Viareggio
April 28th, 2020

Introduction

This application note shows the performances of the **Shaping Amplifier for Fast Signals N1168** used in conjunction with the **N6741 Peak Sensing ADC**. The energy spectra of a ^{137}Cs source has been taken with a $LaBr_3$ detector coupled with a PMT. The advantage of using a N1168 is that the signal from PMT can be directly fed into the N1168 input without the use of a charge sensitive preamplifier **[1]**. The board has two outputs for each input channel, where the first output is proportional to the integration charge (called SLOW output), and the second is proportional to the signal amplitude (called FAST output). The latter gives information of the shape of the input pulse, thus giving information to perform pulse shape discrimination with detectors that have a different response to particles, like gamma-neutrons.

In this application note, we will consider only the SLOW output, leaving the FAST for a further application note. The ^{137}Cs energy spectrum from $LaBr_3$ detector has been compared with those taken with a similar system with N1068 **[2]** and N6741 **[3]**, and with a digital MCA Hexagon **[4]**. Both the possibility to go to low energies to visualize the X peaks of Lanthanum and Cesium, and the consistency of the ^{137}Cs peak resolution among the three systems has been obtained.

Materials and methods

The radiation coming from a source of ^{137}Cs was collected with a $LaBr_3$ scintillator coupled with a PMT, whose output was sent to the N1168, without preamplification stage, and finally to the N6741 peak sensing ADC [**3**]. The peak sensing ADC is able to evaluate the Gaussian peak height from the shaping amplifier within a ”Gate” length. The start of the Gate is provided by the OR port of the N1168, which gives a NIM signal every time there is a trigger (in this case we used channel 0 only, otherwise it corresponds to the OR of all the enabled channels). The Gate length is defined through the configuration file of the Peak Sensing Control Software **[3]**.

The experimental set up is schematized in Fig. **1**.

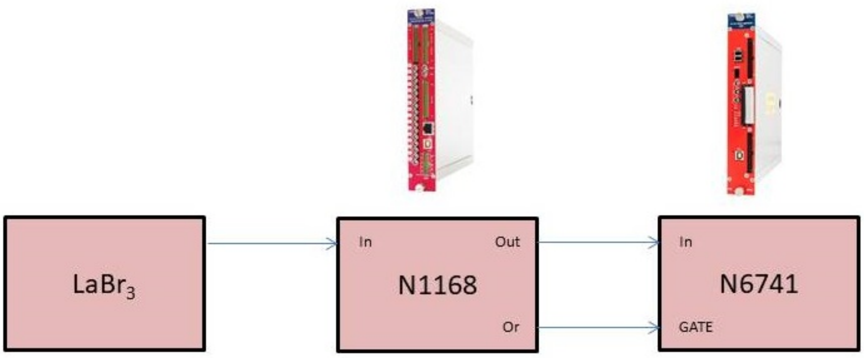


Fig. 1: Experimental set up scheme.

Fig. **2** shows a picture of the CAEN boards used in this setup, in particular, N6741 Peak Sensing ADC on the left, which receives the inputs and the Gate start from the N1168. The shaping amplifier, on the middle, receives on channel 0 the output of PMT signal and propagates the gaussian signal to the N6741. Finally, module N1470 on the right, is the High Voltage power supply used to power the PMT.

Fig. 2: Picture of the used CAEN boards, from left to right, N6741 Peak Sensing ADC, N1168 Fast Shaping Amplifier, and N1470 power supply unit.

Fig. **3** shows the typical signals of the setup in an oscilloscope device. In particular, in green the signal from $LaBr_3$ detector coupled with PMT, in magenta the Gaussian signal from the SLOW output of N1168, in cyan the logic signal of the internal CFD discriminator of N1168, in yellow the NIM output of the OR port.

NOTE: before programming the N1168 through the command prompt (terminal emulator), it is required to adjust the jumper of the CFD delay by following instructions of **[1]**. In particular, the CFD delay must be set as close as possible to the input rise time value, which is T_{rise} = 20ns in our case.

We set value 7.5 ns, which corresponded to the highest allowed value.

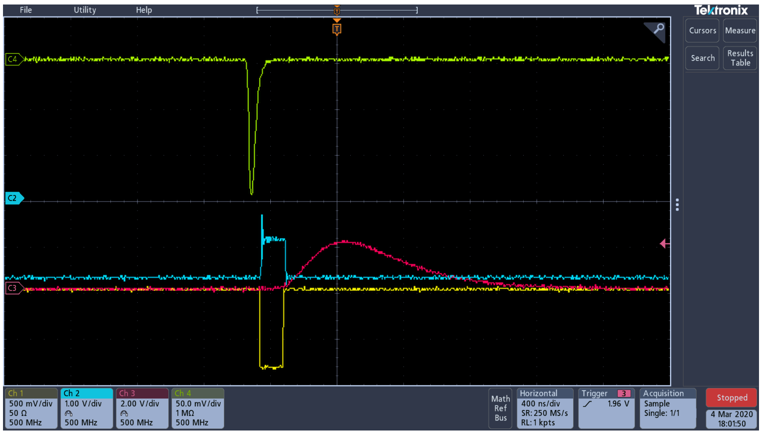


Fig. 3: Signals from the oscilloscope from $LaBr_3$ and N1168. See the text for additional details.

When the Pile-Up Rejection is enabled, the typical situation is as shown in Fig. **4**, where the SLOW output is put in saturation. This event is recognized as piled-up also from the peak sensing ADC and rejected without connecting any other additional cable.

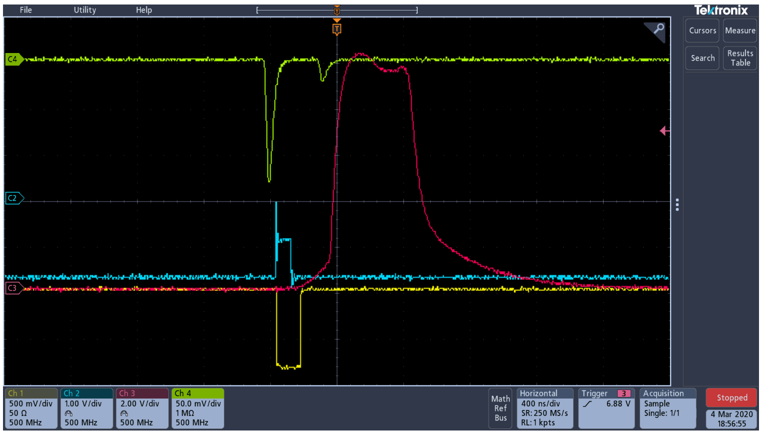


Fig. 4: Signals from the oscilloscope from $LaBr_3$ and N1168 in case of pile-up rejection enabled. The SLOW output is put in saturation.

To correctly set the threshold it is important to verify that the pile-up correctly fired. For example, in case of too low threshold value, the pile-up rejector will fire on noise, and the spectrum will miss many events. See for example Fig. **5** where the output saturated even if no pile-up occurred. Fig. **5** corresponds to a threshold value equal to 11, while Fig. **4** corresponds to a threshold value equal to 12.

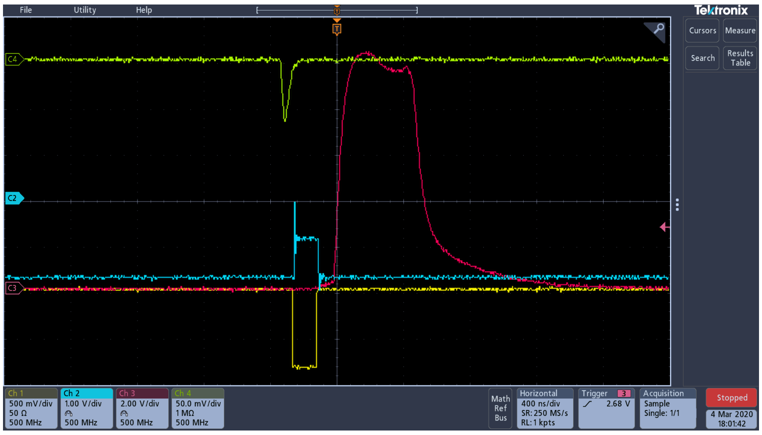


Fig. 5: The threshold of N1168 has been set too low and the board triggers on noise, thus producing pile-up events even if not real.

The threshold must be set as lowest as possible to get a correct pile-up rejection.

Here is a summary of the settings applied to the N1168 and N6741.

N1168 Settings (SLOW output)	Shaping time = 200 ns	Shaping time = 400 ns	Shaping time = 800 ns
Gain	16	16	16
Fine Gain	25	155	25
Threshold	12 mV	12 mV	12 mV
CFD delay	0 ns	0 ns	0 ns
CFD width	0 ns	0 ns	0 ns
OR width	0 ns	0 ns	0 ns
PUR	enabled	enabled	enabled
Offset	123 mV	123 mV	123 mV
N6741 Settings			
Spectra channels	4096	4096	4096
Input polarity	positive	positive	positive
Gate	2 µs	4 µs	6 µs
Sliding scale	active	active	active
Input range	8V	8V	8V
Zero Suppression	disabled	disabled	disabled

Tab. 1: List of settings of the N1168 fast shaping amplifier and the N6741 peak sensing ADC for the acquisition of the ^{137}Cs energy spectrum.

Two other setups for comparison

To compare the energy spectra get from N1168 and N6741 with "consolidated" energy spectra and to the expected value from $LaBr_3$ data sheet, we used two similar setups.

In the first setup, the N1168 was replaced by a N1068, a traditional Shaping Amplifier, which has the possibility to directly accept signals from PMT without the use of a preamplification stage (see Fig. **6**). This option is called "0.5Fast".

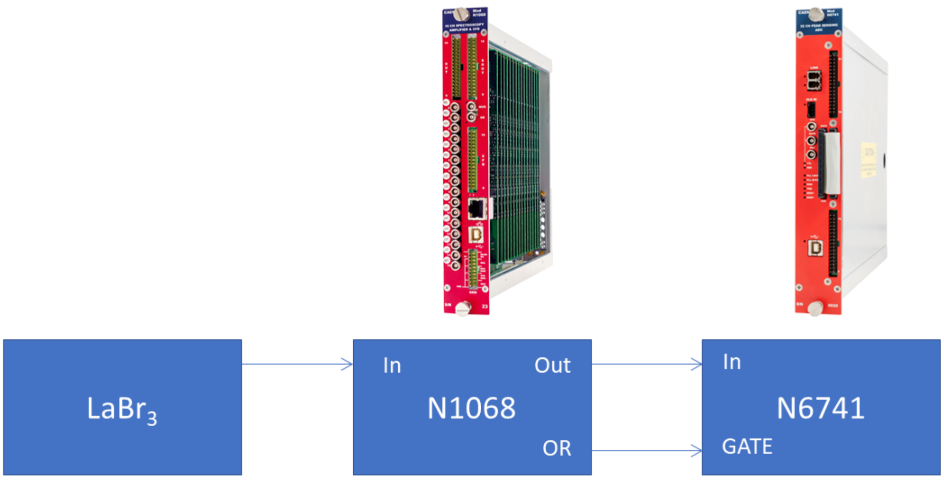


Fig. 6: Setup with N1068 Shaping Amplifier and N6741 Peak Sensing ADC

Here the list of settings applied to the N1068 and N6741.

N1068 Settings	Shaping time = 0.5Fast
Gain	64
Fine Gain	50
TGain	4x
Tint	20 ns
Tdiff	100 ns
Toffset	770 mV
Threshold	67 mV
CFD delay	0 ns
CFD width	0 ns
OR width	0 ns
PUR	enabled
Offset	126 mV
N6741 Settings	**Value**
Spectra channels	4096
Input polarity	positive
Gate	3 µs
Sliding scale	active
Input range	8V
Zero Suppression	disabled

Tab. 2: List of settings of the N1068 shaping amplifier and the N6741 peak sensing ADC for the acquisition of the ^{137}Cs energy spectrum.

In the second setup, all the boards showed in Fig. **2** were replaced by the digital MCA Hexagon (see Fig. **7**), which can accept several input type, like signals from PMT, TRP (Transistor Reset Preamplifier), CSP (Charge Sensitive Preamplifier), etc. and can also provide the power supply for detector and eventually for preamplifiers.

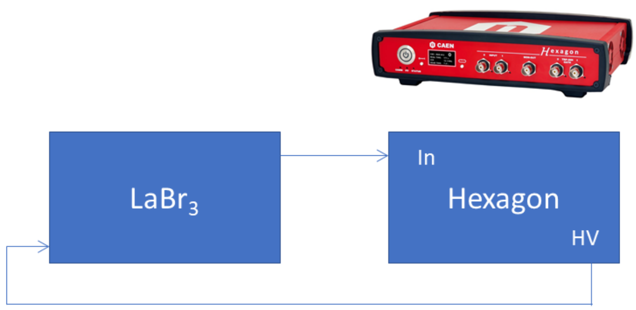


Fig. 7: Setup with Digital MCA Hexagon replacing all the boards showed in Fig. **2**

Here the settings for the Hexagon. For more details about the settings meaning and configuration, please refer to **[5]** and **[6]**.

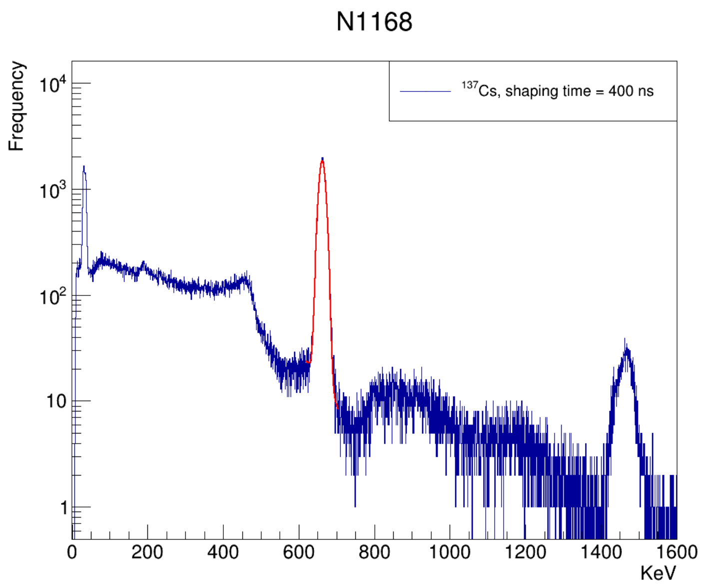
Hexagon Settings	Value
Spectra channels	4096
Input polarity	negative
Trapezoid tail correction	0.4 µs
Trapezoid Rise Time	5 µs
Trapezoid Flat Top	1 µs
Peaking time	50 %
Baseline Mean	Fast

Tab. 3: List of settings of the digital MCA Hexagon for the acquisition of the ^{137}Cs energy spectrum.

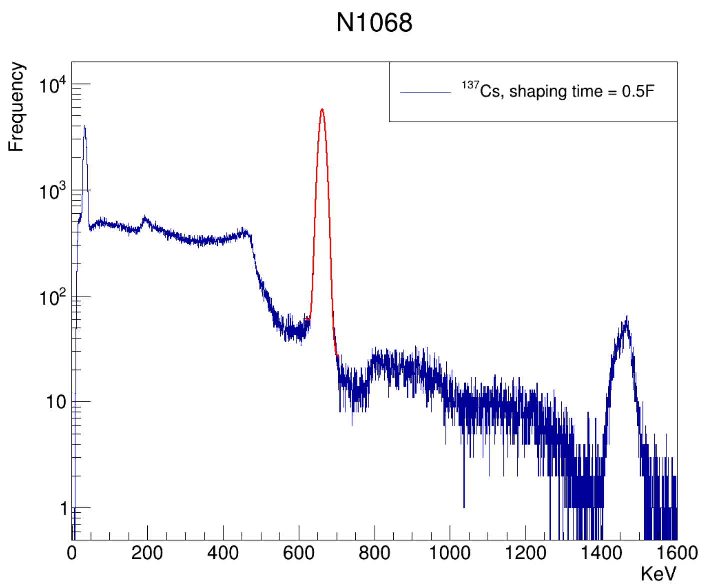
Results

Spectra were acquired with the Peak Sensing Acquisition Software and MC^{2}Analyzer for the N6741 and Hexagon respectively, then saved into .txt file, and further analyzed with ROOT **[7]**. In this way the analysis technique is the same for the three spectra for not introducing a bias in the peak resolution result. The following pictures show the resulting spectra obtained in the three different configurations.

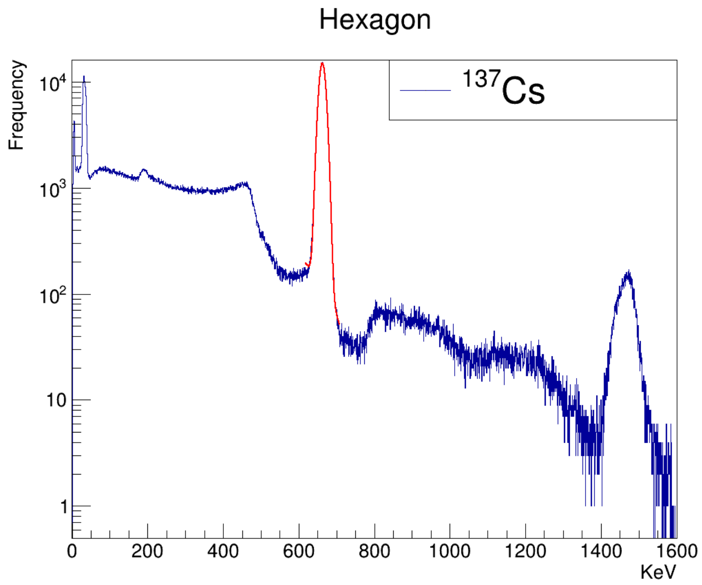
N1168 and N6741



N1068 and N6741



Hexagon



From all the plots it is possible to see that the energy spectrum is very similar in the three cases, in particular, a X-ray peak is also visible, which is a superposition of the X-ray of Lanthanum (35 keV) and X-ray of the ^{137}Cs (32 keV).

The resolution of the ^{137}Cs peak (which is defined as the FWHM over the peak energy value) has been evaluated with a fit with a Gaussian function and a linear function to model the background. Results for the three configurations are reported in the table below.

^{137}Cs 661 keV resolution		
N1168&N6741	N1068&N6741	Hexagon
3.0 ± 0.1 %	3.1 ± 0.1 %	3.2 ± 0.1 %

Tab. 5: ^{137}Cs 661 keV energy peak resolution for the three configurations.

The results are all in agreement with the expectations (3.0 % of resolution for the 661 keV of ^{137}Cs source). The setup with N1168 and N6741 shows slightly better results, though under the statistical uncertainty.

Conclusions and discussion

Results from the three setup shows very compatible values for the resolution of the ^{137}Cs peak. In addition, in all the three cases, it was possible to identify the X-ray peaks, thus making confident of the goodness of the algorithms and filters that could be able to trigger even small signals up to 32-35 keV. The setup with N1168 and N6741 is therefore suitable to get good energy measurements with scintillator detectors like $LaBr_3$ detectors coupled with PMTs. The pulse shape discimination has not been tested in this application note and it will be argument for a future application note.

It must be also highlighted that the digital MCA Hexagon is working at the limit of its performances, indeed, it is working with a pulse with very short exponential tail (minimum required is 400 ns, while with $LaBr_3$ we are below 100 ns) and getting a very nice spectrum even at small energies, and a ^{137}Cs resolution compatible with the expectations.

References

[**1**] UM7327 – N1168 User Manual.

[**2**] UM3267 – N1068 User Manual.

[**3**] UM7493 – N6741 User Manual.

[**4**] DS6511 – Hexagon Digital Multi-Channel Analyzer with Quantus Spectroscopy Software.

[**5**] UM3182 – DPP-PHA and MC2Analyzer User Manual.

[**6**] UM6907 – Quantus User Manual.

[**7**] Rene Brun and Fons Rademakers. "ROOT - An Object Oriented Data Analysis Framework". In: *Proceedings AIHENP'96 Workshop, Lausanne, Sep. 1996, Nucl. Inst. and Meth. in Phys. Res. A*. Vol. 389. 1997, pp. 81–86. URL: `http://root.cern.ch/`.

CAEN
Tools for Discovery

CAEN SpA
Via Vetraia 11
55049 – Viareggio Italy
Tel +39.0584.388.398
Fax +39.0584.388.959

info@caen.it www.caen.it

www.caen.it