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ICRM GSWG

DIGITAL SIGNAL PROCESSING

EXPERIENCE FEEDBACK

DSP: EXPERIENCE FEEDBACK

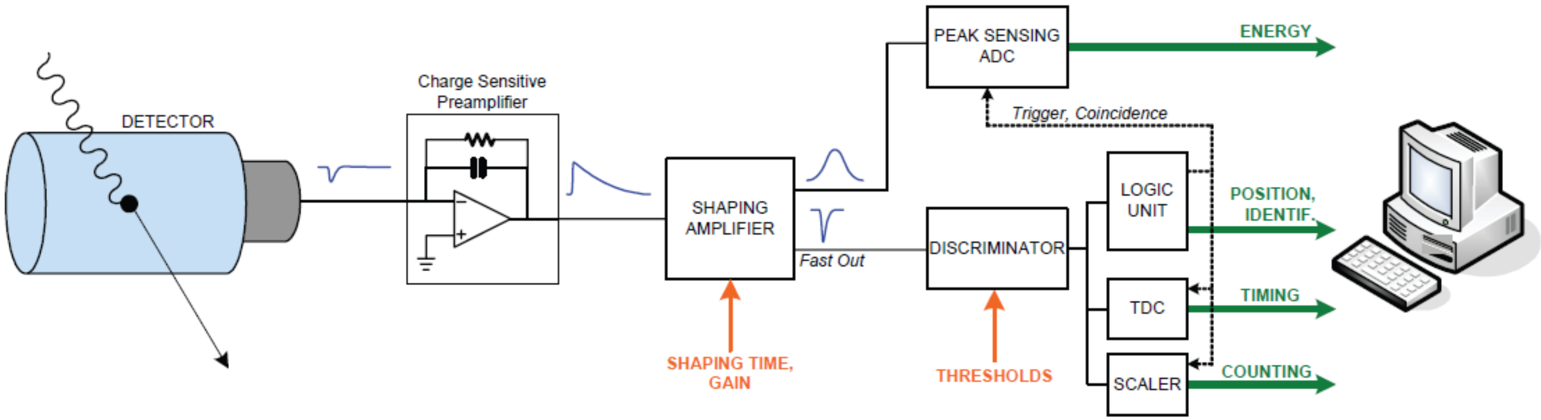
ELECTRONICS (BASICS)

TEST OF DSP MODULES

GAMMA-SPECTROMETRY CHAIN

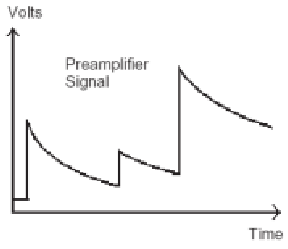
Analog circuit: Preamplifier – Amplifier – ADC - MCA

+ use of time control for specific use (coincidences, …)



Preamplifier (close to the detector)

critical step for the noise level
charge (energy) information : pulse height

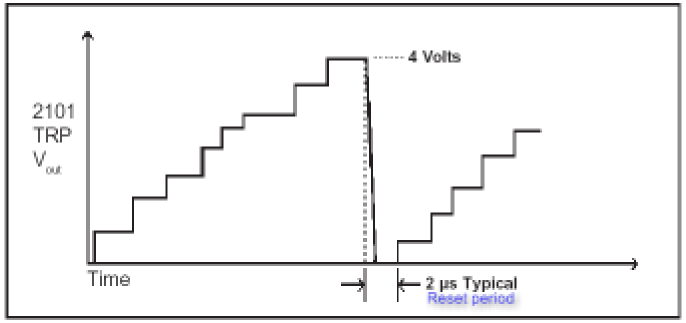


Resistive feedback :

fast rise time (some 100 ns depending on the detector)
and long exponential decay (several tens of µs)
Pile-up

Reset (Optical (low-energy) or Transistc

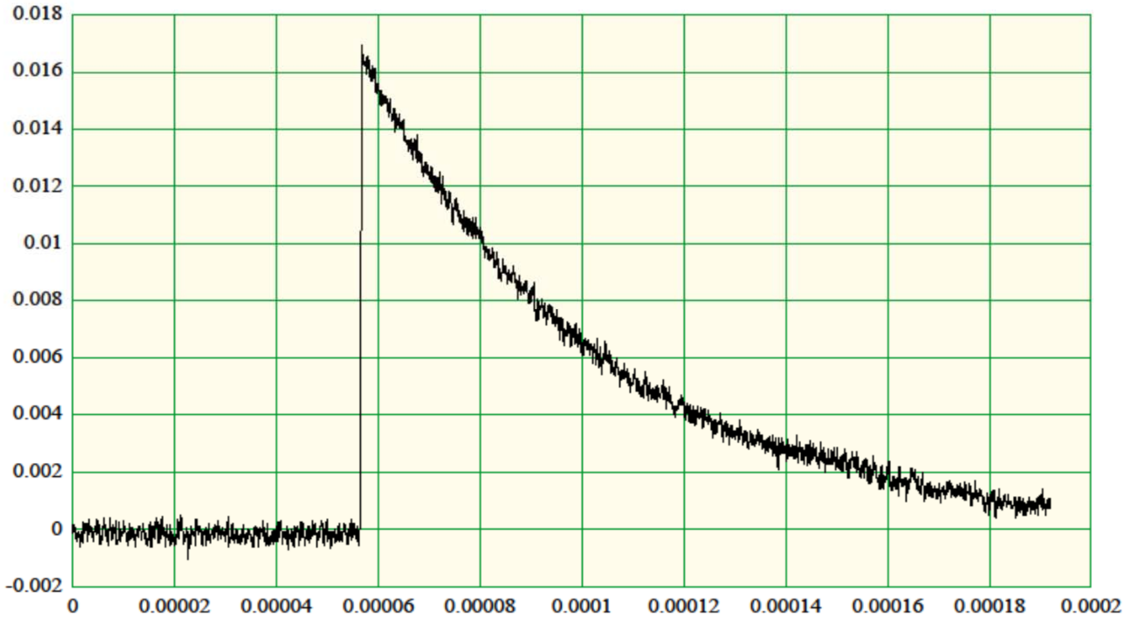
- Only the amplitude variation is kept
- Accumulation of the pulses of charge
- Reset period: inhibit



PREAMPLIFIER ROLE

Pulse shape at the preamplifier output

γ 59 keV, ^{241}Am

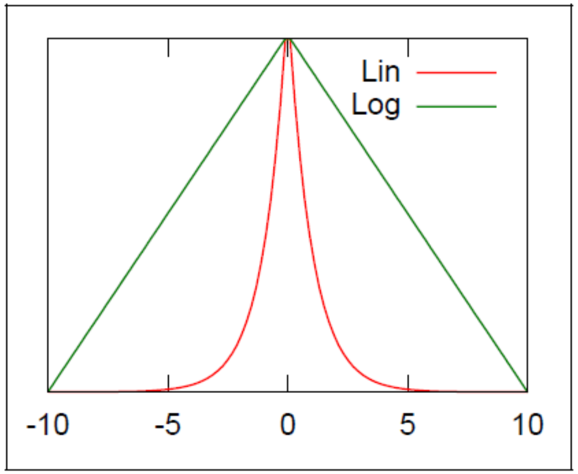


AMPLIFIER ROLE

Amplifying and shaping (without increasing the noise level)

Typical shape in analog circuits: RC (semi-Gaussian or semi-trapezoidal)
Pole-zero cancelllation – restoring baseline – pile-up rejection

Optimizing the pulse shape: maximising the signal-to-noise ratio using a filter that produces a Cusp-like impulse response.

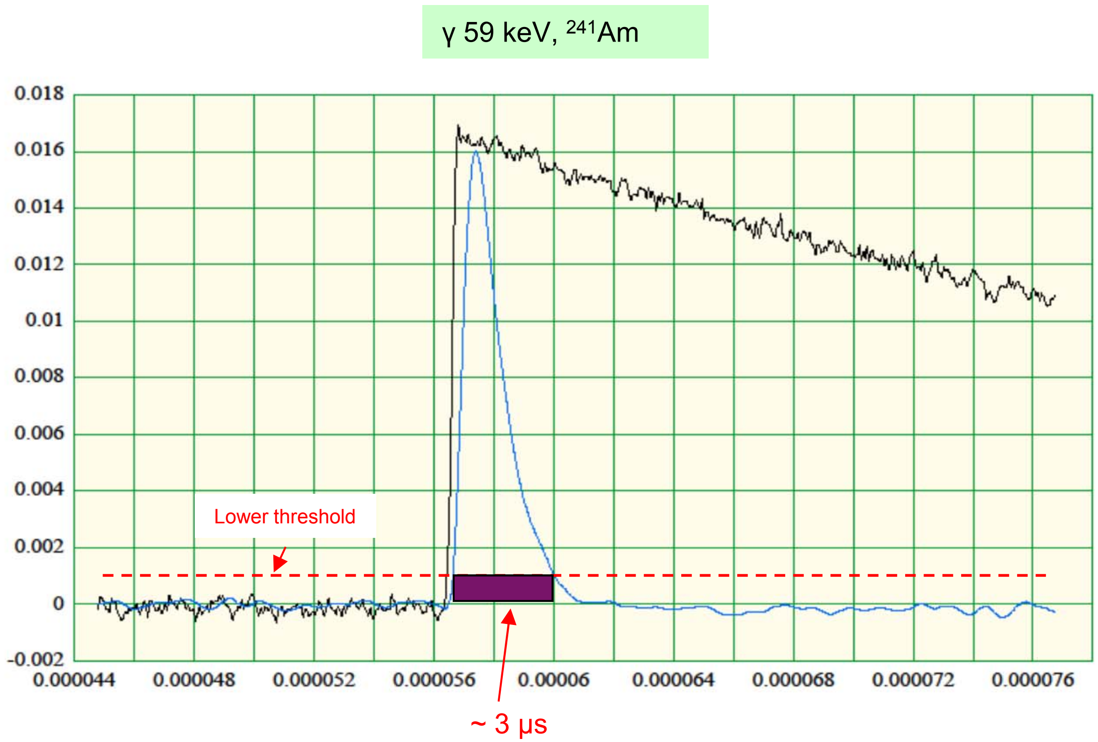


However, there are practical problems to implement such a filter -> triangular shape

Addition of a flat top reduces the effect of incomplete charge collection (large HPGe detectors)

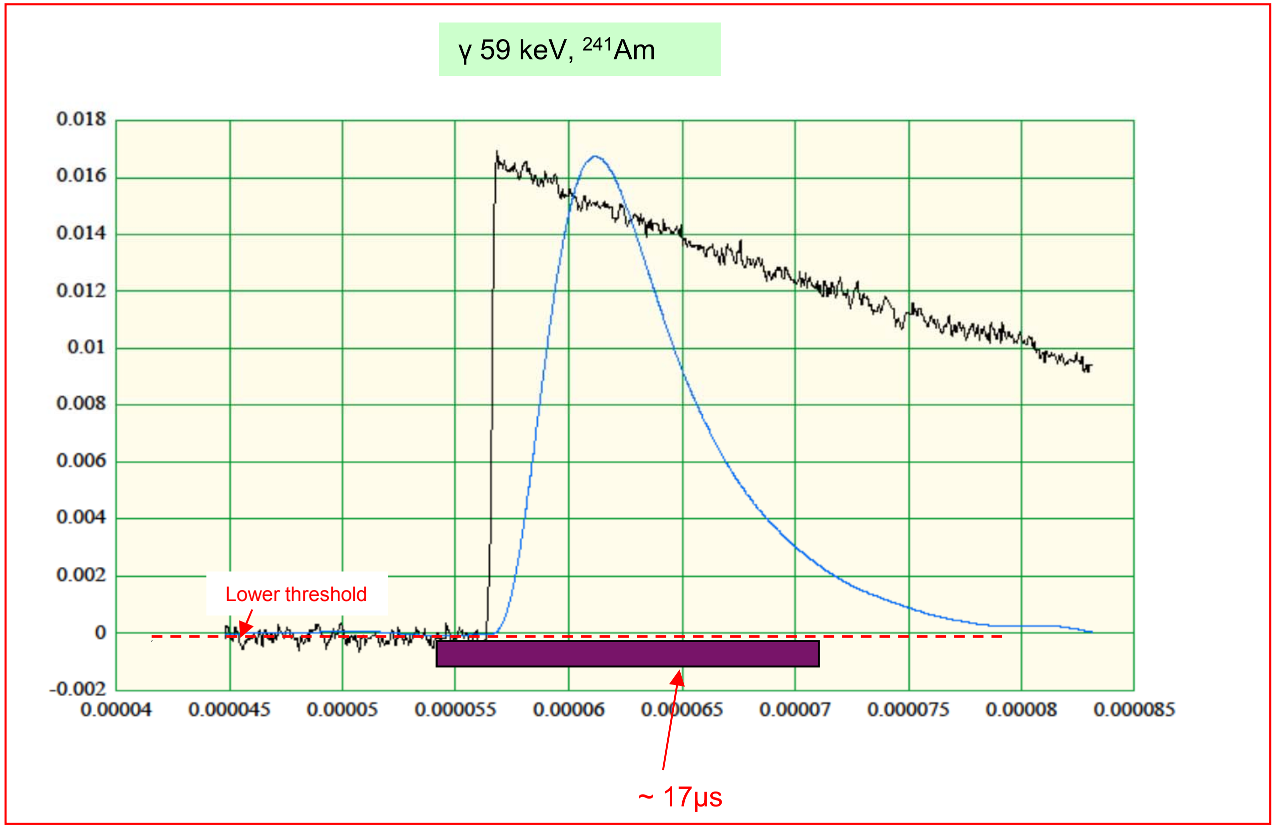
AMPLIFIER ROLE

Filtered signal (short shaping time)



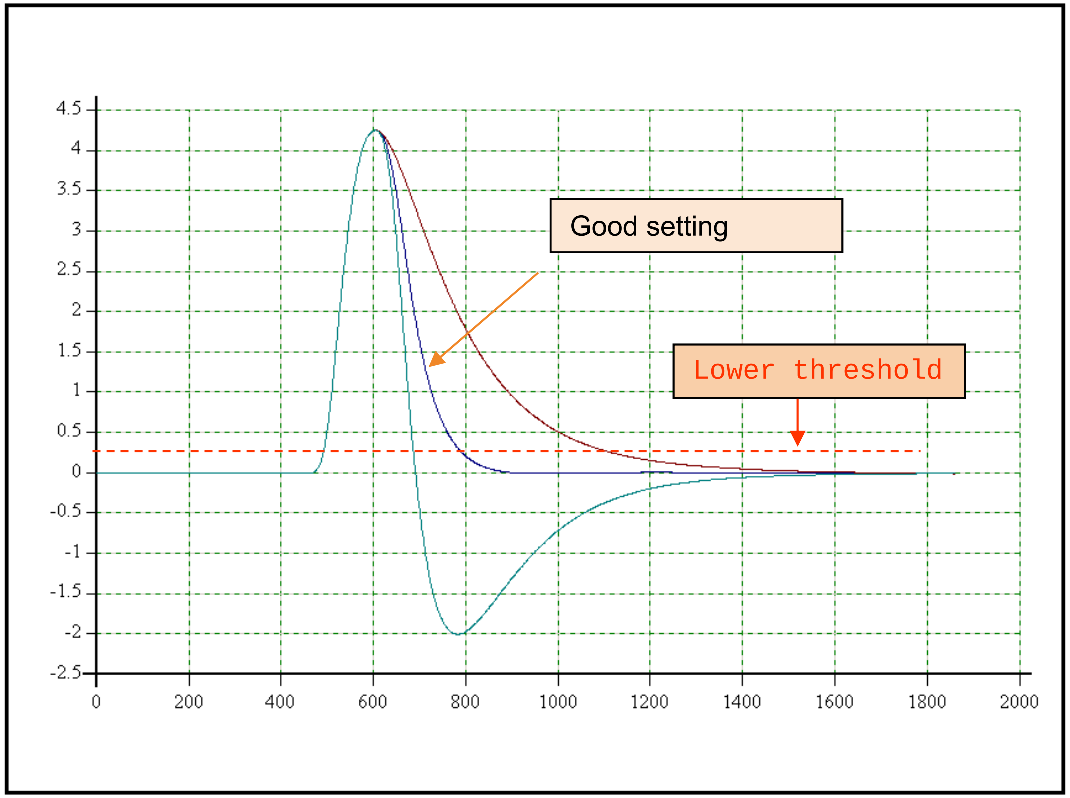
AMPLIFIER ROLE

Filtered signal (long shaping time)

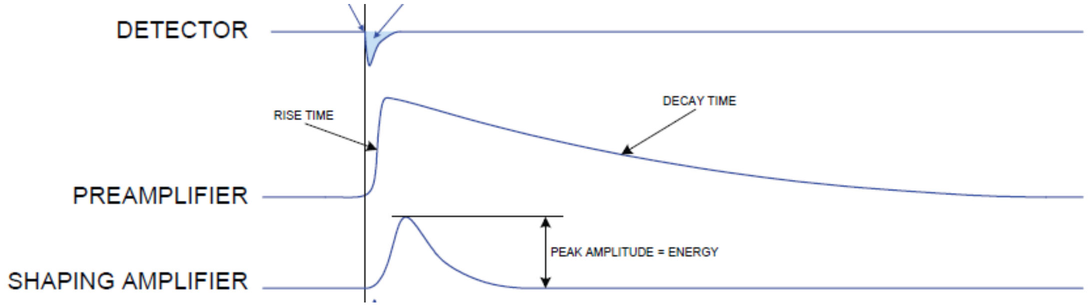


AMPLIFIER ROLE

Amplifier: “PZ” adjustment (pole zero)



SIGNAL PROCESSING



The ADC measures the voltage of the analog signal and produces a digital number corresponding to that voltage. The sampling frequency of the ADC determines how often the analog signal is measured and converted to a digital word.

Between the 1980's and the beginning of 21st century, the sampling frequency increased from tens of MHz to the GHz range.

Coding approaches : Wilkinson, successive approach, flash compared

The MCA -> histogram of the pulse heights (energy distribution) -> Energy spectrum

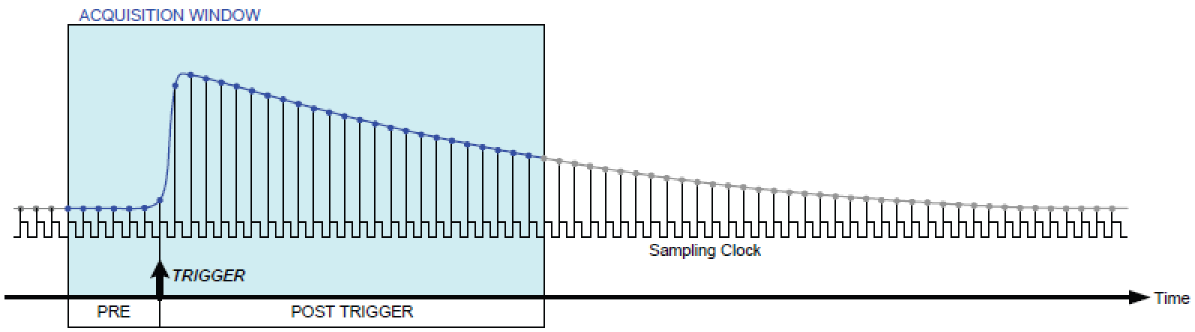
DIGITALIZATION

Previously, information processing was purely "analog".
Problems: long-term drifts on old assemblies, "complexity" of settings, etc.

Since early 2000’, digital signal processing based on specialized "ADC, DSP, FPGA" processors

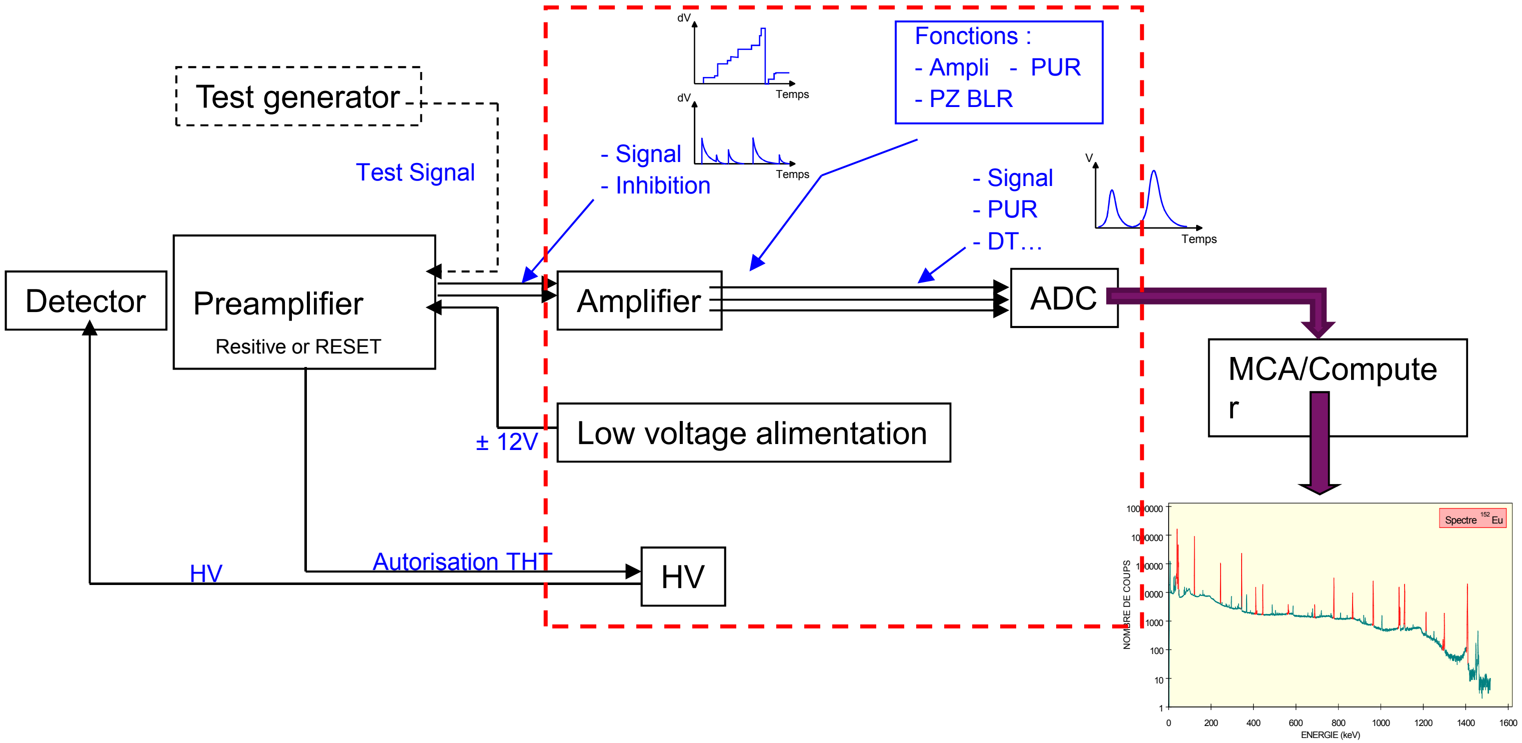
- ADC: analog to digital converter
- DSP: digital signal processor
- FPGA: field programmable gate array

The constant improvement of these specialized processors (sampling frequency, number of bits, computing power, etc.) now allows a more complete and efficient processing of the information.



DIGITALIZATION

In a digital system, the signal is sampled as soon as possible by an ADC . These samples are then digitally processed (filtering, selection, dead time processing, etc.) (off-line or on-line).



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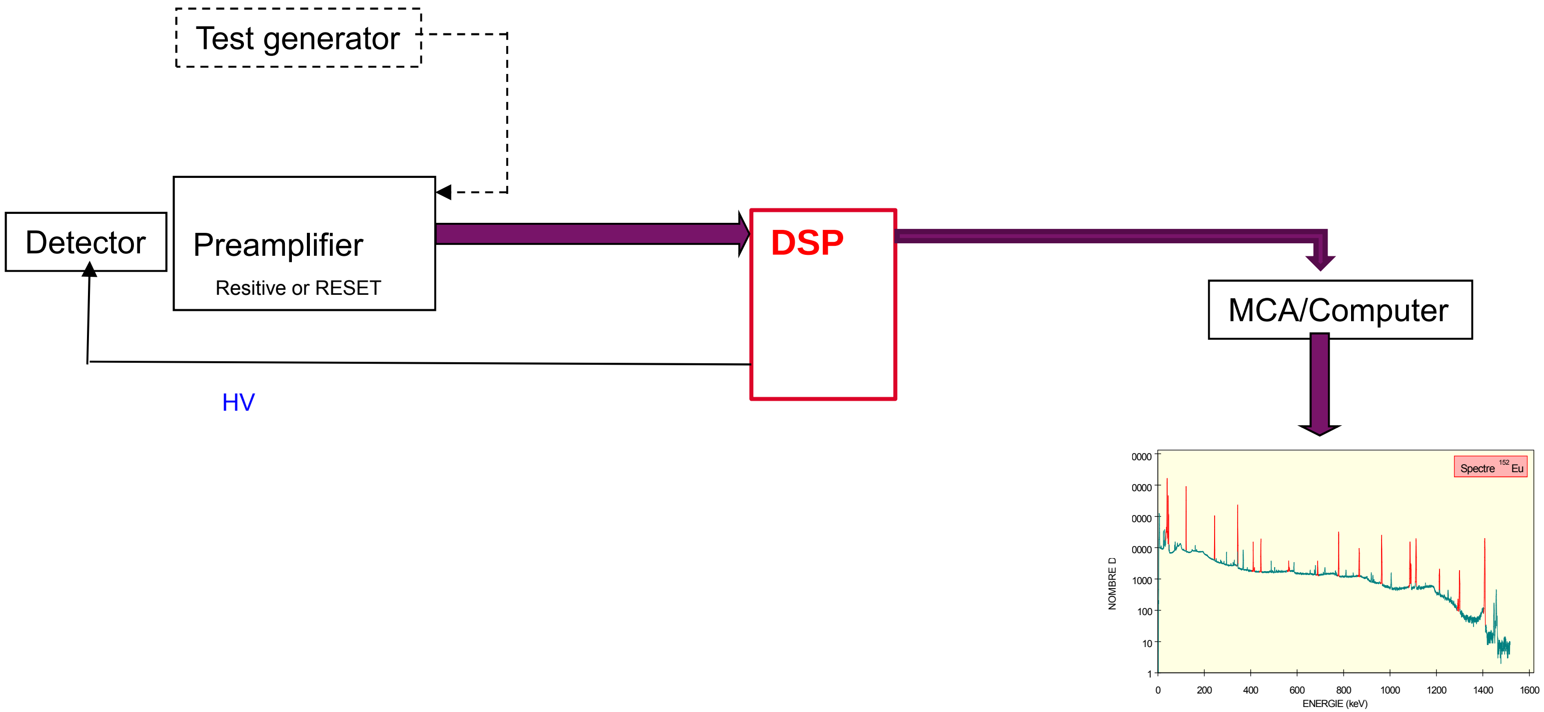


DIGITAL / ANALOG

Advantages:

Digital analysis methods provide an almost infinite flexibility, e.g. regarding choice of parameters for signal filtering.
Digital filtering can be performed in a way that is difficult or even impossible with analog techniques. (e.g. triangular, trapezoidal or cusp-shaped pulse shapes)
Increased stability after digitalization: does not depend on e.g. temperature anymore.
Perfect linearity. The digitized signal can be used in mathematical algorithms. In an analog system, there will always be sources of non linearity, e.g. from small feedback loops.

Disadvantages:
The information in the digitized signal is limited by the frequency of the sampling unit (the ADC). This could be an important limit when very fast timing information is needed from the signal.
A fast ADC and digital electronics to process the digitized signal require more power than an equivalent analog shaper.
(Too) large choice of parameters …

TEST OF SOME DSP MODULES

CANBERRA (LYNX^{TM})

ORTEC (Analog and DSPEC-50)

LABZY (nano-MCA)

DSPEC-50 (ORTEC)

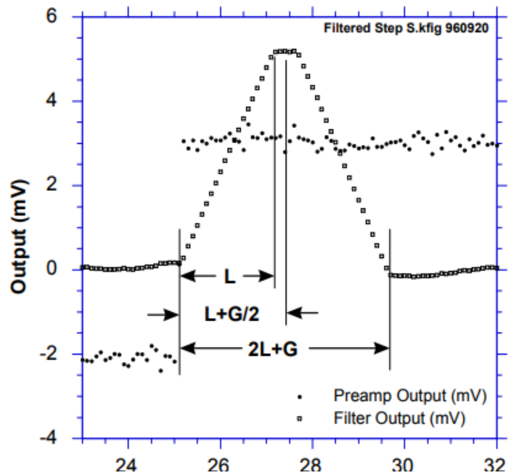
LYNX™ (CANBERRA)

Analog electronics
Gaussian or
triangular shaping

Digital electronics
Trapezoidal shaping, with choice of:

- Rise time
- Flat top
- Tilt of the top (only DSPEC-50)

Test conducted using a
HPGe N-type detector with transistor reset preamplifier

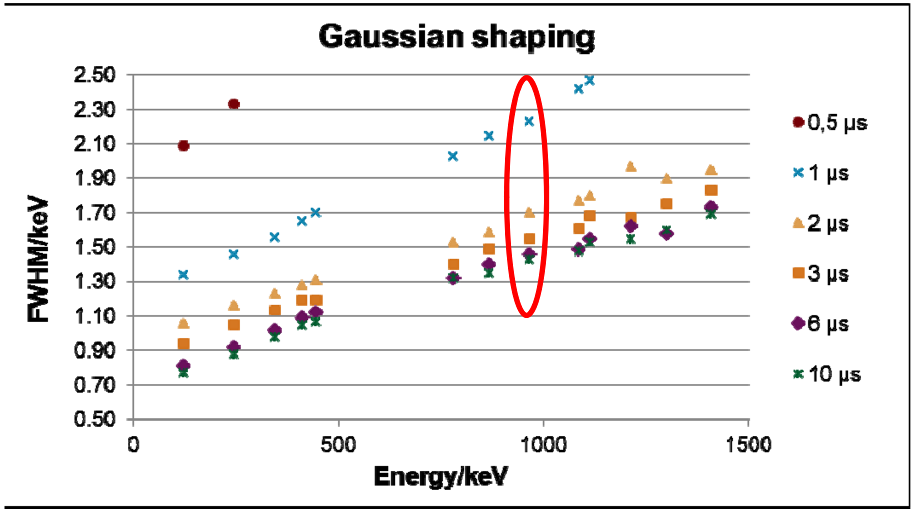


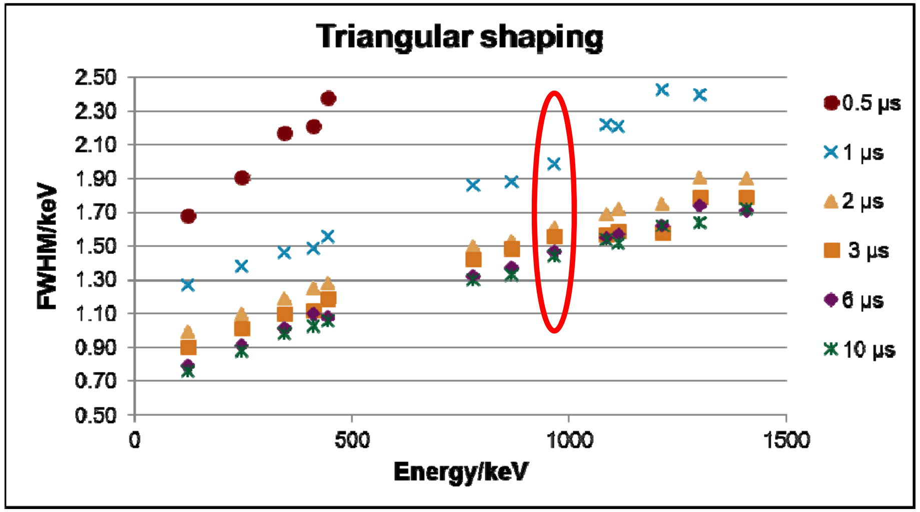
FWHM versus the energy

^{152}Eu point source at 15 cm from the detector window, energy calibration using 122 keV and 1408 keV peaks, and an acquisition time of 5000 seconds.

The count rate was about 900 s^{-1}.

Analog electronics : shaping Gaussian of triangular – shaping time from 0.5 µs to 10 µs





Best results with large constants 6-10 µs
(1.4 keV @ 1 MeV)

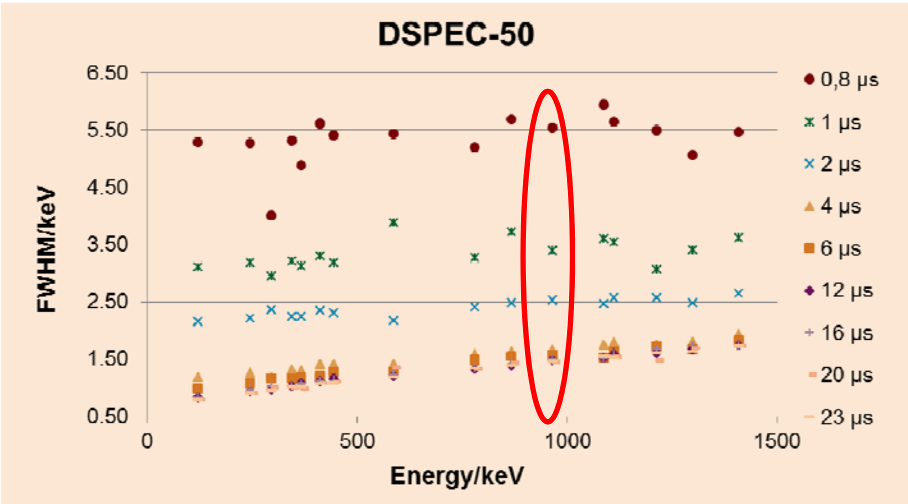
FWHM versus the energy

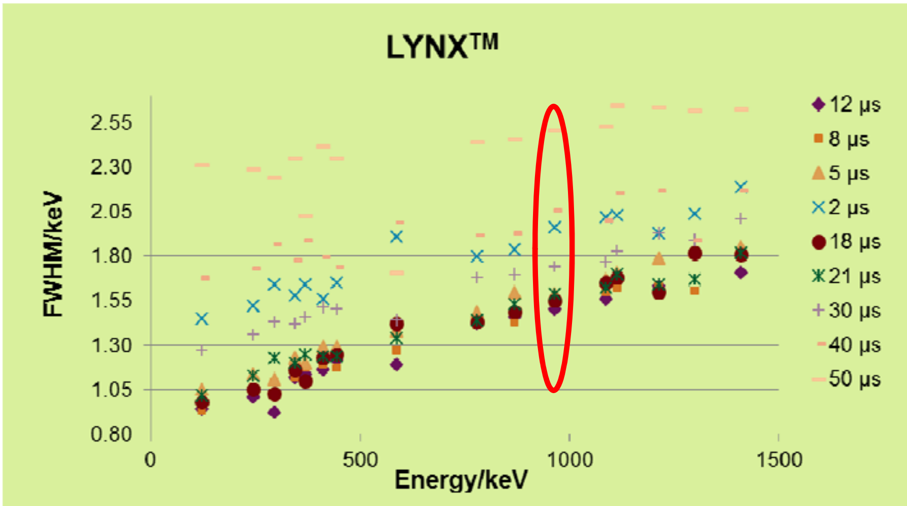
^{152}Eu point source at 15 cm from the detector window, energy calibration using 122 keV and 1408 keV peaks, and an acquisition time of 5000 seconds.

The count rate was about 900 s^{-1}.

Digital modules : trapezoidal shaping : more choices in the RT

In the trapezoidal shaping, the output signal width is the sum of the rise time (RT) and flat top (FT). Thus, trapeze RT of 10-12 µs roughly corresponds to a Gaussian with a 6 µs shaping time.

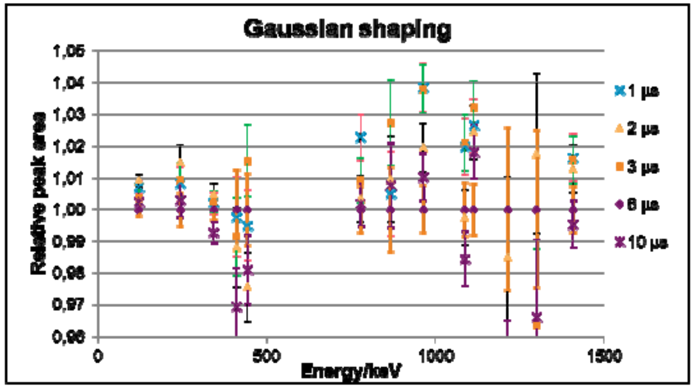


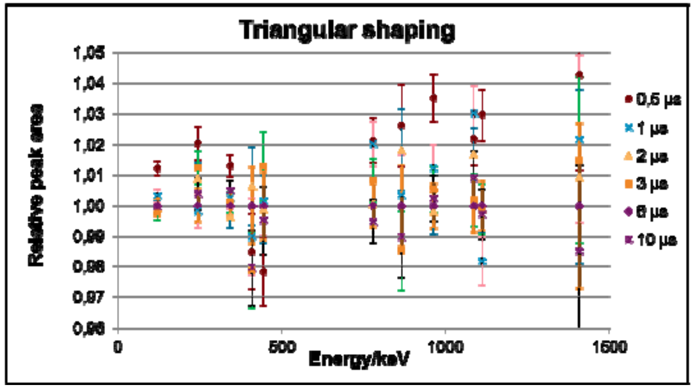


Best results with RT ~20 µs (1.5 keV @ 1 MeV)

Peak area versus the energy

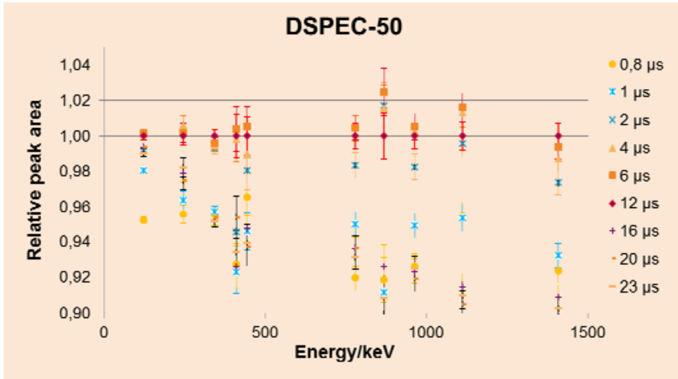
The peak areas were computed relative to those obtained with the 6 µs Gaussian shaping in the analog configuration

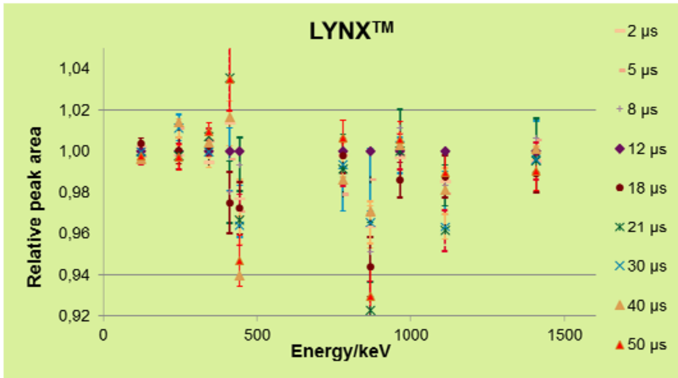




Larger deviations at low shaping times

For the DSP modules, the relative peak areas were computed using the 12 µs RT spectrum as reference.

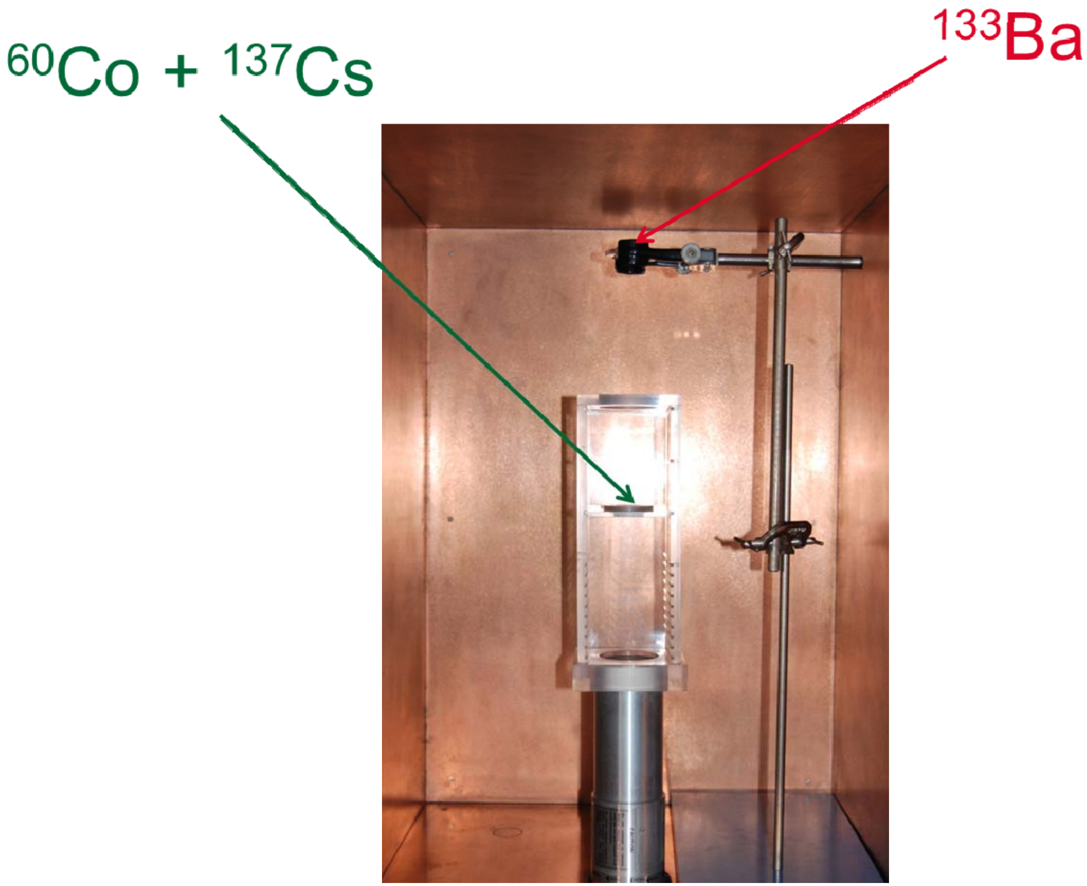




Peak area versus the counting rate

1 source in a fixed position (^{60}Co (662 keV) + ^{137}Cs (1173 and 1332 keV)) : 600 s^{-1}

^{133}Ba (Maximum energy = 383 keV) moved towards the detector to increase the counting rate

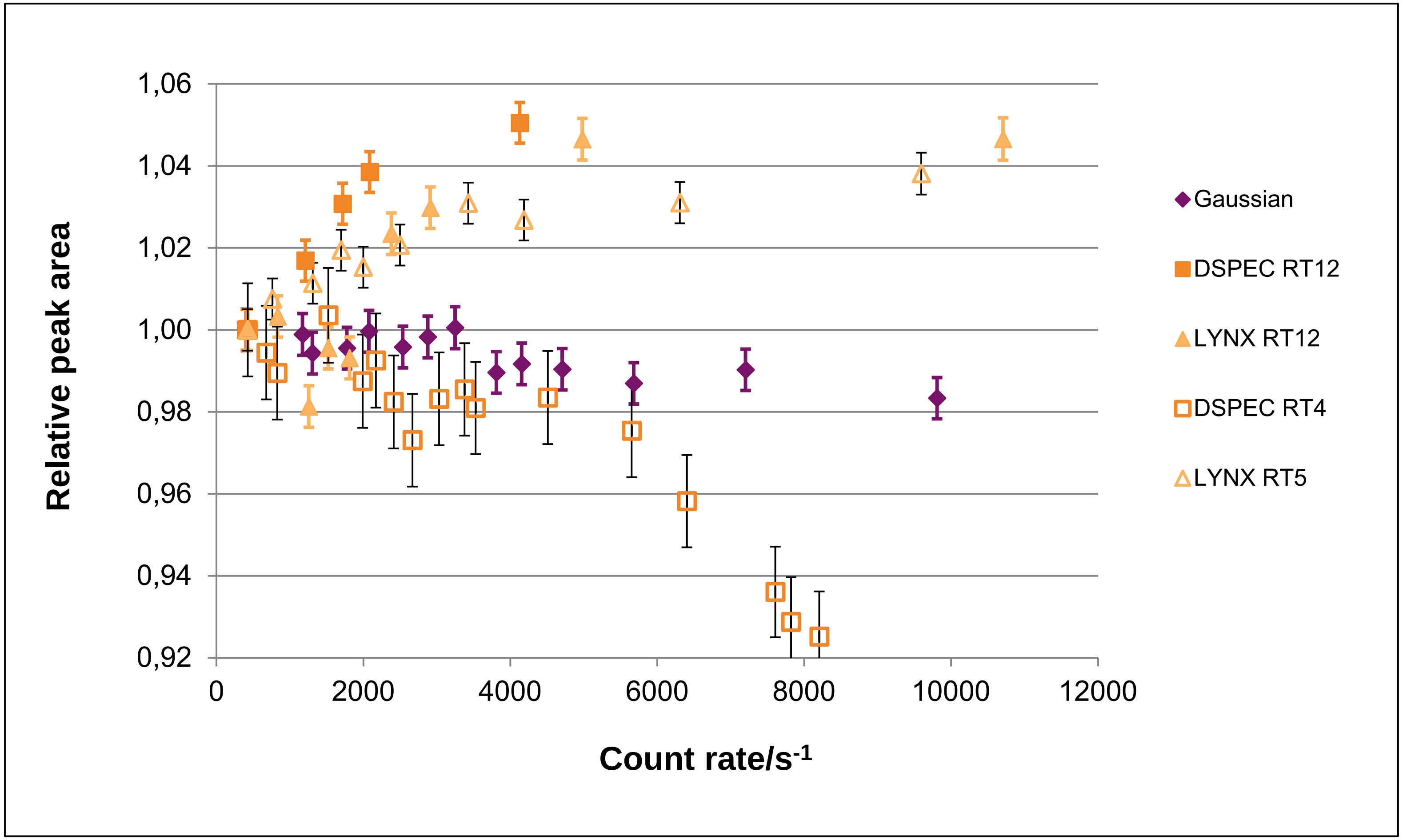


Shaping characteristics:

12 µs RT with 2 µs FT

Peak area versus the count rate

Relative peak area @ 1332 keV



Peak area versus the count rate

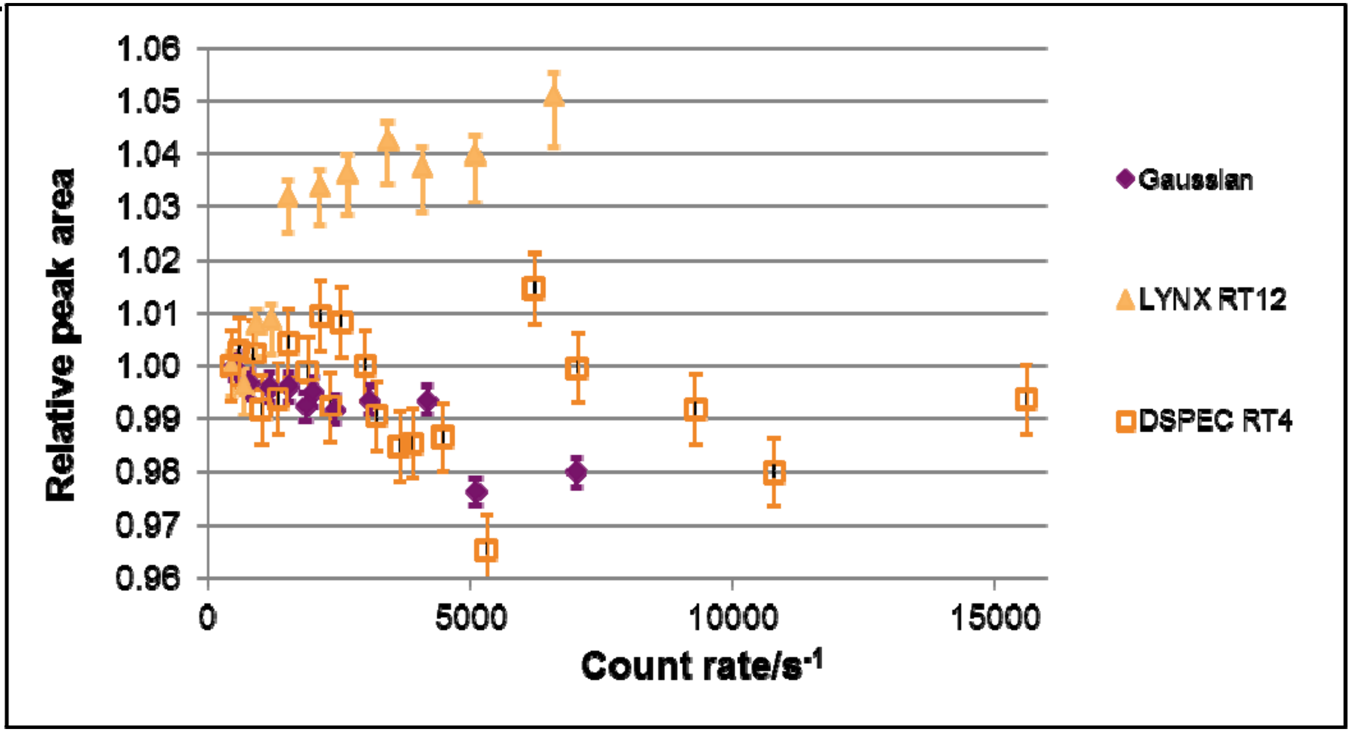
Source at fixed position : ^{137}Cs (662 keV)

^{60}Co (1173 keV and 1332 keV) moved closer to the detector to increase the counting rate

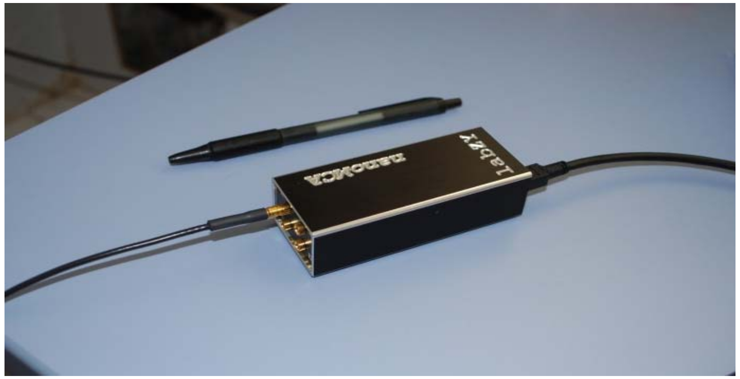
Shaping characteristics:

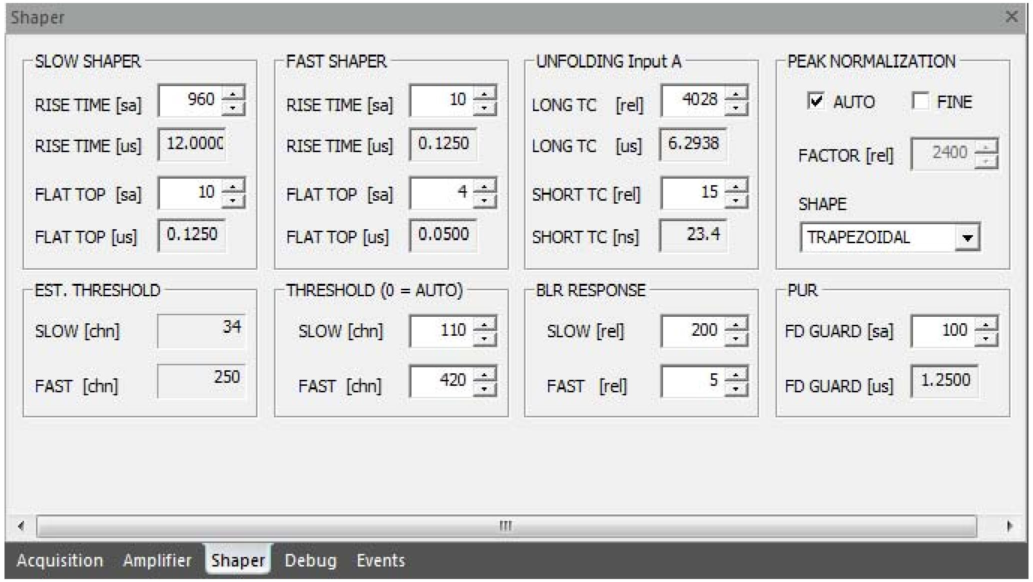
12 µs RT with 2 µs FT

Relative peak area @ 662 keV



Nano-MCA module





Different settings:

Amplifier window: Preamplifier type, gain, PZ…

Shaper window :

"Slow " and " fast" shapers: threshold, rise time (*RT)* et flat top (*FT),*

Short and Long Time Constant (TC),

BLR Response (Base line restoration)

FD Guard (pile-up)

Nano-MCA module

The oscilloscope allows to observe the changes made in the Amplifier and Shaper windows.

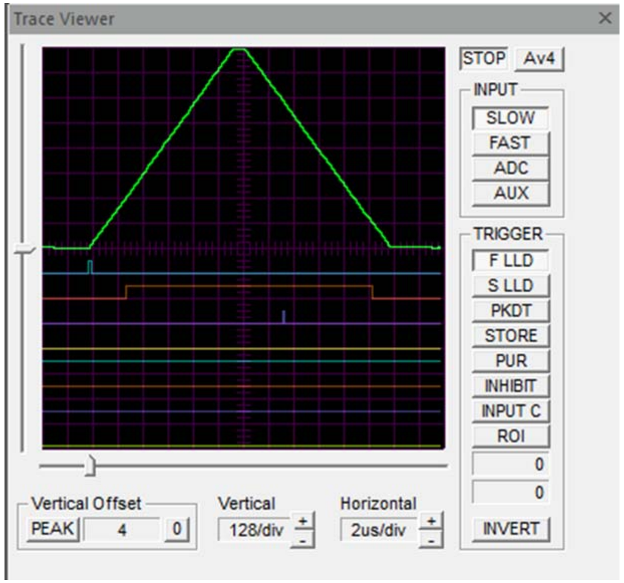
It is particularly useful for setting the pole-zero, Fast Shaper and BLR values.

“Slow shaper” is the main element for

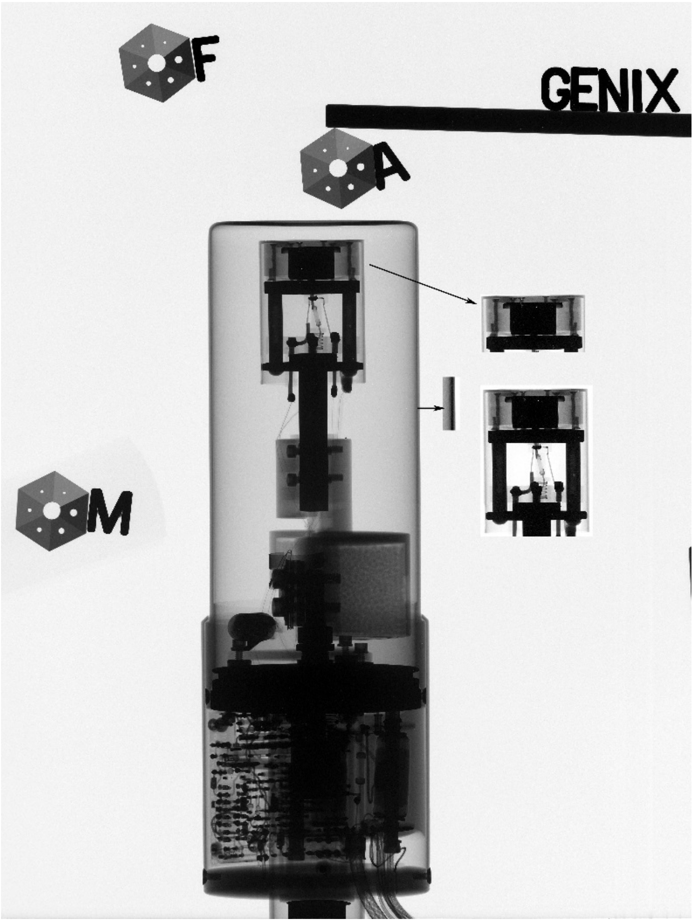
processing the input signal

Test with ^{133}Ba – counting rate about 420 s-1

(Dead time between 0.1% and 1.4 %)

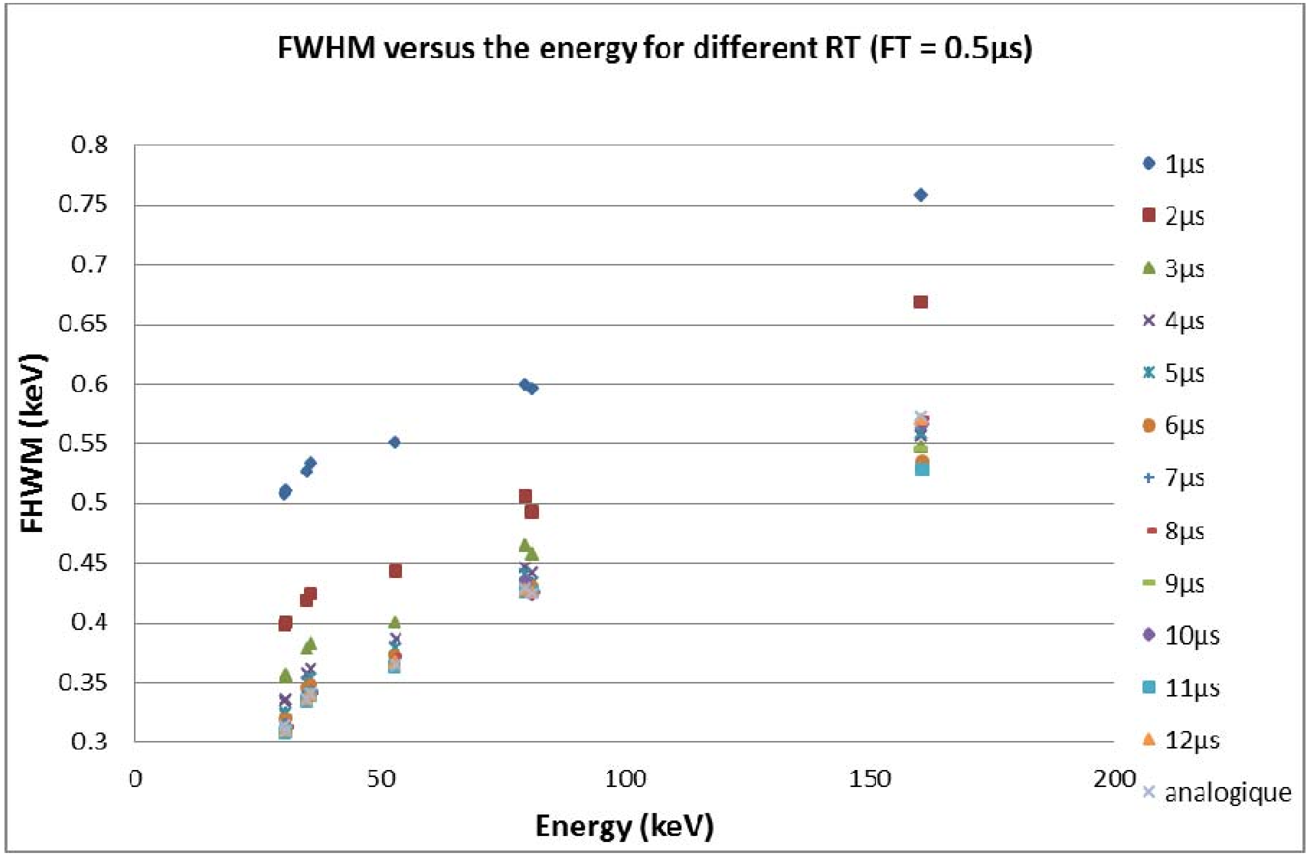


Test using planar HPGe detector (low energy)



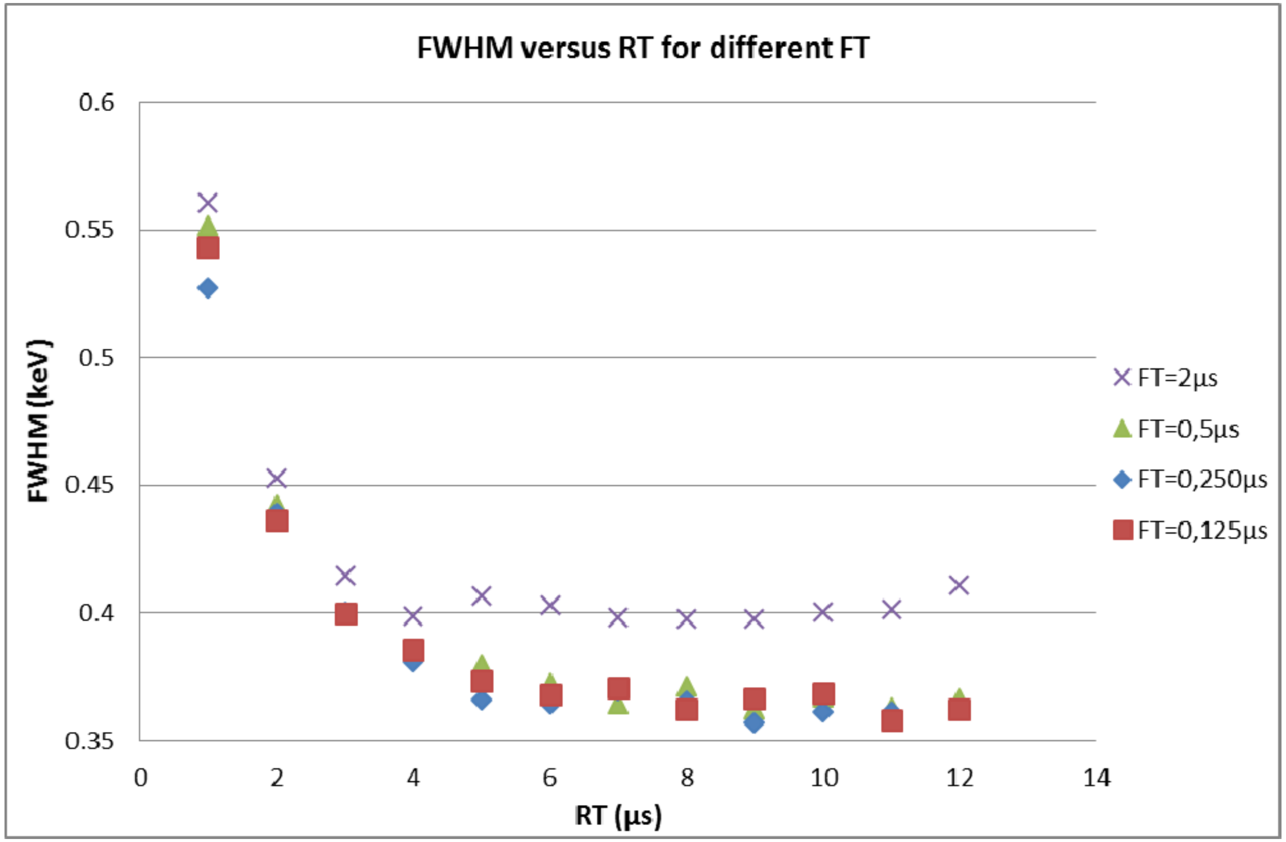
FWHM versus the energy

^{133}Ba – Fixed FT



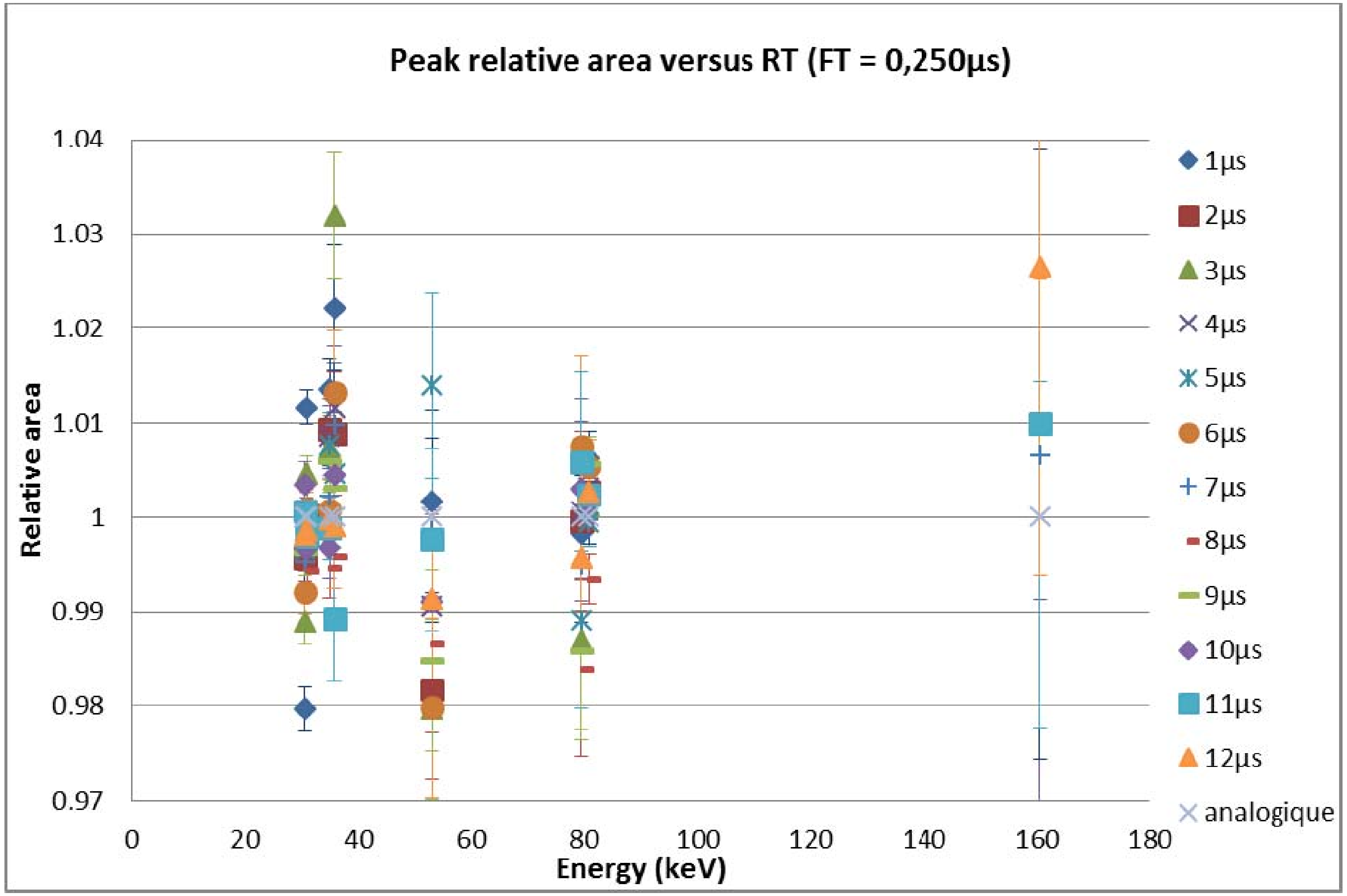
FWHM versus the energy

^{133}Ba – Peak at 53 keV



Interest of short FT

Peak area versus the energy



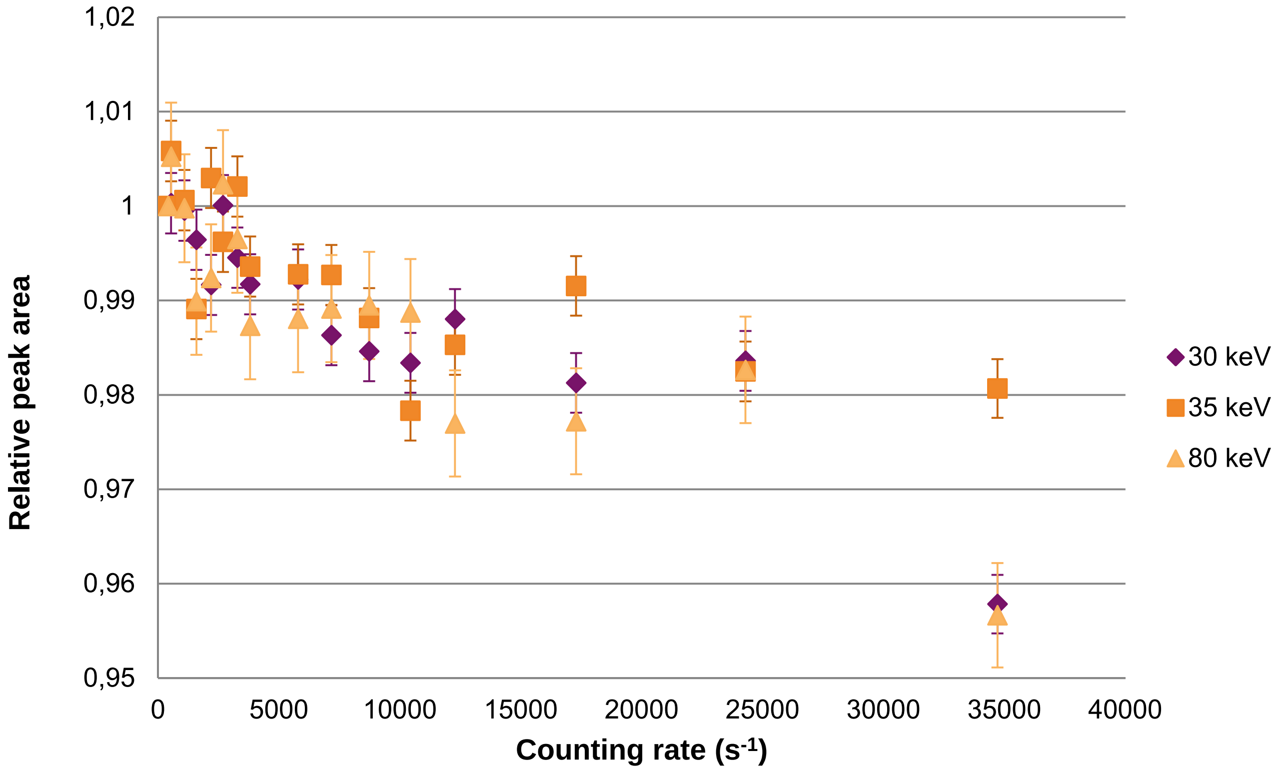
No clearly significant tendency

Peak area versus the counting rate

Source in a fixed position (133Ba): 600 s^{-1}

^{55}Fe(5.9 keV) to increase the counting rate

RT=12 µs – FT = 0.125 µs



RECOMMENDATION

The tests presented in this study show that changing the shaping parameters of the DSP modules can significantly modify the quantitative information derived from gamma-ray spectra. Therefore, it is important to keep constant these shaping parameters between calibration and measurement stages.

This is necessary to obtain reliable results, within 1 %, as required for metrological applications such as determination of photon emission intensities or activity measurement of radiopharmaceutical nuclides.

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THANK YOU FOR YOUR ATTENTION !

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