Application Note AN3110
Energy Resolution and Linearity of the MCA CAEN DT5780

Viareggio
20 January 2014

Introduction

The **MCA DT5780** represents the synthesis of CAEN long lasting experience in high voltage (HV) power supplies and in digital acquisition systems. The device houses two HV channels with ±5 kV maximum voltage and two 14 bit acquisition channels with 100 MS/s sampling rate. The device allows through its internal logic to require coincidences and anti-coincidences between events triggered by the two acquisition channels.
In the present Application Note we report the results obtained in internal tests of the MCA DT5780. We are going to show the resolution of the energy measurement of gamma and X rays obtained with a HPGe detector. The wide spectrum of energy available allows also to obtain a preliminary test of the linearity of our MCA. We want underline that this test is preliminary and does not take into account the nonlinearity of the HPGe detector and the preamplifier, and possible dependencies on the event acquisition rate.

Hardware setup

For this measurement we used the Canberra coaxial HPGe detector 7229P, with cryostat model 7500 and preamplifier model 2001. We set the diode bias voltage to 4.5 kV and we located different calibration radiation sources at fixed distances from the cryostat entrance Aluminum window.
The four calibration sources available for our measurements contain the radioactive isotopes ^{60}Co, ^{137}Cs, ^{241}Am and ^{204}Tl. In the test of the MCA linearity we identified the following emitted radiation:

- the 1173.2 and 1332.5 KeV lines from the Cobalt source [2];
- the 661.7 keV line from the Cesium source [2];
- the 59.5 KeV gamma emission from ^{237}Np from the Americium source [2];
- four lines from k-shell x-ray emission of ^{204}Hg atom de-excitation from Thallium source: 68.9, 70.8, 80.2 (+ 79.8) and 82.5 KeV photons [1];
- the line relative to the natural activity of the ^{40}K [2].

The input range of the MCA CAEN DT5780 was set to 1.4 V, so that the natural gamma activity of the Potassium could be contained in the spectrum. During the data taking the radiation input rate in the detector was in between 100 and 500 cps. We optimized the parameters of the acquisition rate to optimize the energy resolution, maintaining the dead time lower than 2%. The parameter settings for the data acquisitions are listed in the table below (please refer to the UM2088 User Manual [3] available on the website www.caen.it for more information).

Preamplifier Decay Constant	47.0 µs
Samples for Baseline Calculation	1024
Trapezoid Rise Time	5.0 µs
Trapezoid Flat Top	2.0 µs
Peaking Delay (from Flat Top Start)	1.5 µs
Baseline Holdoff	0.1 µs
Peak Holdoff	20.0 µs

Tab. 1: MCA parameter settings.

Energy Resolution

In this section we report the comparative test of the energy resolution of three MCA DT5780 using both the available acquisition channels. For these measurements we used only the ^{60}Co calibration source.

The spectra obtained with the MCA show two peaks due to the 1.17 and 1.33 MeV gamma rays from ^{60}Co decay and one peak due to the 1.46 MeV gamma ray from ^{40}K activity. The position of the peaks is obtained with a fit to the spectrum using ROOT 5.30.06 analysis framework [4]. The function used for the fit is:

$$f(x) = pol3(x) + a \cdot Gaus(x)$$

where the third degree polynomial represents the background contribution and the Gaussian the emitted photon lines. The following figure is an example of the fit on the three gamma ray peaks (^{60}Co and ^{40}K gamma lines).

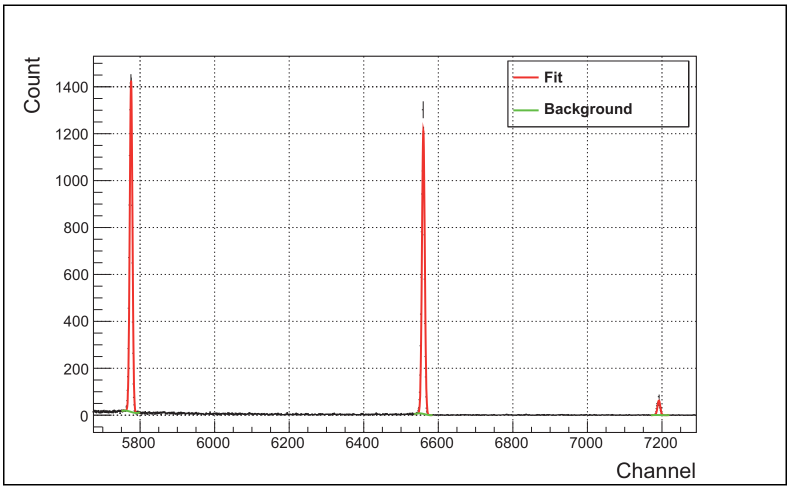

Fig. 1: Example of spectrum showing the 1.17, 1.33 and 1.46 MeV gamma peaks from ^{60}Co and ^{40}K isotope decays. In red the result of the fit to the histogram, in green the modelling of the underlying background.

We represent the result of this fit on a scatter plot, where the energy is on the abscissa and the peak position is on the ordinate. The error on the peak position in the spectrum is taken from the fit to data. We operate a second fit to the data with a line, whose result is represented in the following Fig. 2.

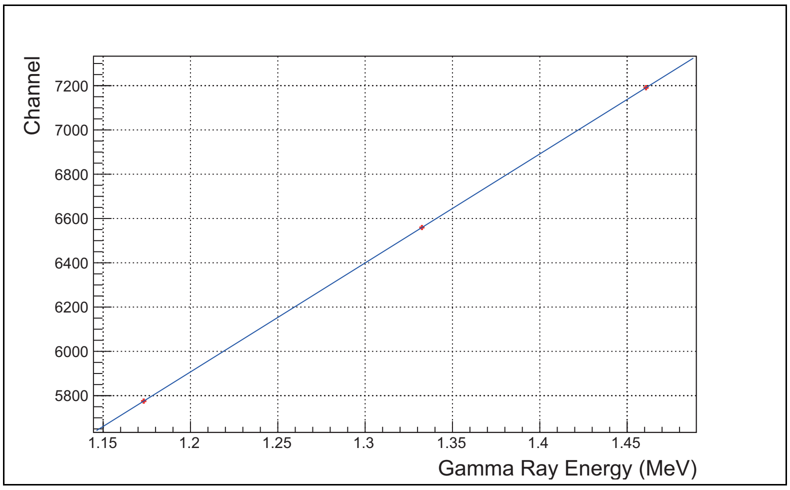

Fig. 2: Linear Fit of the peak position in function of the gamma ray energy. The uncertainty on the peak position is given by the fit to the spectrum (example shown in Fig. 1).

From the parameters of this second fit we can calibrate the MCA and obtain the peak energy and distribution FWHM. We obtain from the use of three DT5780 devices the results in Table 2, where we report the Serial Number (SN) of the devices and the resolution expressed in full width half maximum (FWHM).

Device	Energy (KeV)	FWHM (KeV)
SN 360 Channel 0	1173.2	1.70 ± 0.01
	1332.5	1.78 ± 0.01
	1460.8	1.64 ± 0.09
SN 360 Channel 1	1173.2	1.68 ± 0.01
	1332.5	1.77 ± 0.01
	1460.8	1.90 ± 0.12
SN 370 Channel 0	1173.2	1.67 ± 0.01
	1332.5	1.77 ± 0.01
	1460.8	1.64 ± 0.10
SN 370 Channel 1	1173.2	1.67 ± 0.01
	1332.5	1.79 ± 0.01
	1460.8	1.82 ± 0.11
SN 387 Channel 0	1173.2	1.67 ± 0.01
	1332.5	1.78 ± 0.01
	1460.8	1.84 ± 0.12
SN 387 Channel 1	1173.2	1.69 ± 0.01
	1332.5	1.77 ± 0.01
	1460.8	1.70 ± 0.12

Tab. 2: Summary of the energy resolution obtained with six the different acquisition channels mounted on three MCA DT5780.

The observed FWHM of the 1.33 and 1.46 MeV lines are fully compatible within the statistical uncertainty. The observed FWHM of the 1.17 MeV gamma ray measured with different channels differ at most for three standard deviations from channel to channel. This difference can be either considered compatible within the statistical uncertainty or addressed to the intrinsic quality of the acquisition channel. Anyhow we observe a spread in the measured resolution that is less than 2%. We want to add that in this document there is no evaluation of possible contribution from accidental microphonic noise or evaluation of the systematic uncertainty of the fit, linked to the choice of the histogram range

Linearity

This test takes into account gamma and X ray emissions over a spectrum ranging from approximately 50 keV to 1.50 MeV. The data sets used for these measurements is taken in three runs using all the available sources listed in the section Hardware Setup and the DT5780 with SN 387. The first data set was obtained with the Americium and Cobalt calibration sources, the second one with the Thallium and Cobalt sources and the third one with Thallium and Cesium sources.

We fit the function reported in the previous section to the MCA histogram obtained with the Cesium, Americium and Cobalt sources. Figure 3 shows the data distribution and the best fit in a range close to the 661.8 keV peak of the ^{137}Cs source and the 59.5 keV peak of the ^{241}Am source.

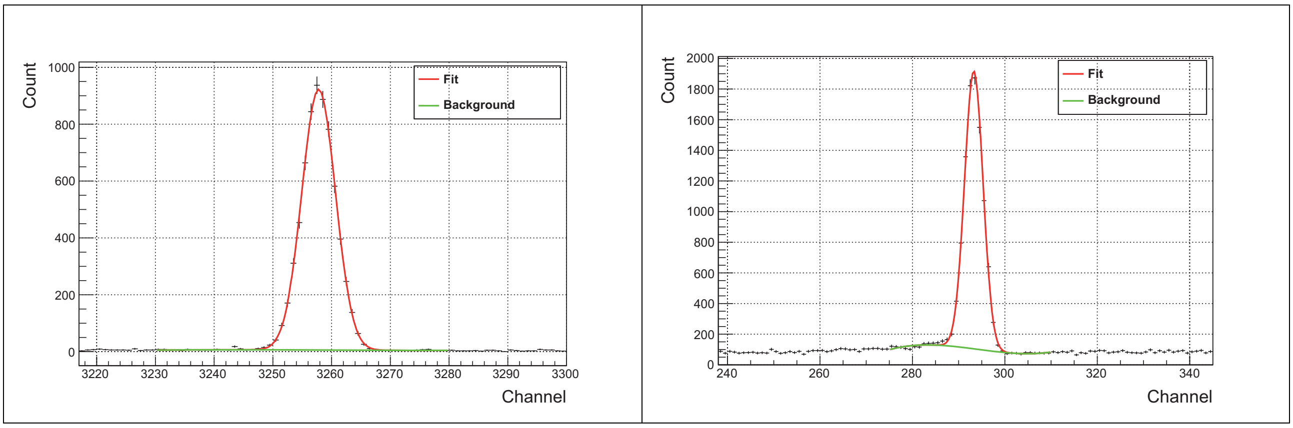

Fig. 3: Examples of spectra obtained with 661.8 keV gamma ray from the ^{137}Cs source on the left and the 59.5 keV from the ^{241}Am source on the right. In red the result of the fit to the histogram, in green the modelling of the underlying background.

The X rays emitted by the Thallium sources are grouped in four peaks showed in Fig. 4. The first two peaks correspond to the Kα_2 (68.9 KeV) and Kα_1 (70.8 KeV), while the other peaks are given by the overlap of multiple emissions [1][2]. For the present test on the MCA linearity we use only the information from the X ray emission Kα_2 and Kα_1.

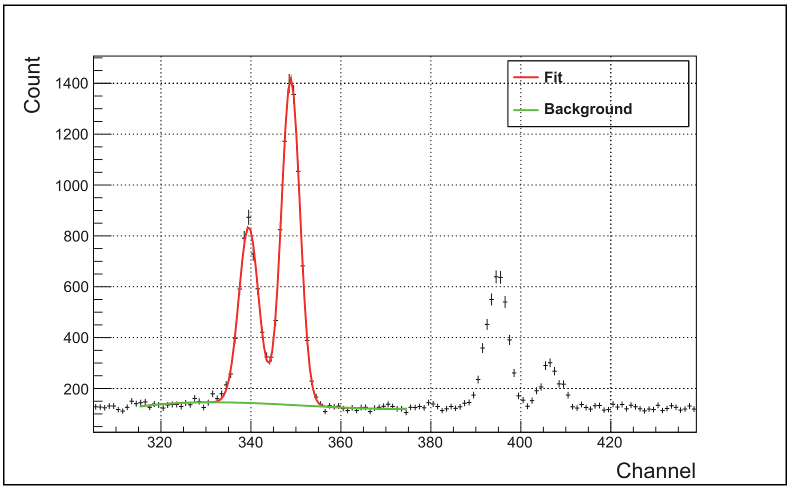

Fig. 4: X ray emission from ^{204}Tl calibration source, corresponding to the K-shell transitions of the ^{204}Hg.

We fit the peaks of the Kα_2 and Kα_1 X ray lines with the function

$$f(x) = pol3(x) + a \cdot Gaus_1(x) + b \cdot Gaus_2(x)$$

which represents the sum of two Gaussian distributions of the photo peaks and a third degree polynomial used to model the underlying background. As done for the results in the previous section, we represent the result of the different fits to data on a scatter plot with the energy is on the abscissa and the peak position is on the ordinate. The uncertainty on the peak position is given by the fit uncertainty on the peak centroid. The information on the energy of the emitted gamma and X rays is provided in [1][2] and we assign ±1 eV uncertainty. We operate a second fit to the data with a line, whose result is represented in the following Fig. 5.

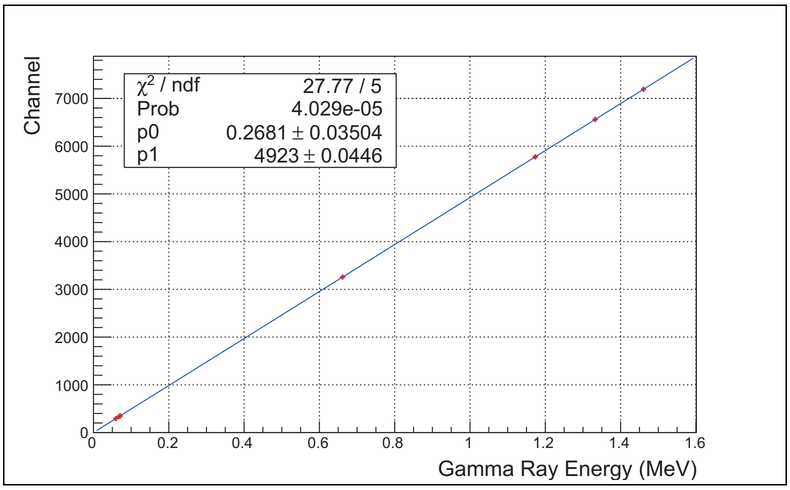

Fig. 5: Linear fit of the peak centroid position in function of the electromagnetic emission energy.

The result of the fit is reported in Tab. 3 as follows.

Energy (KeV)	Fitted Energy (KeV)	FWHM (KeV)
59.541	59.521 ± 0.004	0.95 ± 0.01
68.895	68.910 ± 0.010	1.04 ± 0.03
70.819	70.809 ± 0.006	0.98 ± 0.01
661.659	661.716 ± 0.008	1.37 ± 0.01
1173.240	1173.233 ± 0.006	1.68 ± 0.01
1332.508	1332.487 ± 0.008	1.77 ± 0.01
1460.822	1460.833 ± 0.033	1.76 ± 0.06

Tab. 3: The result of the linear fit in comparison with the data given by [1][2]. The uncertainty on the term Fitted Energy is relative to the centroid of the Gaussian fit to the data.

Fig. 5 shows that the fit to the data has a reduced chi squared of about 5 and Table 3 shows that the position of Cesium 661.7 keV and Americium 59.5 keV peaks differ from the values given in literature by less than 0.03%. This disagreement is compatible within the gain stability of the available preamplifier as function of time and acquisition rate.

Conclusions

The study of the MCA CAEN DT5780 shows that there are minimal differences in the performances of different acquisition channels. On average the differences in energy resolution are approximately 1%. The energy resolution expressed in FWHM of the 1.33 MeV peak distribution is about 1.8 keV, which is also relatively close to the intrinsic resolution of the HPGe detectors, as reported in literature [5][6]. At last we tested the linearity of the device DT5780. The result shows good linearity over a wide range of energies, with minimal disagreement, of the order of 0.03%, which can also be addressed to the ultimate performances of the detector system.

References

[1] "X-Ray Data Booklet", update of October 2009, available at xdb.lbl.gov.
[2] "Recommended Data" of Laboratoire National Henri Becquerel available at www.nucleide.org/DDEP_WG/DDEPdata.htm.
[3] "UM2088 - Digital Pulse Height Analyzer (DPP-PHA) User Manual" available in the Document Library section of CAEN web site.
[4] "ROOT, A Data Analysis Framework", software for statistical data analysis, available at root.cern.ch.
[5] "Radiation Detection and Measurement", G. F. Knoll, Edited by John Wiley & Sons, Inc.
[6] S. Croft, D. S. Bond, Int. J. of Rad. Appl. and Instr. Part A, Vol. 42 (1991), 1009-1014.

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