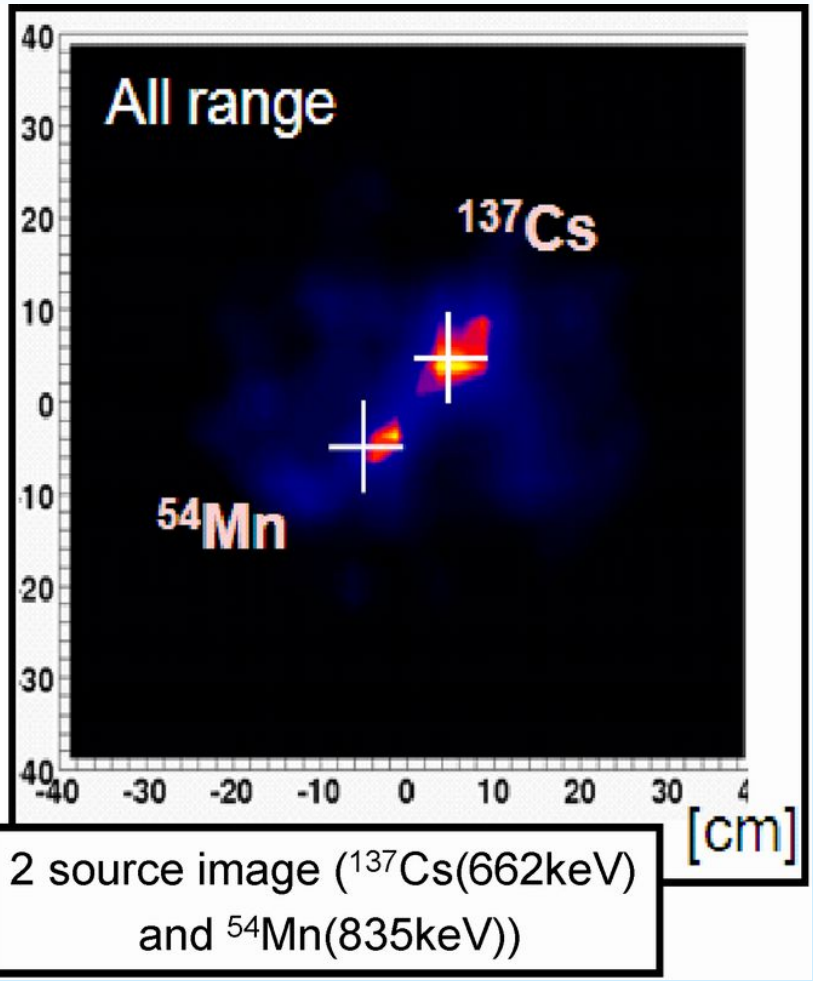


- **micro-TPC**
  - ・Gaseous Time Projection Chamber
  Based on μ-PIC as readout system
  =>Track and energy of recoil electron

+

- **Scintillation Camera**
  Pixel Scintillator Array
  +Multi Anode PMT
  =>Position and energy of scattered gamma-ray

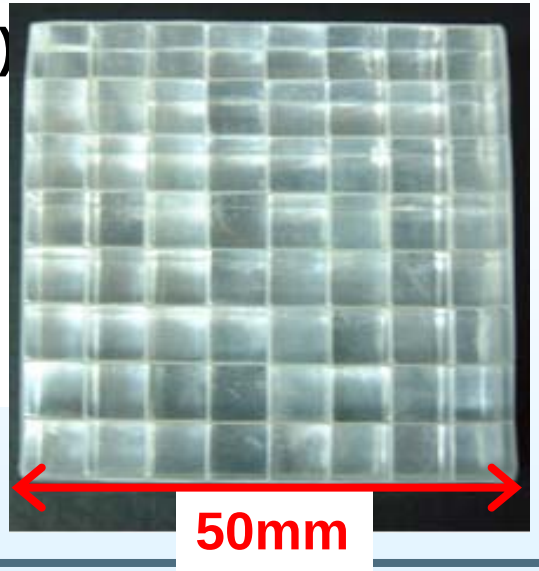
Reconstruct Compton Process
Determine direction and energy of incident gamma ray event by event



2 source image (^{137}Cs(662keV) and ^{54}Mn(835keV))

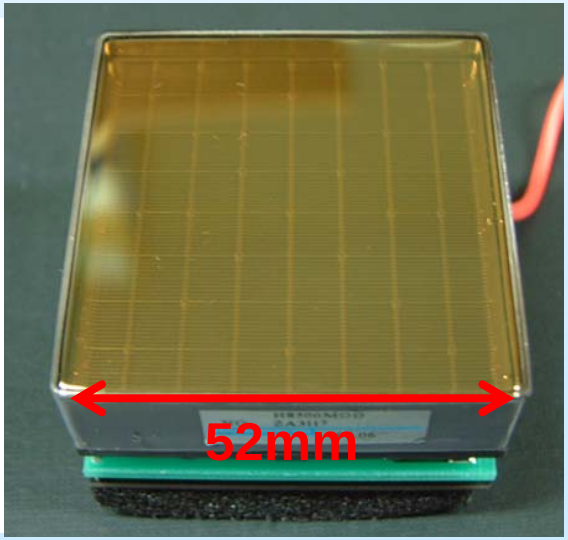
Scintillation Camera

Pixel Scintillator Array (PSA)
- GSO(Ce) crystal
- array : 8 × 8
- Pixel size : 6 × 6 × 13mm^3
- Pixels are optically isolated with the ESR(3M)



PSA is optically glued to H8500 with OKEN-6262A grease

Multi Anode PMT H8500 (HPK)
- anode : 8 × 8
- Size : 52 × 52 × 20mm^3
- Effective area: 49 × 49mm^2(89%)
- Gain : ~10^6@ -1000V
- Gain uniformity : ~1:3



Signal size ~500pC@1MeV

SMILE

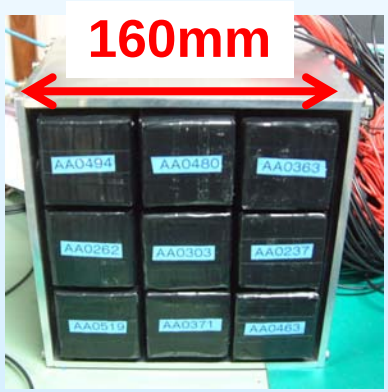
Sub-MeV gamma-ray Imaging Loaded-on-balloon Experiment

SMILE-1 (Sep. 1st, 2006)

- $10 \times 10 \times 15 cm^3$ TPC 33 Scintillation Cameras
- Operation test of our ETCC@ 35km
- Background Measurement
  (Diffuse cosmic and atmospheric gamma)

SMILE-1 has been successful.

Scintillation camera
- Anode signal is grouped by chained resistor.
- Measured by discrete NIM/VME modules
  Energy Resolution : 11%@662keV(FWHM)
- Dynamic range : 80keV~800keV
- Power Consumption : 2.7W/64pixels



SMILE-2 (2011)

- $(40\ cm)^3$ TPC + 192 Scintillation Cameras
- Observation of Crab or Cyg X-1

We are developing a larger detector.

Requirements for scintillation camera

- Position resolution
- Energy resolution

} -Affect the angular resolution of Compton Camera

- Dynamic range

-Affect the dynamic range of Compton Camera

- Radiation hardness

-Scintillator is activated with cosmic ray in the sky.

- Power consumption

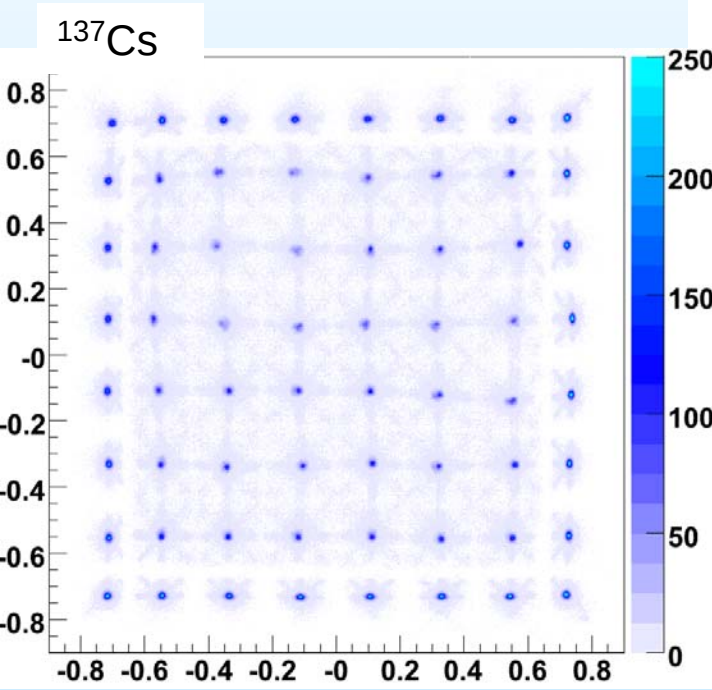
-Power is limited in the sky.

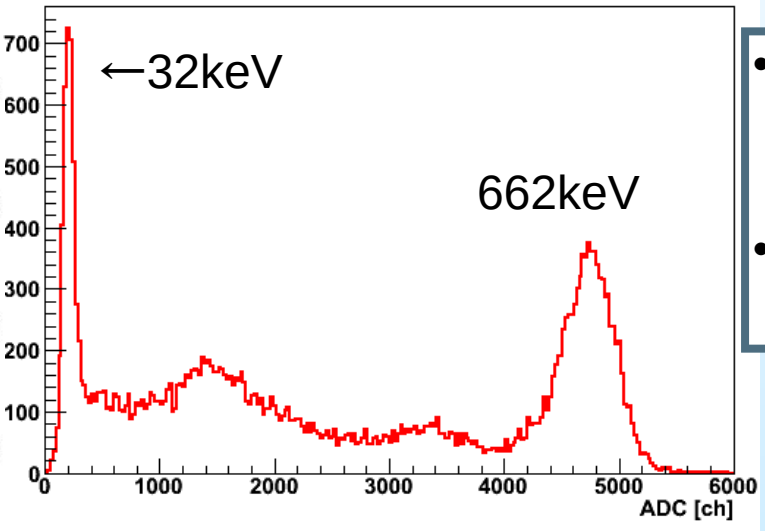
	Number of MAPMT	Power Consumption [W/64pixels]	Energy Resolution (FWHM)@662keV	Dynamic Range [keV]
SMILE-1	33	2.7W	~ 11.0%	80-800
SMILE-2	192	< 400mW	~ 11.0%	80-1000

We have improved new readout system with low power consumption.

Readout system with ASIC（VA/TA）

CP80168 (Clear Pulse)
- 32ch CMOS ASIC (by IDEAS ASA) *2
- 64ch readout
- Input dynamic range : ~35pC
- 80 us/64ch to read out
- Power Consumption : 1.05W



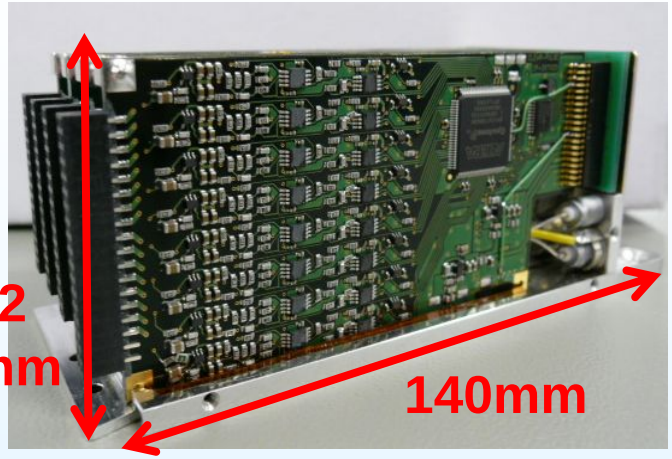


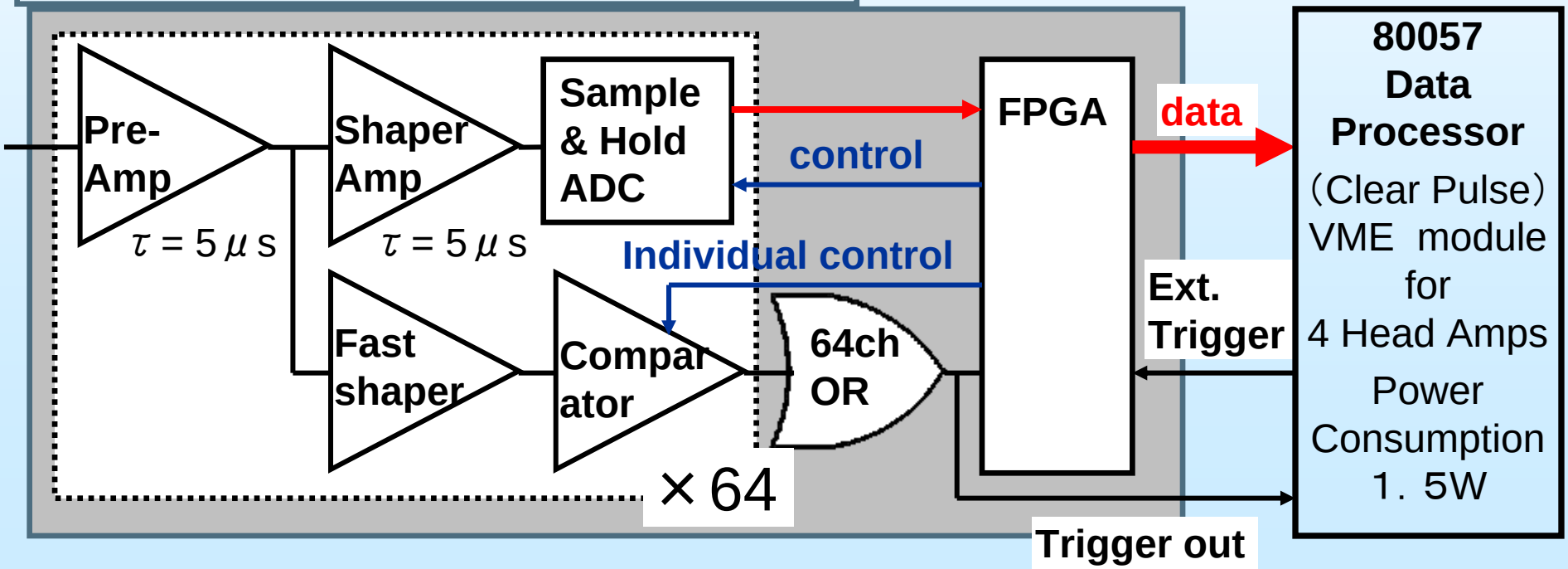
- Energy Resolution : ~11%@662keV (FWHM)
- Dynamic range : 30keV~800keV

- Narrow input dynamic range
- Large power consumption.

New Readout System

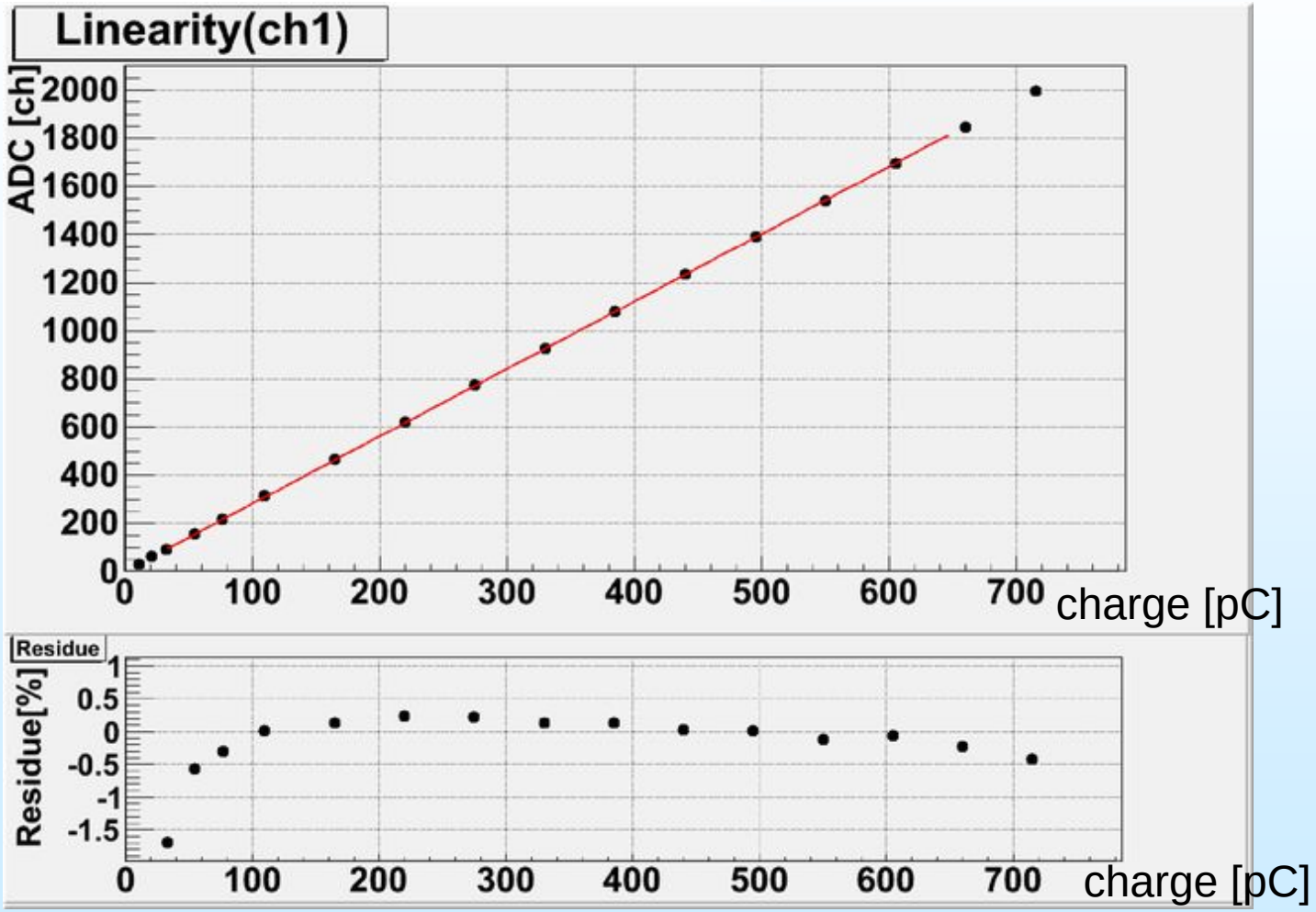
Head Amp Unit CP80190(Clear Pulse)
- 64ch readout
- Using only discrete devices.
- Input dynamic range is variable by replacing feedback capacitor. (Adjusted to <750pC)
- Power Consumption：1.2W
- 20s/64ch to read out





Linearity of CP80190

- Input some test charge into CP80190



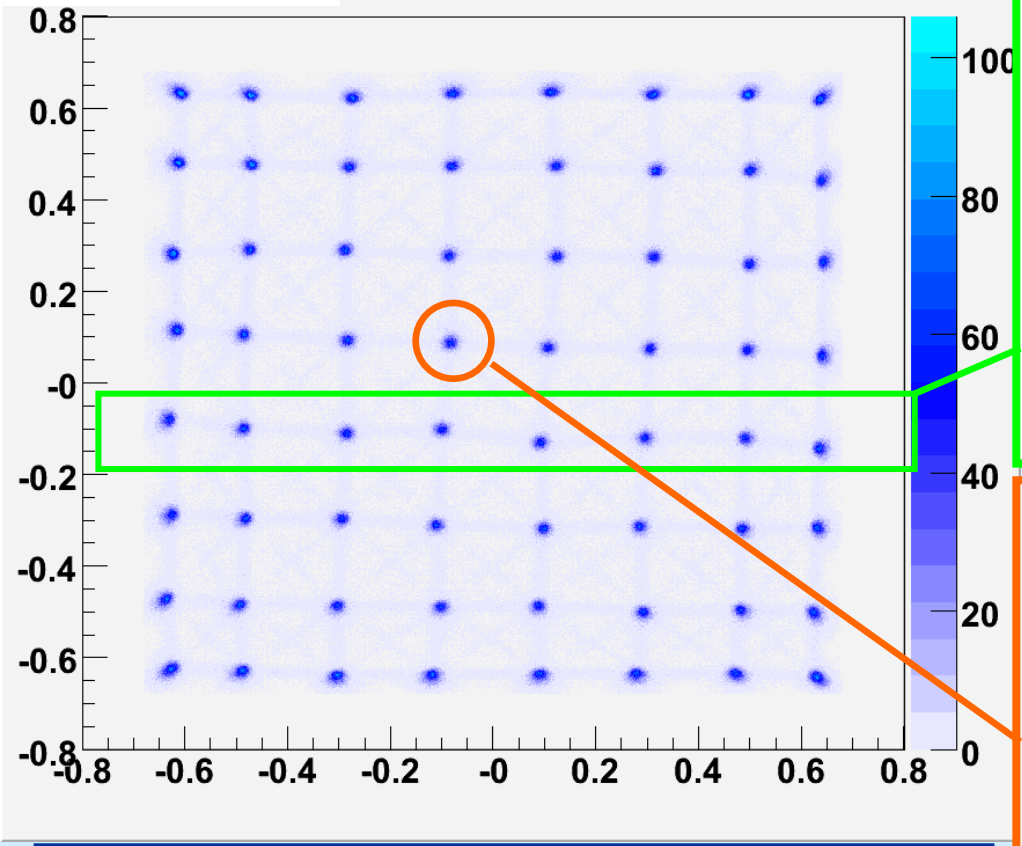
Linearity is kept from 50pC to 700pC (±0.5%)

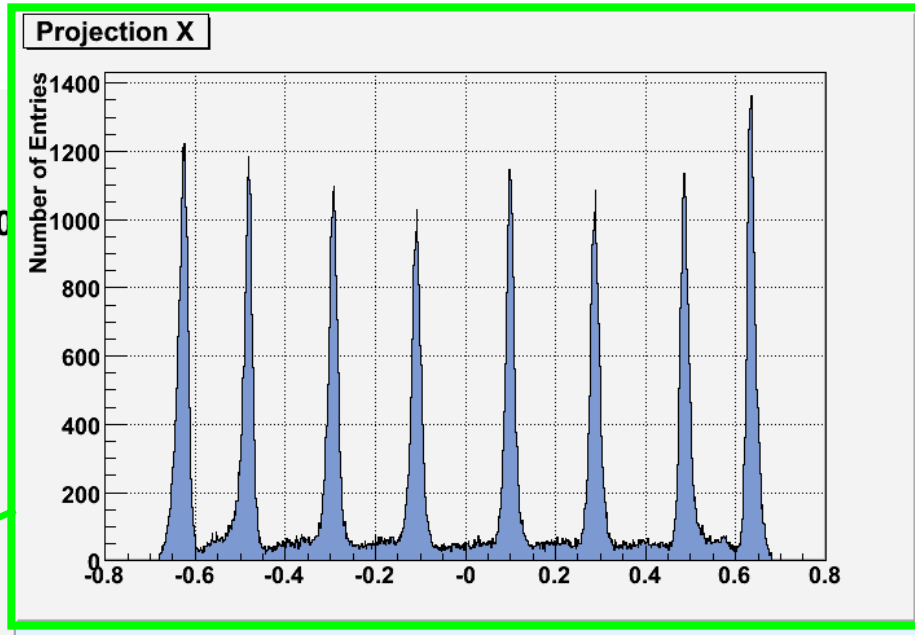
⇒ Enough for our Scintillation Camera.

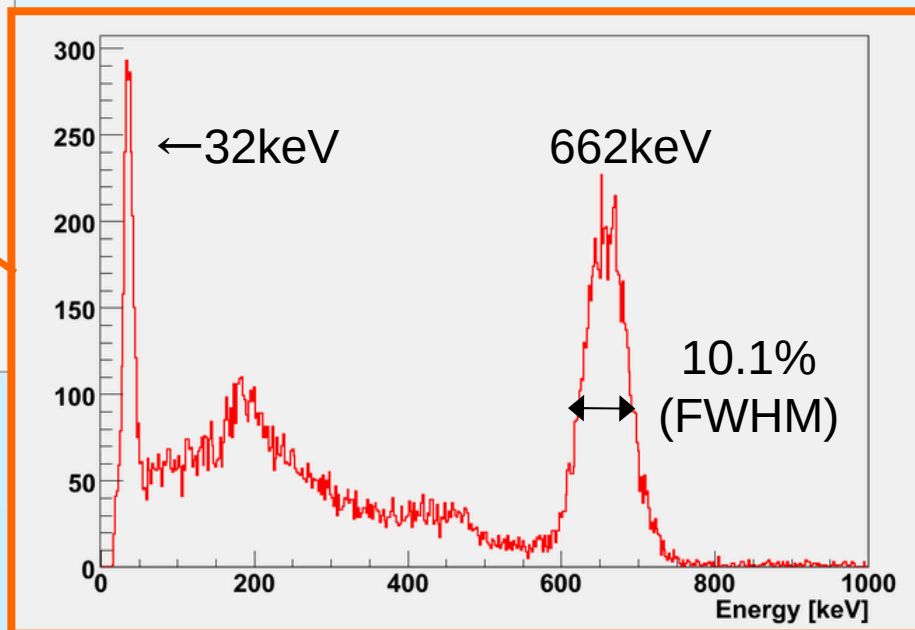
GSO + CP80190

- Reconstructed image and spectra

^{137}Cs



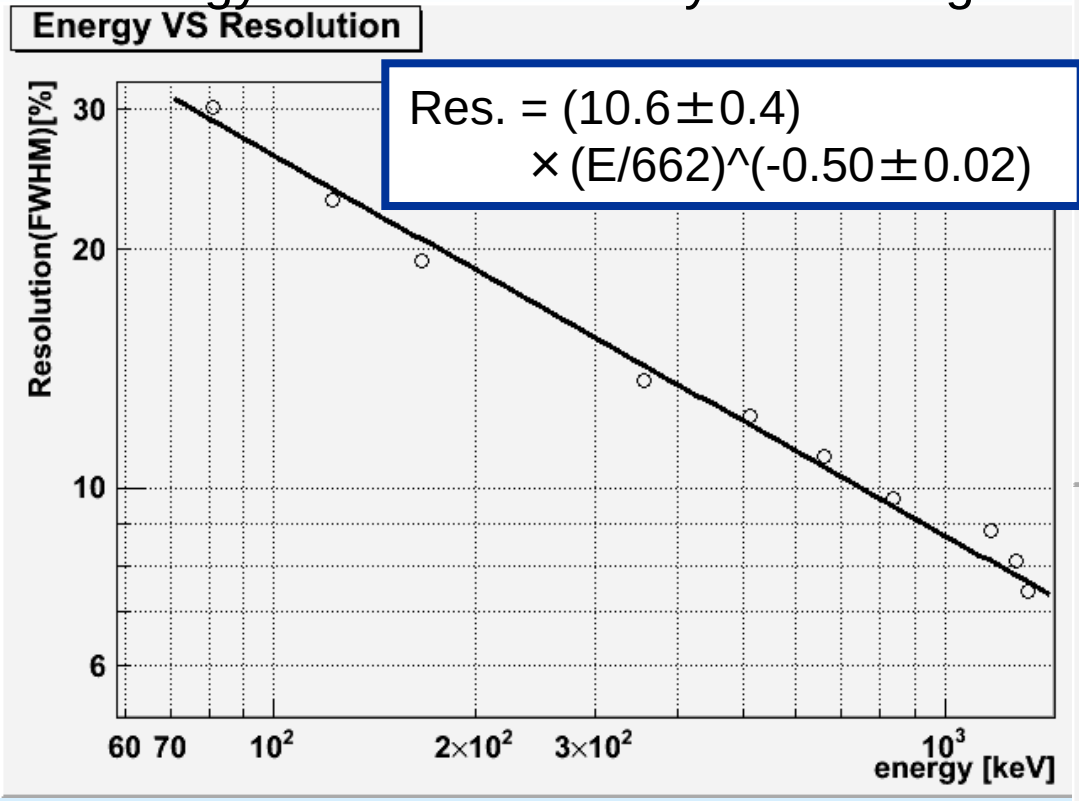


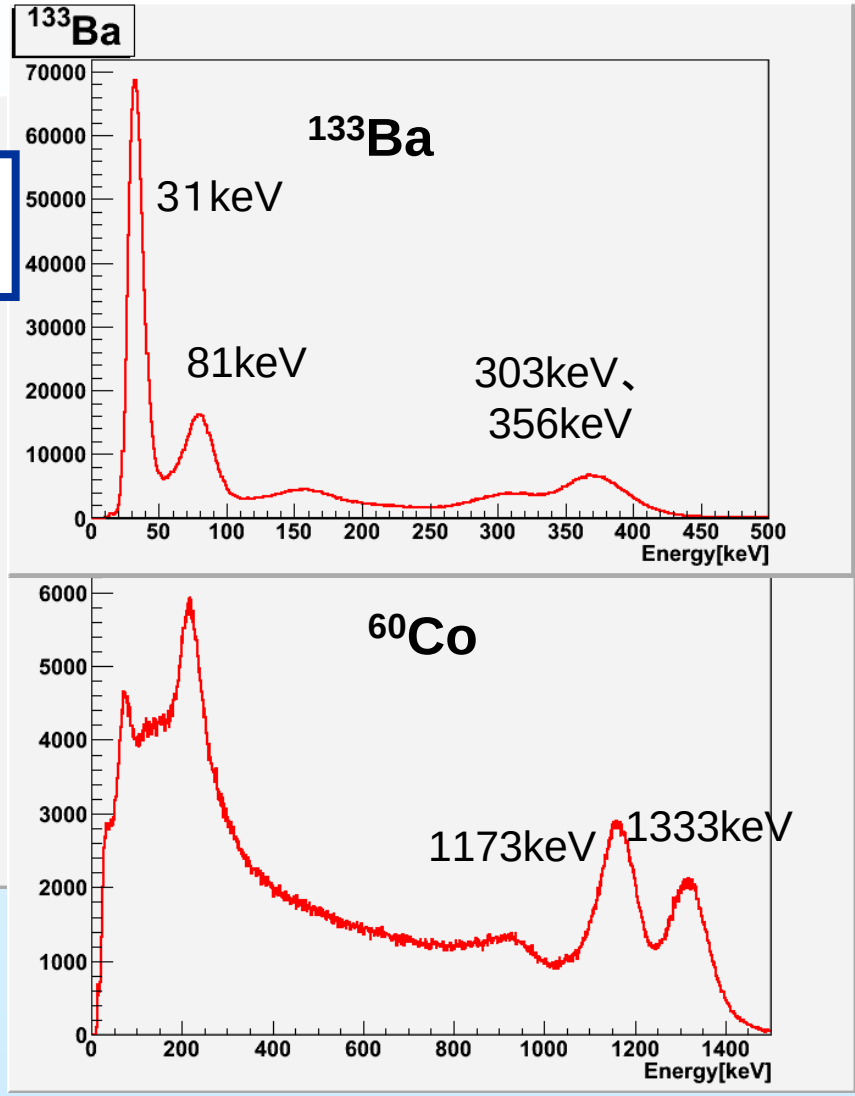


- Reconstructed by Center of Gravity Method.
- Each 64pixel is clearly resolved

GSO + CP80190

- Energy Resolution and Dynamic range



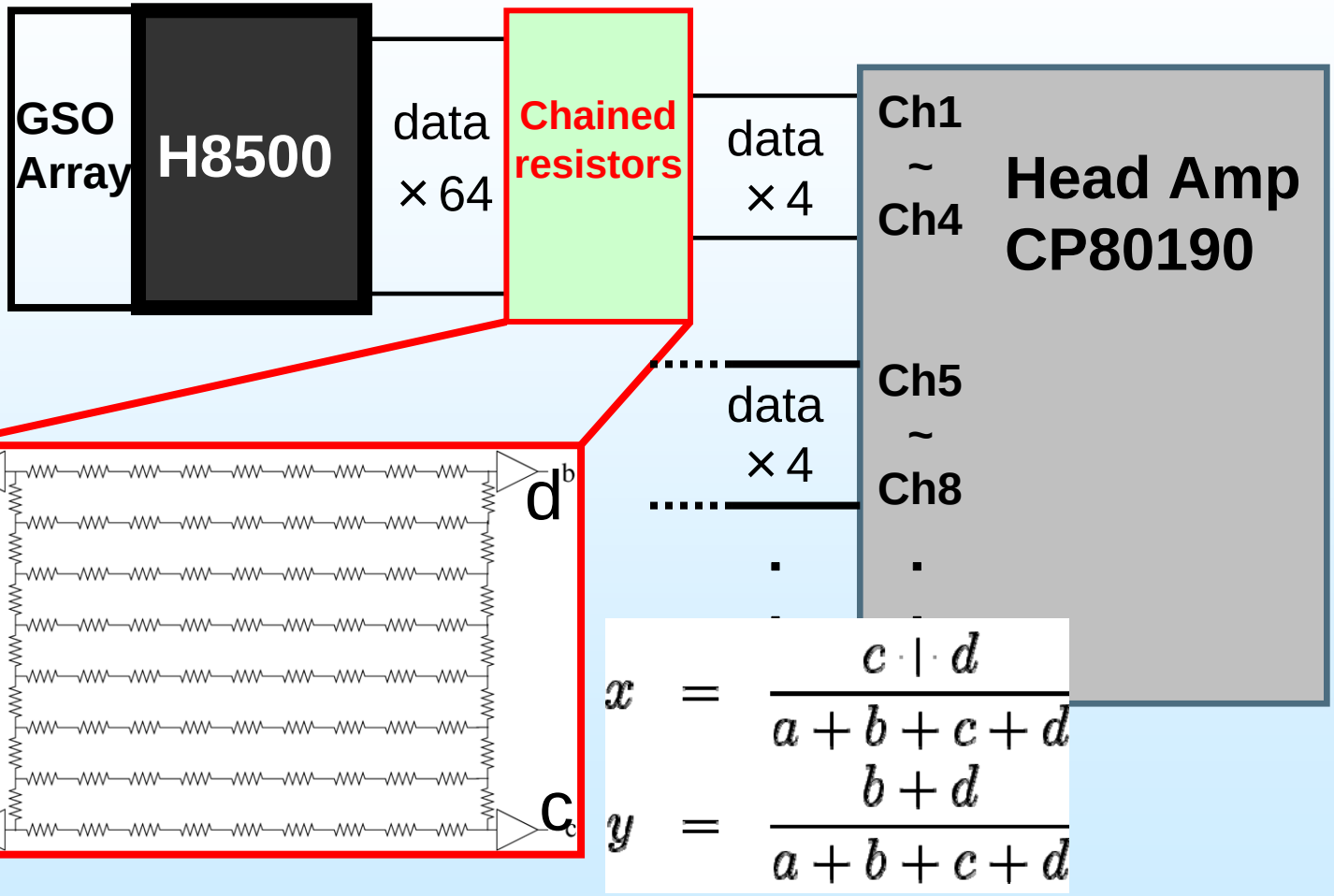


- Energy Resolution (average): 10.6%@662keV(FWHM)
- Dynamic range : **30keV~1.3MeV**
- Power Consumption : 1.55W/PMT

=> Too large power consumption for SMILE-2

Chained Resistors + CP80190

In order to reduce further the power consumption…



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

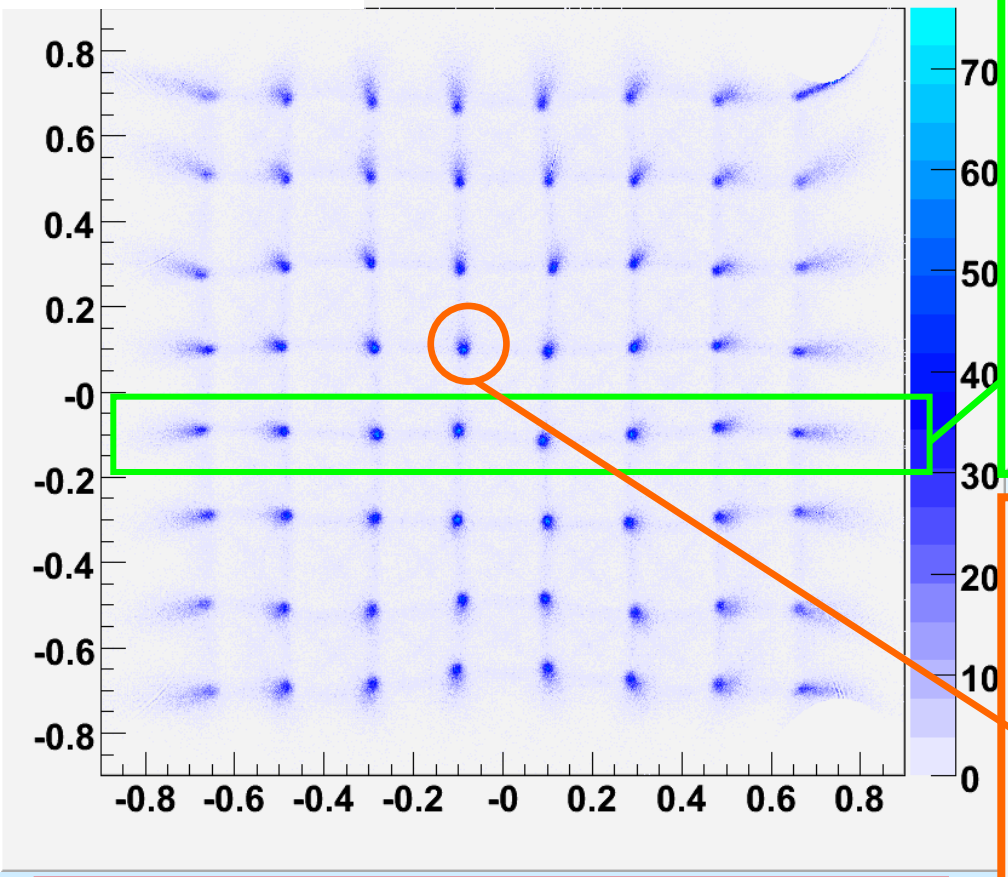
$$y = \frac{b+d}{a+b+c+d}$$

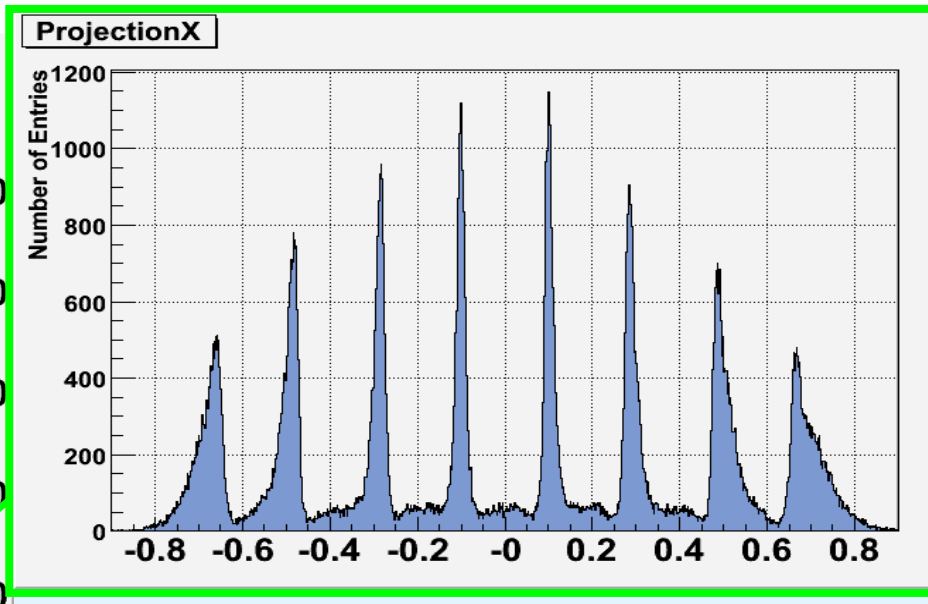
The number of readout ch is reduced to 1/16
=> total power consumption is reduced.

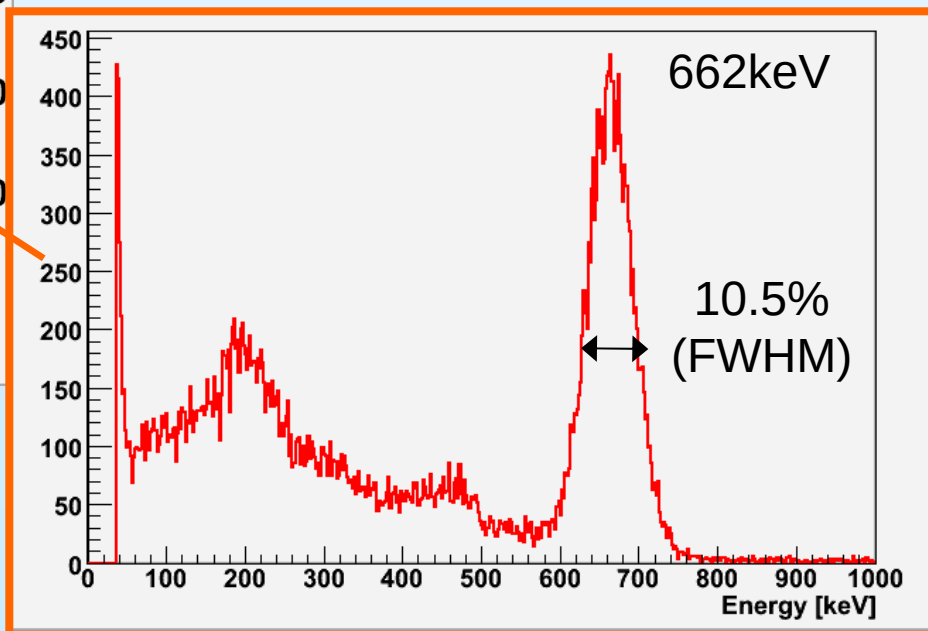
Chained Resistors + CP80190

- Reconstructed image and spectra

^{137}Cs



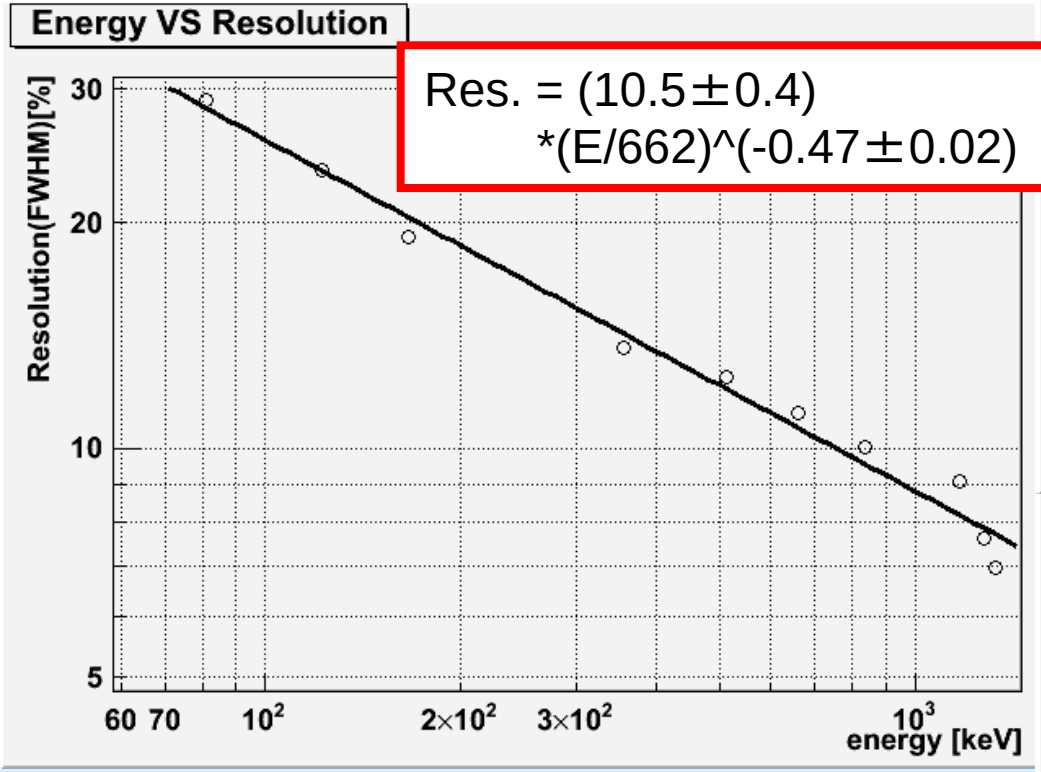




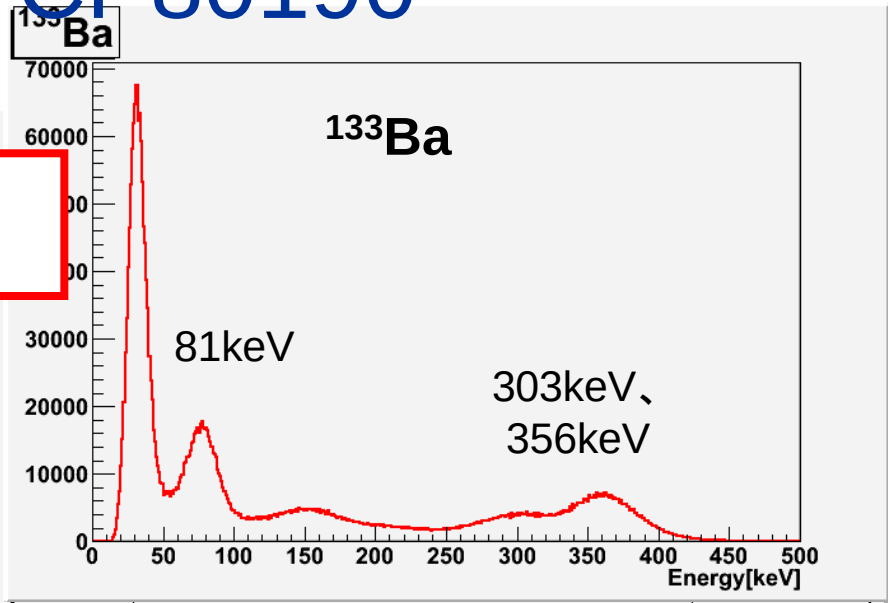
•Each 64pixel is clearly resolved

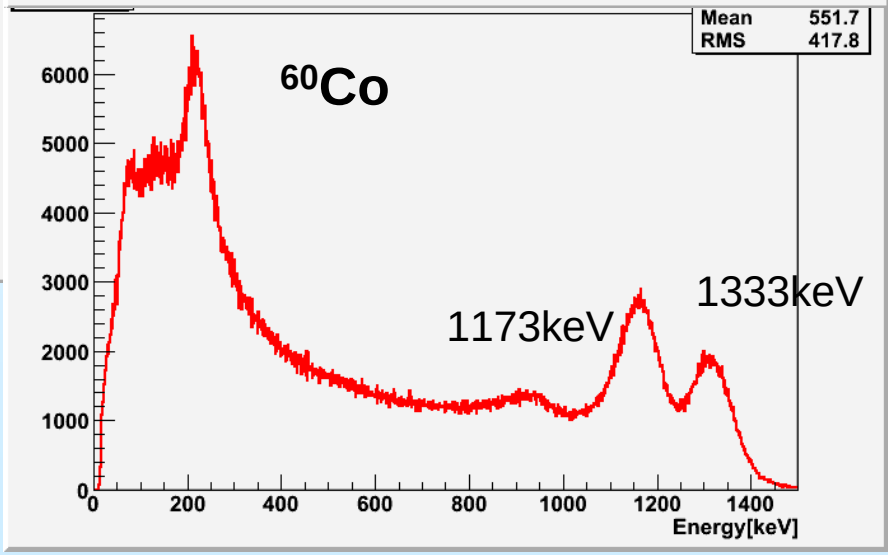
Chained Resistors + CP80190

- Energy Resolution and Dynamic range



Res. = (10.5±0.4)
*(E/662)^(-0.47±0.02)





- Energy Resolution (average): 10.5%@662keV(FWHM)
- Dynamic Range: 80keV~1300keV
- Power Consumption: **100mW/PMT**

=>Satisfy all requirements of SMILE-2

$LaBr_3(Ce)$ Scintillator

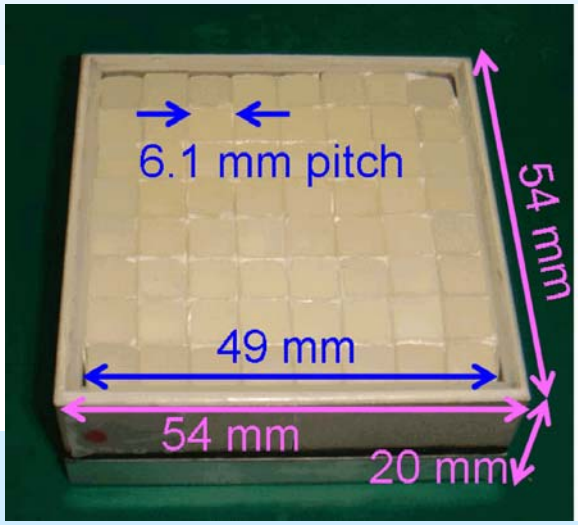
For next experiment after SMILE-2, or medical imaging,
It is important to improve angular resolution of ETCC.

Saint-Gobain
BrilLanCe380
Size: ϕ 38 × 38mm

◎Excellent Energy Resolution
: ～3%@662keV(FWHM)

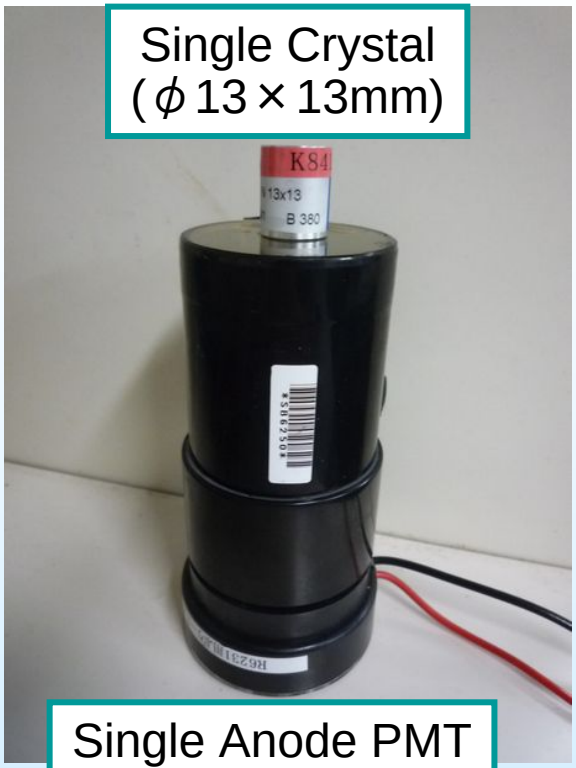
× Strong Hygroscopic

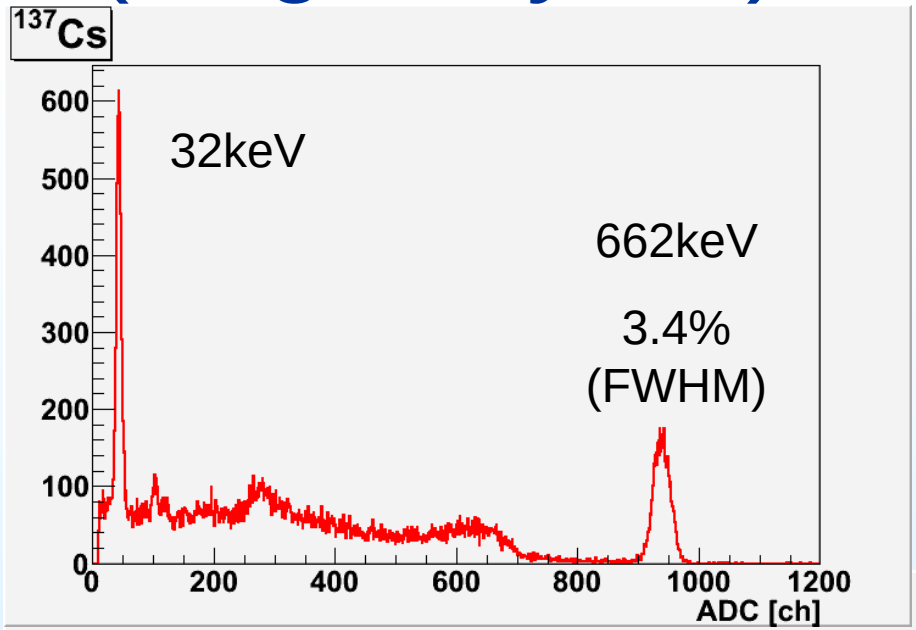
- Pixel size : 5.9 × 5.9 × 20mm^3
- 8 × 8 array
- Glass window :
  Quartz (t 2.3 mm)
- Hermetic package :
  Aluminum (t 0.5 mm)

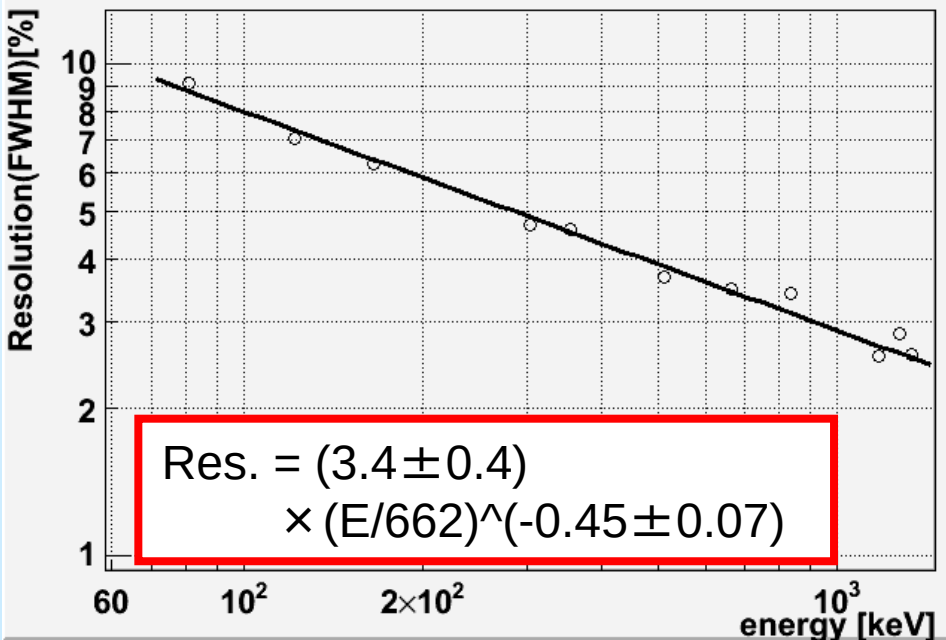


Energy Resolution measured with
discrete NIM/VME modules is
5.8%@662keV(FWHM)

CP80190 + $LaBr_3$ (single crystal)



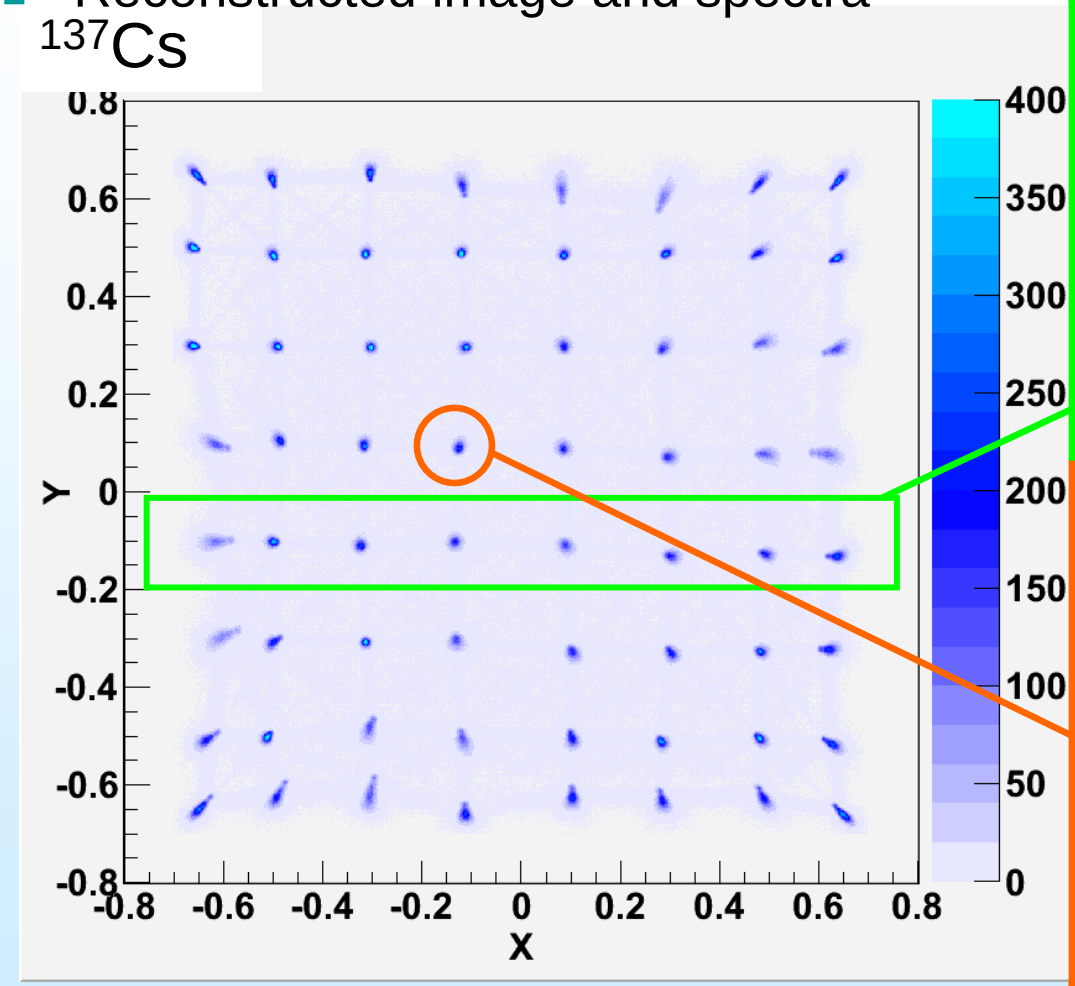


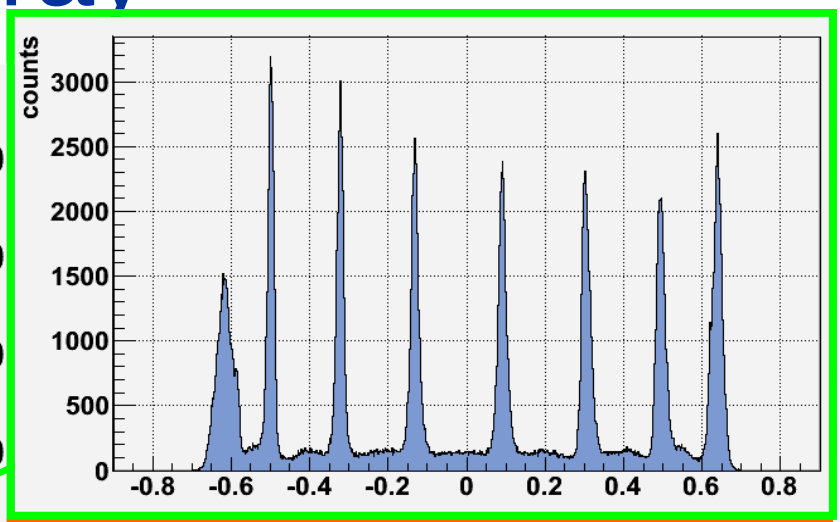


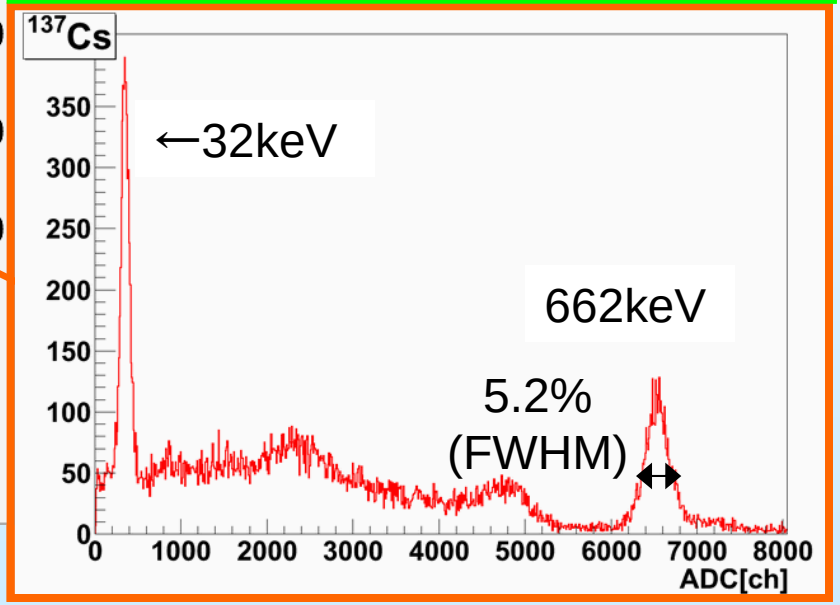
- Energy Resolution :
  3.4%@662keV(FWHM)
  (consistent with NIM/VME discrete readout system)
- Dynamic range：80keV~1.3MeV

CP80190 + $LaBr_3$ Array

- Reconstructed image and spectra



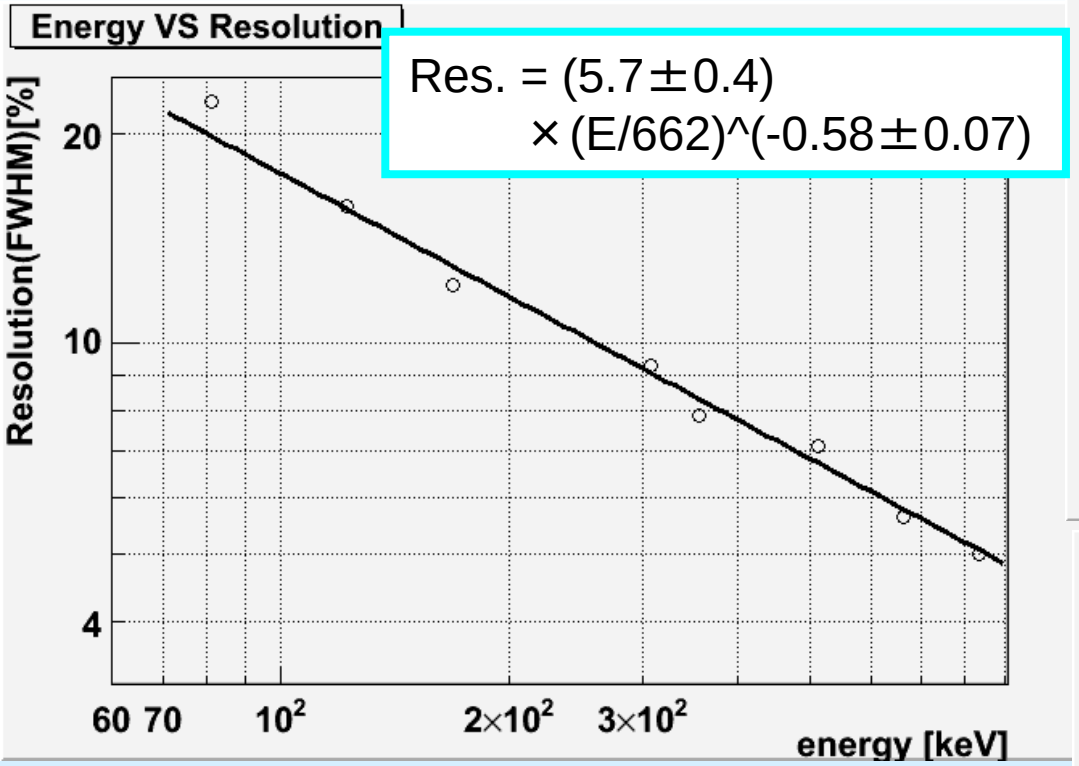




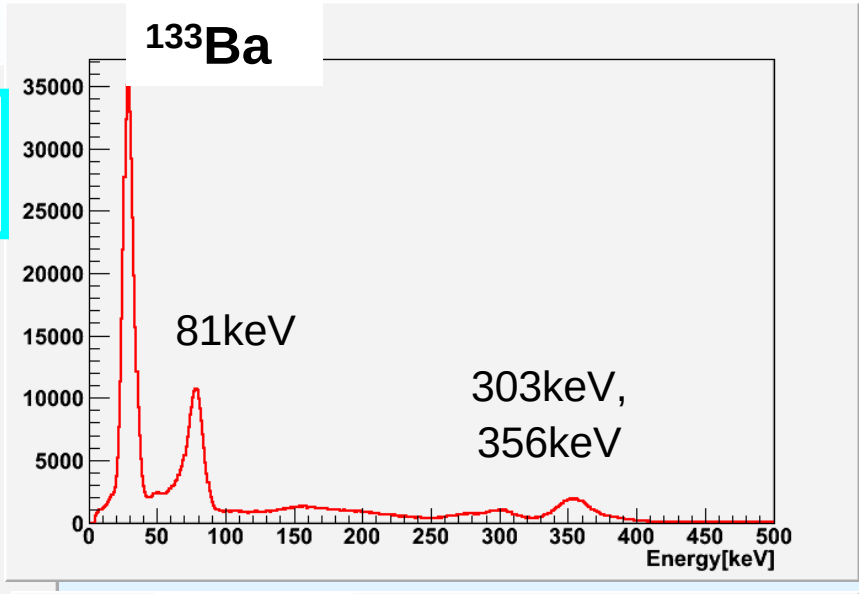
- Each 64pixel is clearly resolved

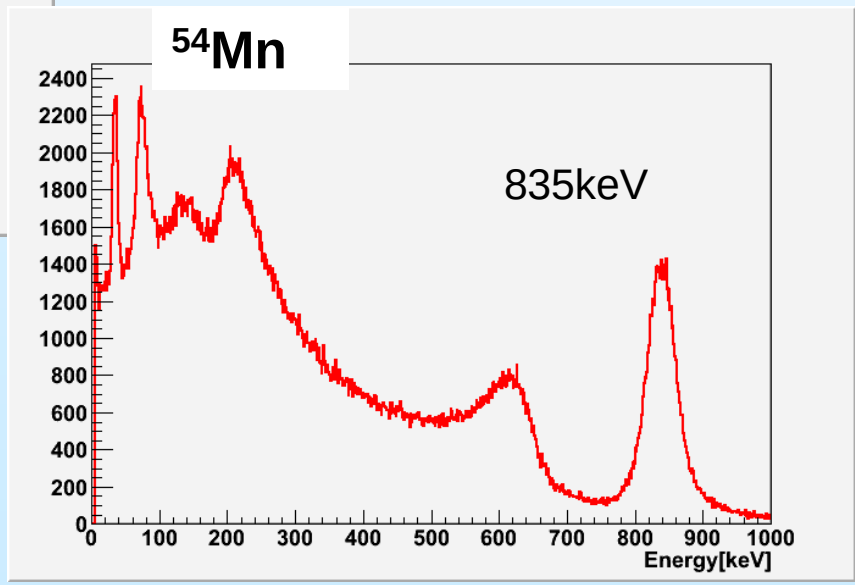
CP80190 + $LaBr_3$ Array

- Energy Resolution and Dynamic range



Res. = (5.7±0.4)
×(E/662)^(-0.58±0.07)





- Energy Resolution (average):
  5.4%@662keV(FWHM)
- Dynamic Range:
  80keV-800keV

Summary ~For SMILE-2~

- We have developed ETCC which consists of gaseous TPC and scintillation camera.
- For next balloon experiment, we have developed a new readout system of scintillation camera with very low power-consumption and wide dynamic-range.

	Energy Resolution (FWHM@662keV)	Energy Dynamic range	Power (/PMT)
Requirements	11%	80keV~1MeV	400mW
Chained resistor and discrete NIM/VME modules	○11%	△80keV～800keV	×2.7W
CP80168（VA/TA）（64ch readout）	○11%	△30keV～800keV	×1.4W
CP80190 (64ch readout)	○10.6%	◎30keV～1.3MeV	×1.5W
Chained resistor and CP80190 (4ch readout)	○10.5%	◎80keV～1.3MeV	◎100mW

Future Work

- For SMILE-2
  - Enlargement of the scintillation camera.
  - Install readout system in DAQ system of ETCC.

- In order to improve angular resolution of ETCC.
  (for Medical imaging and next to SMILE-2)

  We have developed $LaBr_3$ arrays.
  - Energy resolution of the array（FWHM, @662keV）

    -Discrete modules (4ch readout) : 5.8 %

    -New readout system (64ch readout) : **5.4%**
  - Dynamic range : 80 - 800 keV

Thank you