

QtCDB2 software for coincidence Doppler broadening measurement system

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Abstract. A digital system for the coincidence measurement of Doppler Broadening of positron annihilation (CDB) has been changed to one which is fully software based. Spectrometer is based on two HpGe detectors, HV sources and PC with PCI-9820D digitizer. Detector pulses are digitized directly at the HpGe detector pre-amplifier outputs. The previous external trigger chain was replaced by data processing system with a software trigger. All pulses from detectors are processed by a trapezoid filter. Spectrometer performance was tested and compared in various conditions.

1. Introduction

In 2011, a new spectrometer for coincidence Doppler broadening (CDB) of the positron annihilation peak was built and tested at PALS laboratory in Bratislava [1]. The spectrometer has new advantages like electrical Cryo - Cooling and digital pulse processing system. As a digitizer, 14bits Adlink PCI9820 was used. The external triggering chain was based on NIM modules: constant fraction discriminators and fast coincidences. The system was tested by measurement of Fe samples with He and H implantation. These measurements showed that the system has a long-term instability caused by temperature changes in the laboratory. To make the system even simpler, the software was rewritten to process all input data without the need of external coincidence trigger signal. Real-time transfer using PCI-9820 on-board 3k-sample FIFO was used to achieve this possibility. This feature is possible only if the data throughput from the digitizer is less than the available PCI bandwidth, therefore a lower sampling speed 20MSps was applied instead of the maximum 60MSps applicable to this device.

2. Hardware setup

Our new CDB system consists of detectors, their power supply and computer with acquisition card, see Fig. 1. As HpGe detectors we used Canberra Gc2019 detectors with relative efficiency 20 %. Both detectors are the same type, but their HV supply is different. The HV source used is Dual NIM based Canberra 3125.

3. Trapezoid filter

Analogous to the old QtCDB software, QtCDB2 uses the same trapezoidal filter [2] for energy extraction from digitized pre-amplifier outputs signals. To see results from the filter, QtCDB2 (Fig. 4) software based on Qt and Qwt libraries can show pulse histograms from output of the



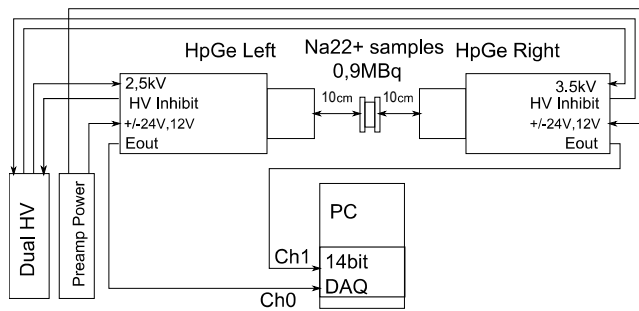


Figure 1. CDB schematic diagram, HPGe Detectors Canberra GC2019, HV Source Canberra 3125, DAQ Adlink PCI-9820, PC Intel Core Quad 2.6Ghz, Win7 64bit, Preamp Power from NIM Bin

trapezoid filter, input of the filter, input of the filter with shifted baseline to same start value, and timing signal which is used to select rise time of the trapezoid pulse (see Figs. 2 and 3). To suppress pile ups shorter than trapezoid length, a shape filter based on controlling flat top deviation from linear shape and pulse height in end of pulse level was used. Pile ups longer than trapezoidal filter ($K+L$) are compensated by the trapezoid filter. Pulses whose heights are below the LLD level are discriminated from the processing.

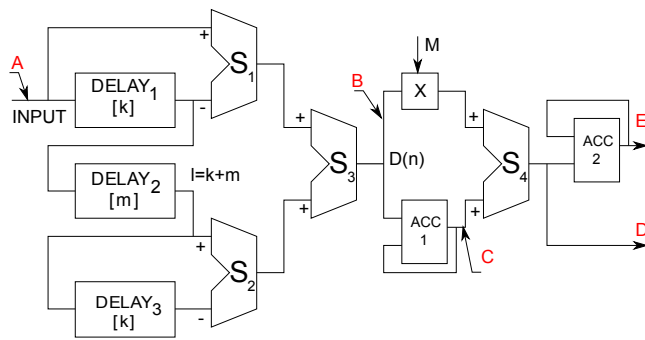


Figure 2. Trapezoidal filter block scheme [2]. Signals in points A..E are shown in Fig. 3,
A: input $v(n)$
B: $D(n) = v(n) - v(n-k) - v(n-l) + v(n-k-l)$
C: integrated B
D: timing output
E: energy output

4. Data acquisition mode

The QtCDB2 software supports two data acquisition modes of the PCI-9820 card.

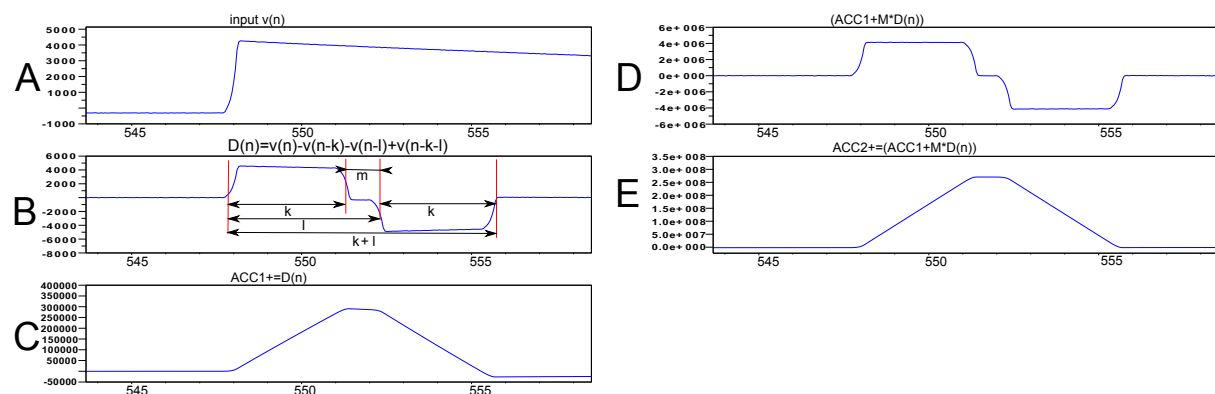


Figure 3. Signals from trapezoidal filter. A,B,C,D,E are points in parts of the filter. (See Fig. 2) The first vertical axis has scale in output values from 14bits ADC, the other vertical axis are in values as computed by filter, horizontal axis are in μs .

4.1. Two steps of data acquisition mode

The old QtCDB code used two steps of data acquisition - DAQSTEPPED mode with external triggering. One pulse processing used in the QtCDB needs a small buffer (about 3kB). Its size was appropriate to trapezoidal pulse size. In the new code we process a long buffer with lot of pulses. The maximum buffer size is determined by internal 128MB SDRAM and card driver. For one measurement we need 2×14 bits, i.e. 4 bytes, therefore in the buffer should be stored 4.2 million samples. DAQSTEPPED acquisition is made in two steps and needs restarting ADC after each data reading from the buffer. This takes death time to acquisition. However in this mode the card should work properly in all available sampling rates supported by the DAQ card.

4.2. Double Buffer mode

This mode applies two acquisition data buffers. The first buffer is filled with data from the ADC, while the second one is used to send data from the card to trapezoidal filter. Role of the buffers is periodically switched. Double buffer mode allows to process all data continuously without the need of ADC restart. The mode is suitable for the ADC sampling rates below 20MSps, due to PCI transfer throughput. The lower sampling speed means few data points in the trapezoid filter with the same shaping time. This means that the resolution is worse than in the previous mode with maximum sampling rate of 60MSps. The obtained resolution with 20MSps, 0.890keV is good compromise between FWHM and count-rate. The results from different sampling rate measurements with the same trapezoidal filter parameters are shown in Table 1. The FWHM was calculated from $E_{left}-E_{right}=0$ diagonal cut Gaussian extrapolation. Shaping time was chosen according to supplied specification of the GC2019 detectors and was same in all measurements - shaping time of 4 μ s and flat top length of 1.1 μ s.

Table 1. Obtained FWHM, count rates with different PCI-9820 ADC sampling rates and acquisition modes. Shaping time 4 μ s and flat top length 1.1 μ s

Sampling Rate [MSps]	FWHM[keV]	Count rate [cps]	(K+L) [samples]	ADC Mode
60	0.883	109	546	DAQSTEPPED
30	0.886	216	273	DAQSTEPPED
20	0.890	623	182	Double Buffer
15	0.915	855	136	Double Buffer
12	0.937	962	109	Double Buffer
10	0.957	1045	91	Double Buffer
5	1.159	1771	45	Double Buffer

5. Long term measurement stability

The previous CDB system [1] had a problem with the HV source stability. This instability was seen in the CDB spectra as a worsening in the FWHM and it depends on temperature changes in the room. The used HV source Canberra 3125 is a dual HV in one NIM module. Temperature dependent errors were seen in both HpGe outputs signal in the same level. Even it was not observed in energy difference, which is the main part of CDB spectra, we decided to eliminate this error. Spectrum shift was eliminated by continuous spectra recalibration. The values computed of trapezoidal filters, which are proportional to gamma energies are stored in buffers. The buffer size is adjustable, but usually it can save energies from about 1 million coincident events. In the first step, from these 1 million values, two one-dimensional 8000 channel

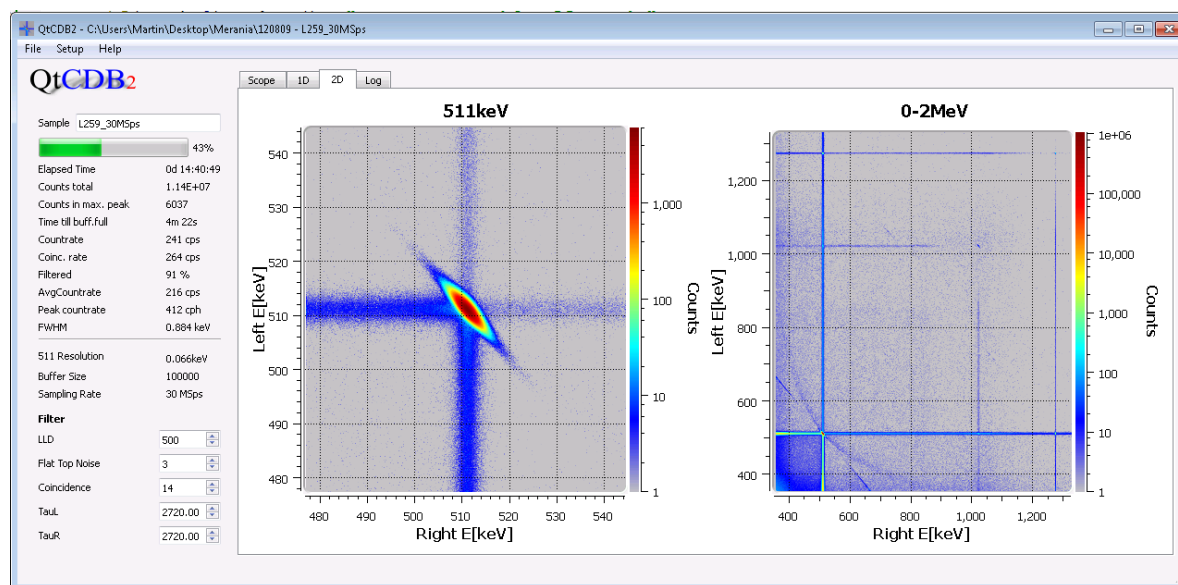


Figure 4. QtCDB2 user interface with 511keV peak for CDB analysis and 0-2MeV spectrogram for positron annihilation in flight analysis [3]

energy histograms for both detectors are made. These collected histograms are calibrated from 511keV and 1274keV peaks by the Gaussian peak extrapolation. In the second step, computed calibration coefficients from these histograms are used to calculate calibrated energy values from the stored events in the buffer. To track the 511keV peak movement even precisely, calibration coefficients are changed linearly from the previous calibration coefficients across the buffer. The calibrated energy values are used for 2D spectrograms (Fig. 4) with desired energy scales. The first spectrogram with 511keV peak in middle is used for the CDB analysis. The second spectrogram with energy coverage from 0 to 2MeV should be used for positron annihilation in flight analysis [3].

6. Conclusion

At the time when we started to build our CDB system (2010), NIM DSP modules used in [4] were discontinued and the multiparameter analogue MCA was expensive. The proposed solution with software trapezoidal filtering realized by PC and automatic spectra stabilisation based on continual recalibration from sodium-22 energy peaks gives good long-term stability and resolution (0.883keV) with the used HpGe detectors even if laboratory temperature is not well stabilized. The QtCDB2 software contains GPL libraries and remain open source. The software sources are available for the positron annihilation community at [5].

References

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