Preliminary performance of a new type of modular gamma-camera prototype

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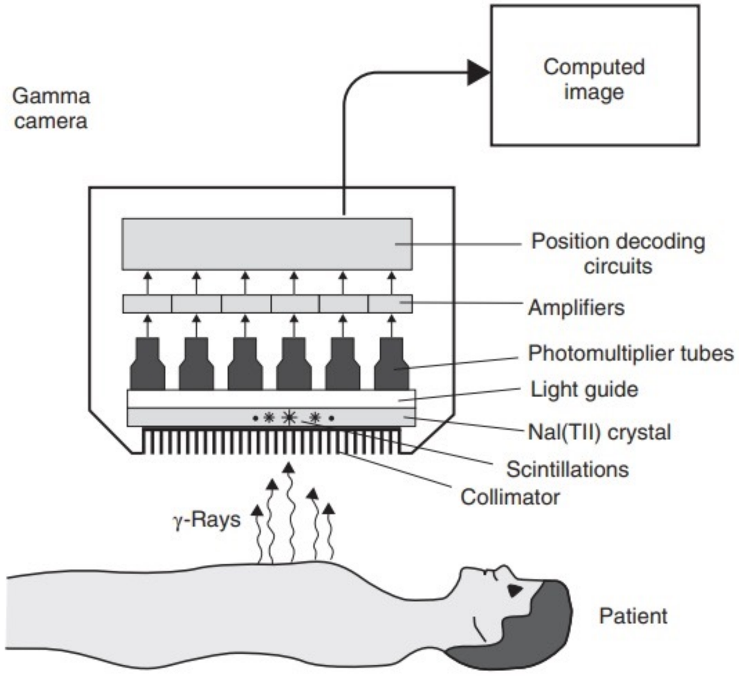
Outline

- History and main types of gamma cameras
- New concept of modular gamma cameras
- Testing prototype of a new type of gamma-camera
- Conclusion

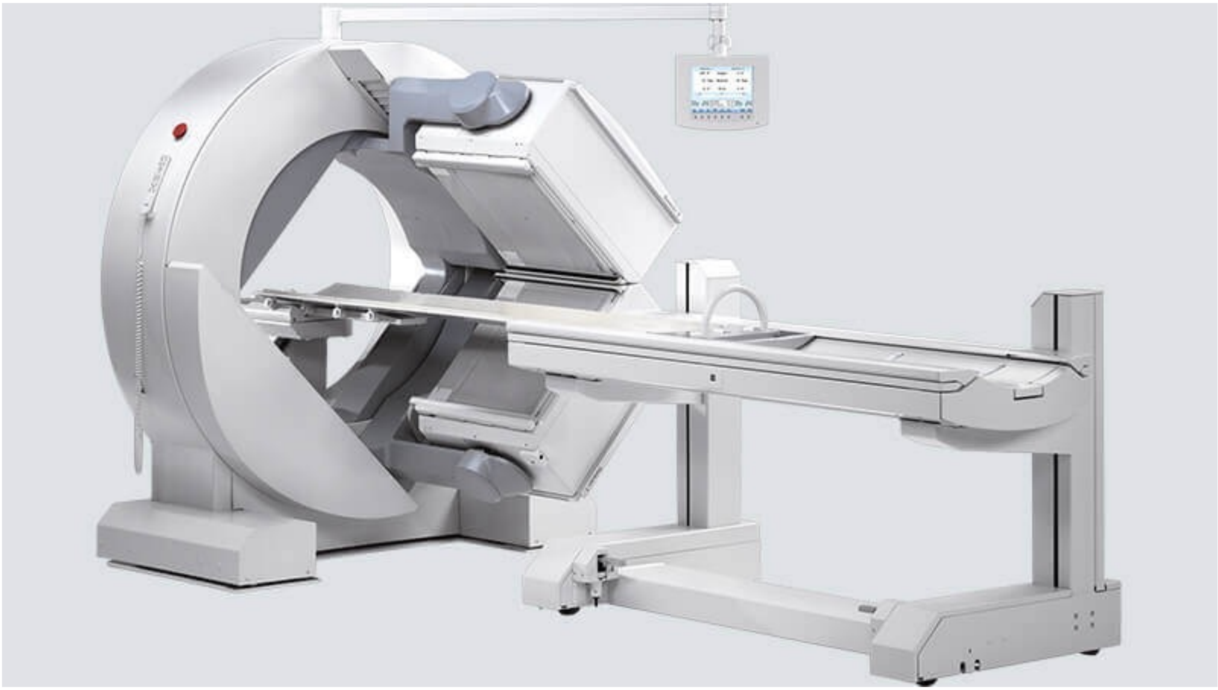
Gamma cameras

Gamma camera is a device aimed to image gamma radiation.

It is one of the most popular tool in nuclear medicine for the tomography of human organs with the single photons emitted by the radioactive isotopes.



Ref: https://www.pharmacy180.com/article/radiopharmaceuticals-for-imaging-1434/

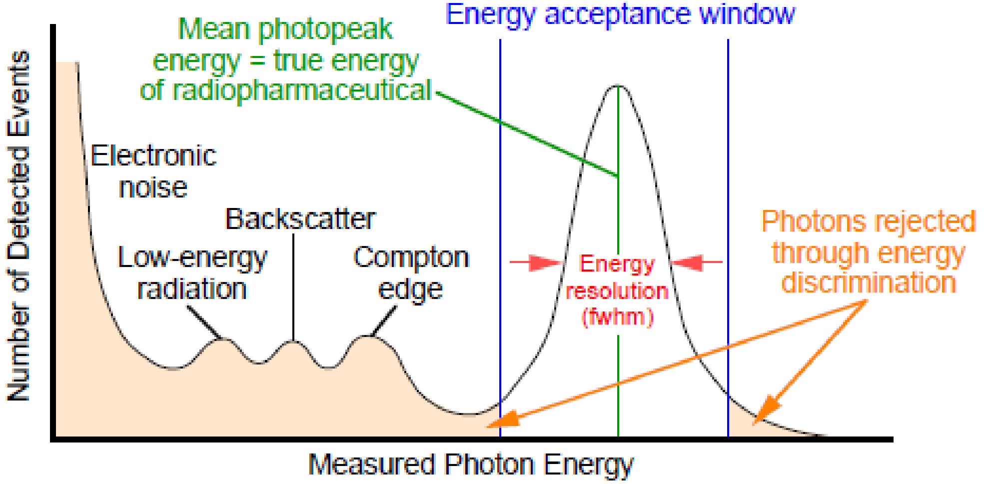


History of gamma cameras

Table 1
Characteristics of the main compact detectors for scintimammography

Detector	$LaBr_3$:Ce 2005	Multi-PSPMT 2003	LumaGEM® Released 1999	LumaGEM 3200® Released 2003	LumaGem3200S® Released 2005
	$LaBr_3$:Ce-H8500 PMT	NaI(Tl) array R8520 PSPMT	NaI(Tl) array—PSPMT	CdZnTe Solid State	CdZnTe Solid State
Field of view	5 cm × 5 cm	18 cm × 16 cm	13 cm × 13 cm	20 cm × 16 cm	20 cm × 16 cm
Dead space	<8 mm from edge	<8 mm from edge	<10 mm from edge	<8 mm from edge	<8 mm from edge
Thickness	<8 cm	<9 cm	<9 cm	<7.5 cm	<7.5 cm
Energy resolution[a]	6% FWHM	15% FWHM	10% FWHM	6% FWHM	4.5% FWHM
Spatial resolution[a]	0.9 mm	2.0 mm	2.2 mm	2.5 mm	1.6 mm
Space bandwidth[a]	Continuous	6930 pixel^2	3136 pixel^2	5120 pixel^2	12,288 pixel^2

[a]Values at 140 keV.



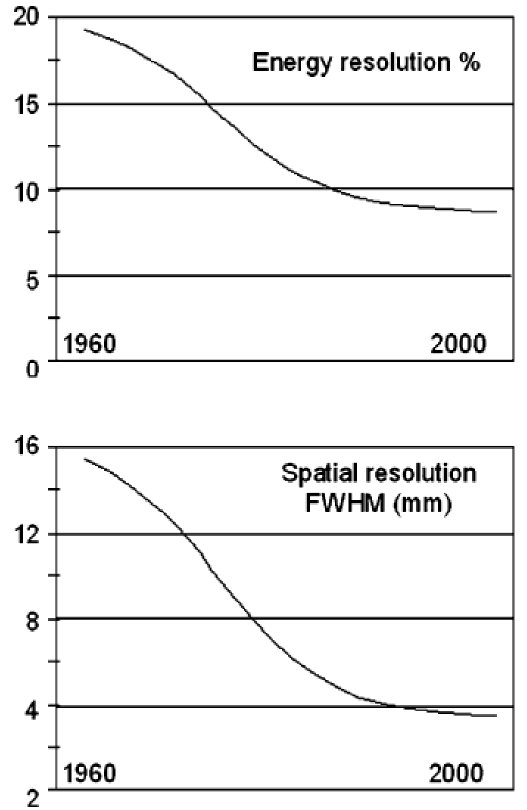


Fig. 4. Improvement of intrinsic energy and spatial resolution of gamma cameras since their introduction.

Two main types of gamma cameras using scintillators:

1. Large continuous crystal with an array of readout photomultipliers
2. Many small scintillator pixels connected to photomultipliers 1-to-1

Gamma cameras with large continuous crystal

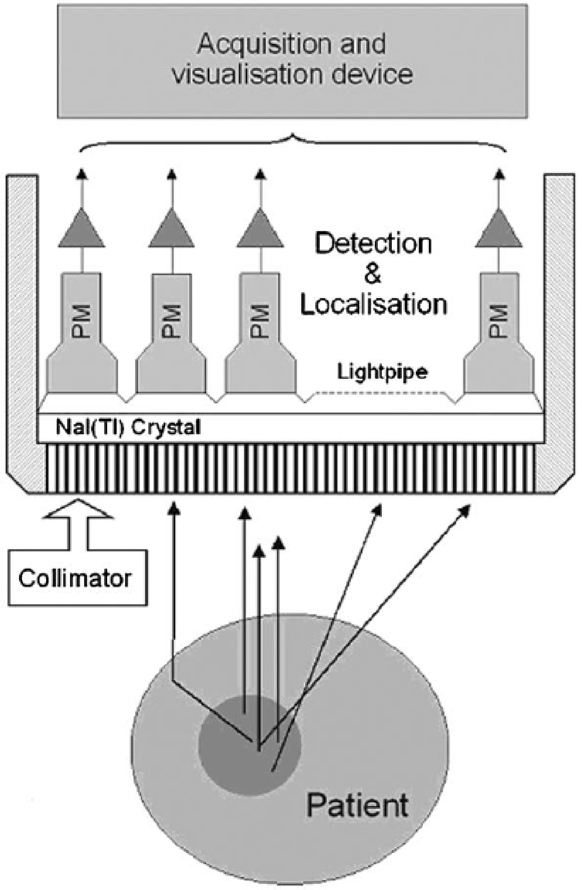
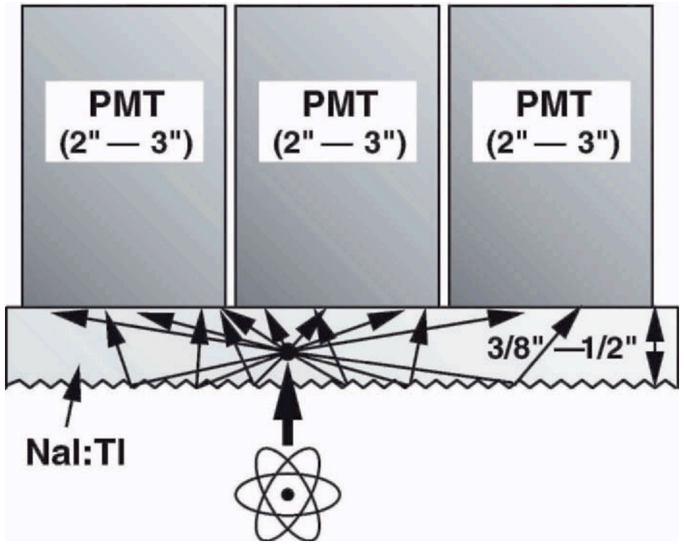
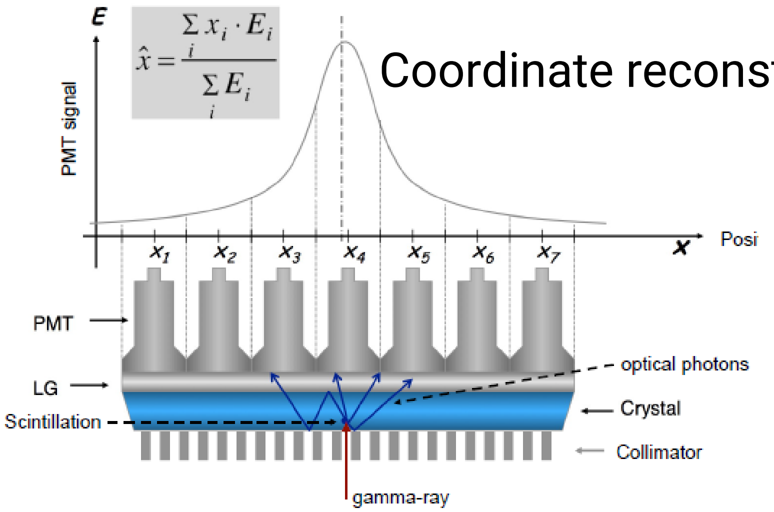


Fig. 1. Block diagram showing the basic components of a conventional scintillation camera.





Coordinate reconstruction

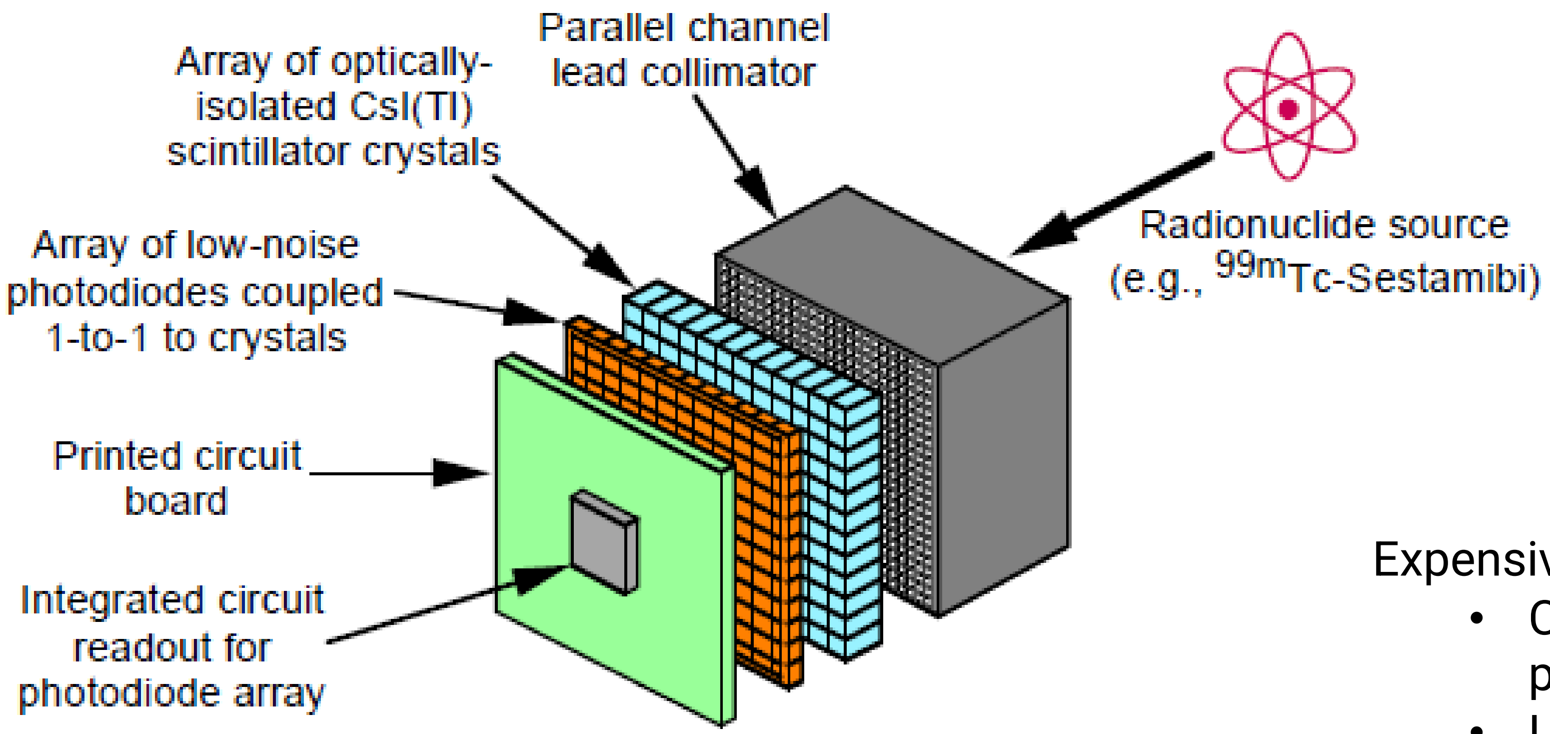
With vacuum PMTs:

- Voluminous
- Expensive (inch multi-channel FEU - $2500)
- High voltage (1.5-2.5 kV)
- Individual voltage (gain) adjustment
- Spatial heterogeneity of the photocathode
- Sensitive to magnetic fields

With SiPMs:

- The more SiPMs are in a matrix, the more is the noise
- Sensitive to temperature

Gamma cameras with many small scintillator pixels



Good spatial and energy resolutions

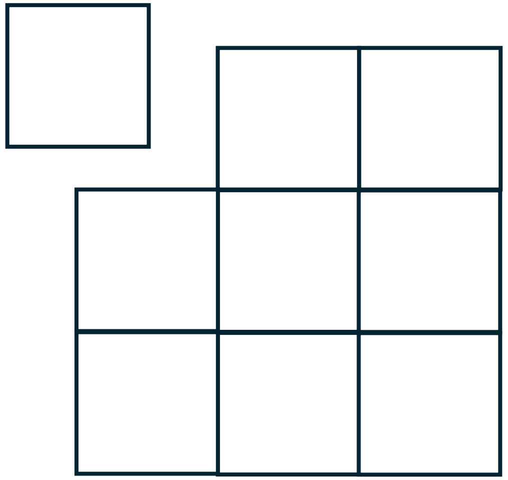
BUT

Expensive on many levels:

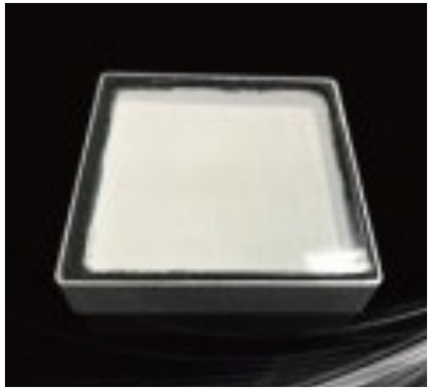
- Complex procedure for making small pixels in a crystal
- Large number of SiPMs
- Large number of readout channels

Modular gamma camera

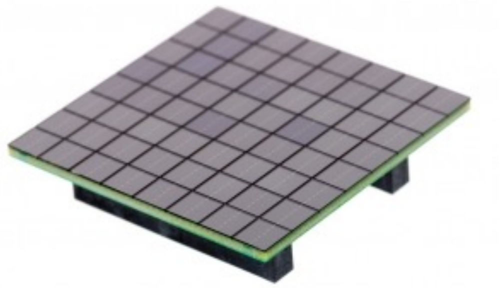
One module (mini gamma camera)



Full scale gamma camera assembled of required number of modules



Scintillator 50x50 mm^2



SiPM matrix 50x50 mm^2

Such a basic element can serve as a mini-gamma camera itself and be used in radiological surgical operations and laboratory research.

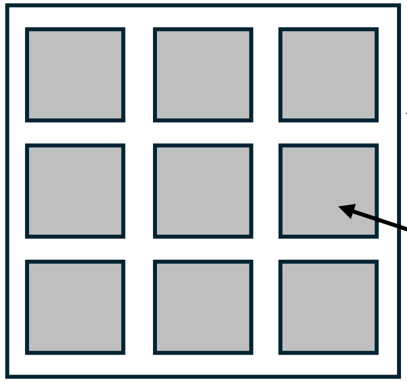
Advantages:

- Scaling
- Simplicity
- Reproducibility of the parameters of separate elements of gamma camera
- Less electronic channels

Expected problems

- Non-linearity of coordinate restoration at the perimeter of a module
- Noises – the more SiPMs are in a matrix, the more is the noise

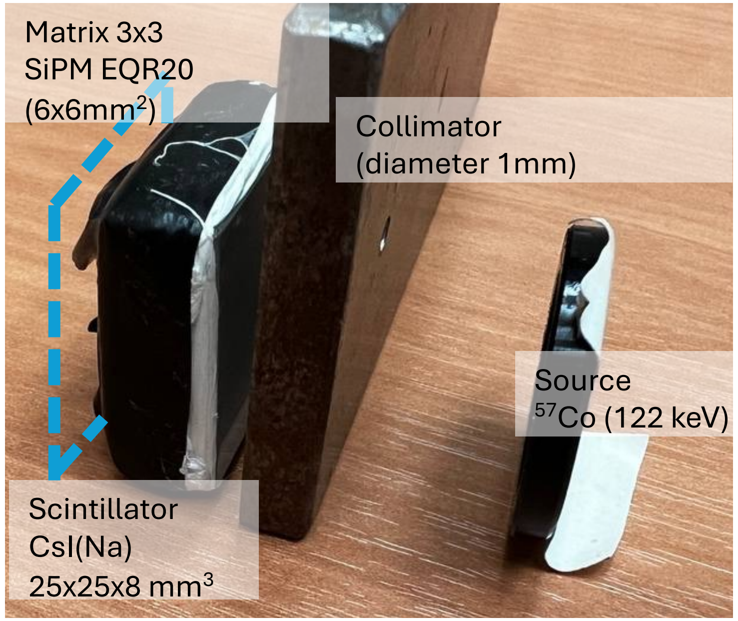
Modular gamma camera prototype



Scintillator
CsI(Na)
25x25x8 mm^3

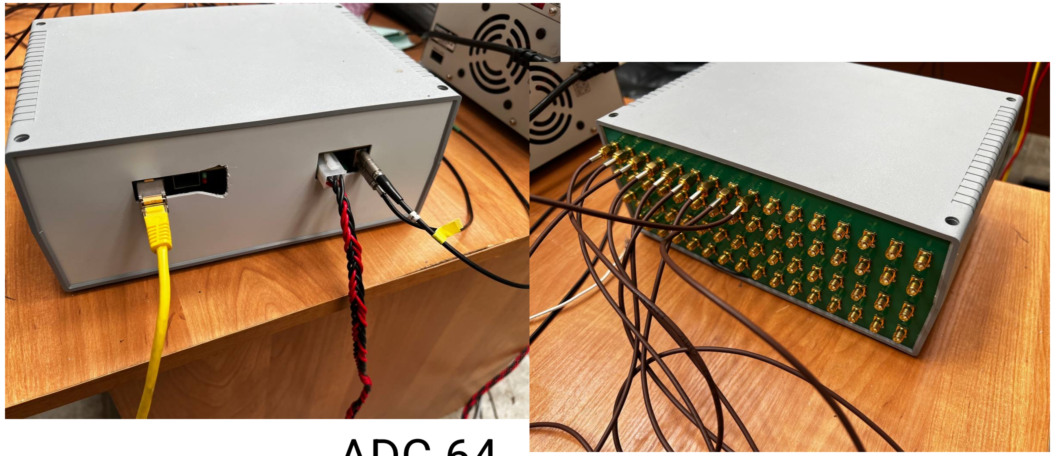
EQR20 SiPM (6x6 mm^2)

3x3 SiPM matrix scheme

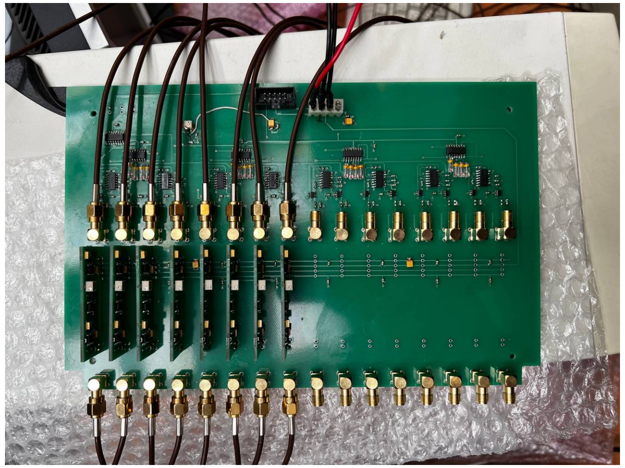


Experimental setup

One module connected to the acquisition system



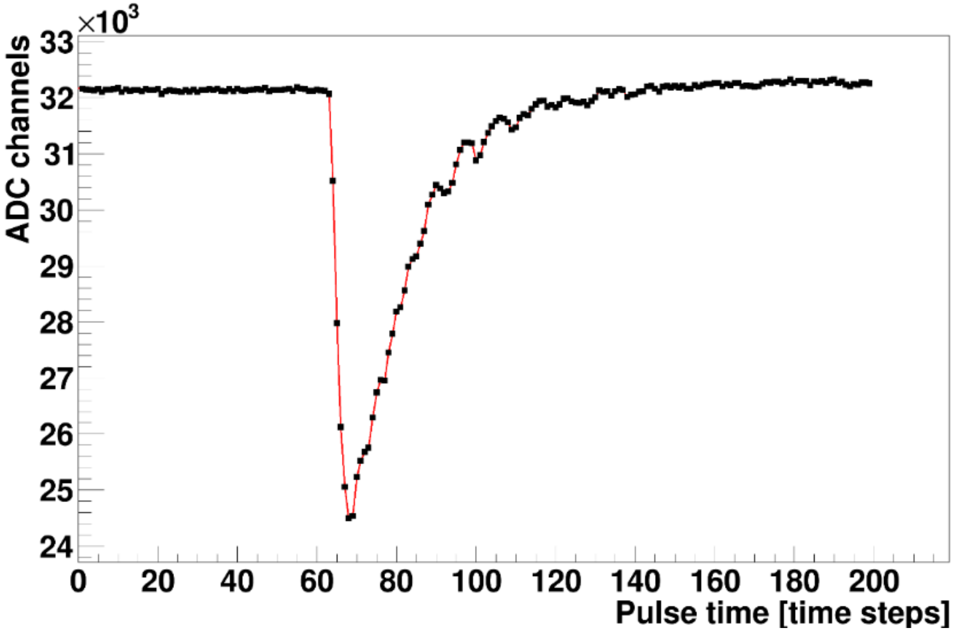
ADC 64
AFI Electronics

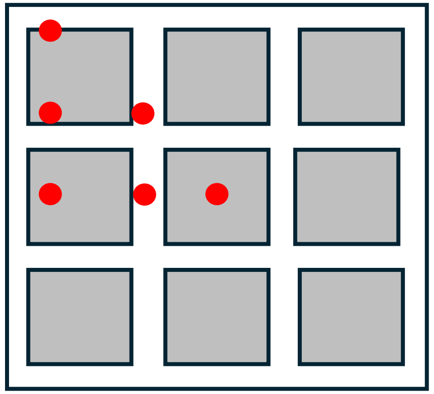


Signal amplifiers

Performance tests

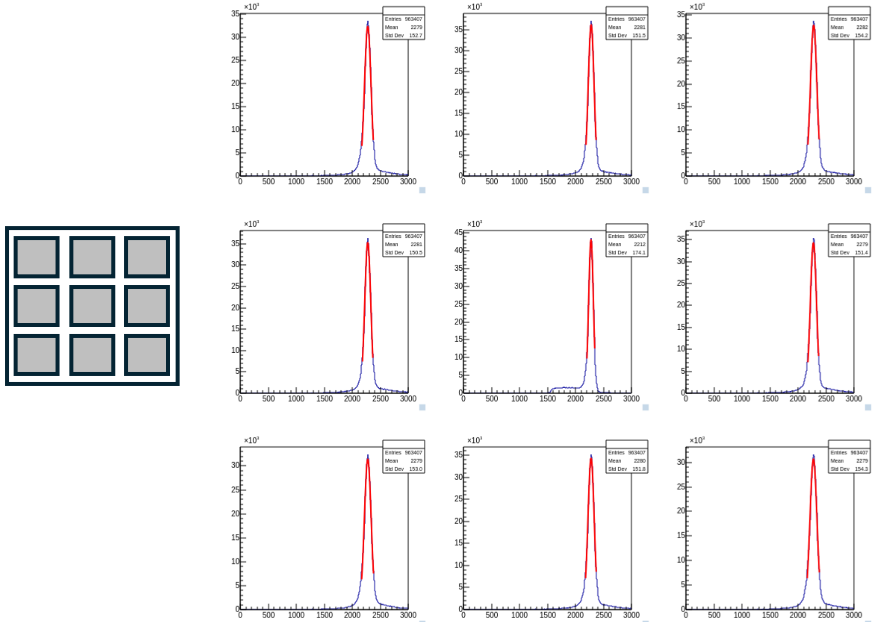
- Test was performed to compare spatial and energy resolutions for different interaction points using lead collimator.
- Data was saved in format of oscillograms for each of 9 channels and processed offline later.



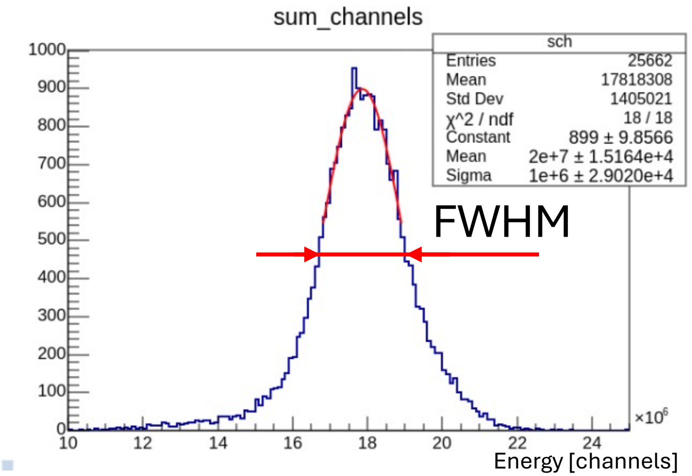


Gamma camera module. Red dots visualize so,e of the interaction points during test.

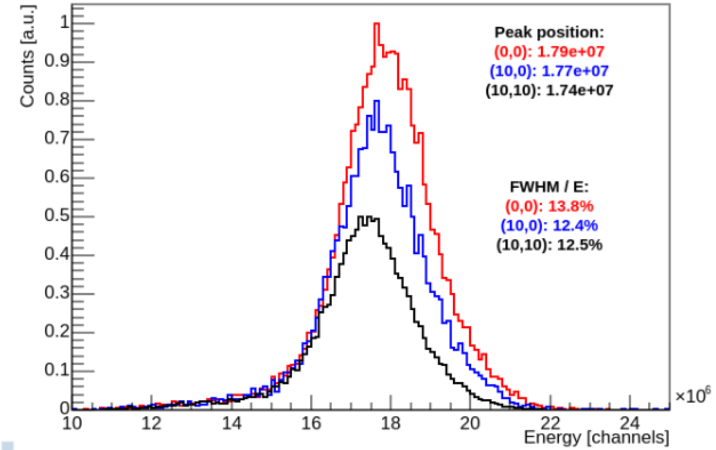
Energy resolution



Charge spectra for matrix channels separately

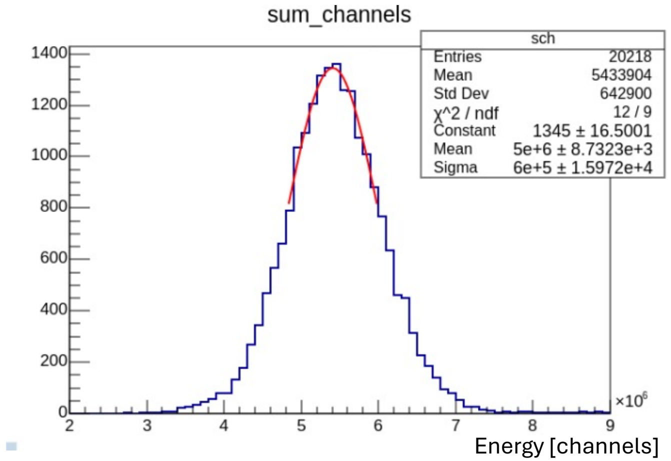


Charge spectrum for CsI(Na)
Resolution $(\sigma_E/E) = 5.8\%$
13.8% FWHM



Charge spectra (sum of all channels) for different interaction points (normalized on different heights for visual representation)

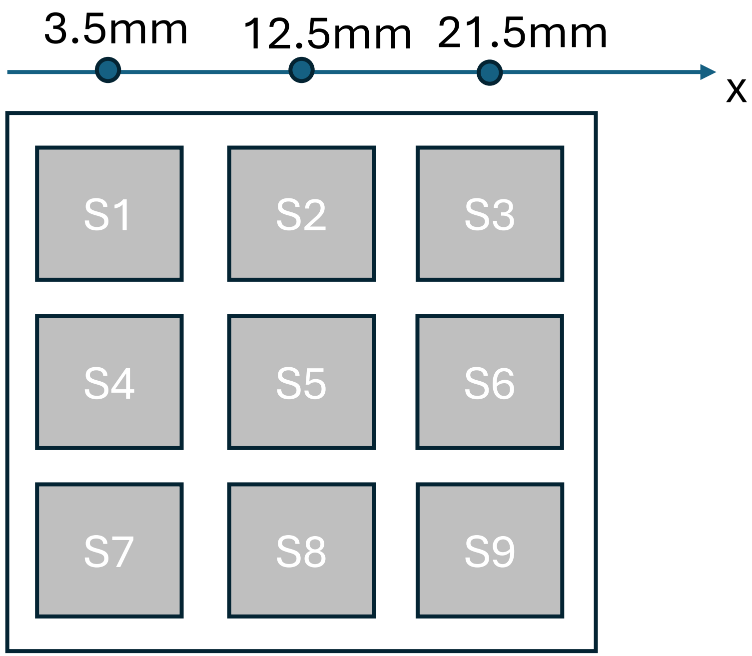
Resolution does not depend on interaction point



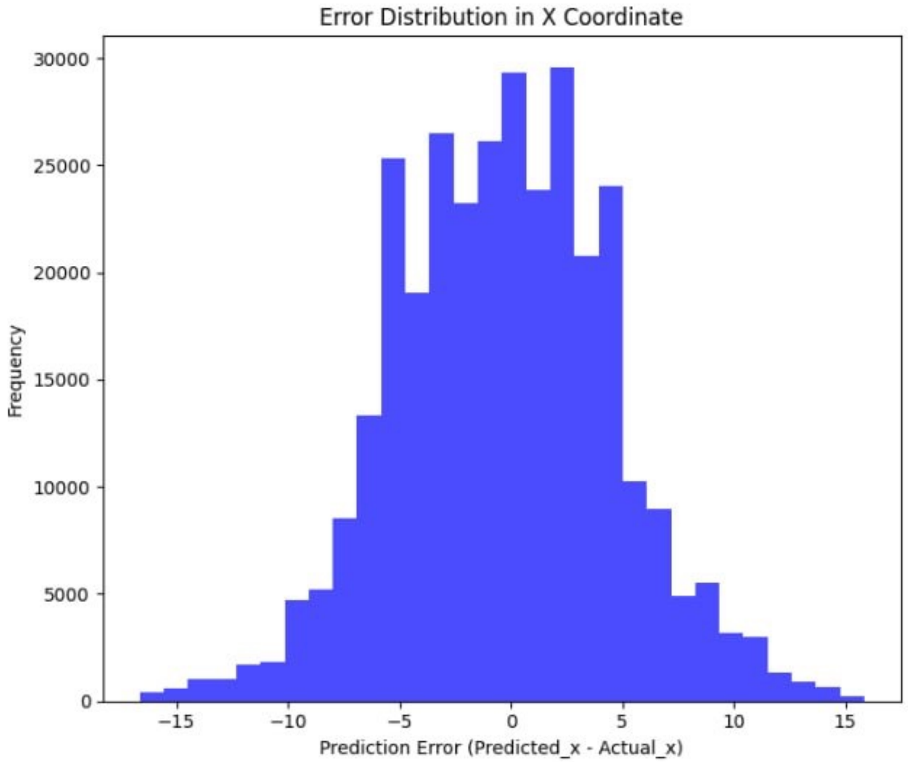
Charge spectrum for CsI(Tl)
Resolution $(\sigma_E/E) = 10.6\%$
24.9% FWHM

Spatial resolution

Anger method $$X_{rec} = \frac{3.5 * (S_1 + S_2 + S_3) + 12.5 * (S_4 + S_5 + S_6) + 21.5 * (S_7 + S_8 + S_9)}{S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 + S_8 + S_9} - 12.5\ mm$$



S_i – charge from i_{th} channel



Error in reconstructed coordinate ($X_{rec} - X_{real}$)
FWHM = 12.1 mm

Conclusion

- A new type of gamma-camera was proposed;
- Prototype of a new gamma camera was tested;
- Energy resolution of a prototype is 14% FWHM. Can be improved by using better scintillators (e.g. $SrI_2(Eu)$);
- Spatial resolution of 12mm FWHM was achieved;

Future work:

- Improving spatial resolution by using more advanced algorithms;
- Prototyping a module with 3x3mm^2 SiPMs.

Thank you for your attention

Abstract

Gamma-cameras are one of the most popular tool in nuclear medicine for the tomography of human organs with the single photons emitted by the radioactive isotopes. As a rule, these cameras consist of a large continuous scintillator or of many small scintillator pixels. Both types have their own advantages and drawbacks. Here we suggest another type of modular gamma-camera that combines the features of the previous two types. Modular structure has a series of advantages, including scaling, simplicity and reproducibility of the parameters of separate elements of gamma camera. We constructed and tested an element of modular camera that consists of inorganic scintillator CsI(Tl) or CsI(Na) with the dimensions 25x25x8 mm3. The light readout is done by 3x3 matrix of 9 silicon photomultipliers with the sizes 6x6 mm2 each. The performance of this prototype was tested with 57Co radioactive source with gamma-ray energy of 122 keV. The obtained energy and spatial resolution are discussed. New algorithms for the reconstruction of gamma interaction point were developed.