International Seminar on Interaction of Neutrons with Nuclei

Digitizers DSR (Digital Signal Recorder) and their application for nuclear physics research

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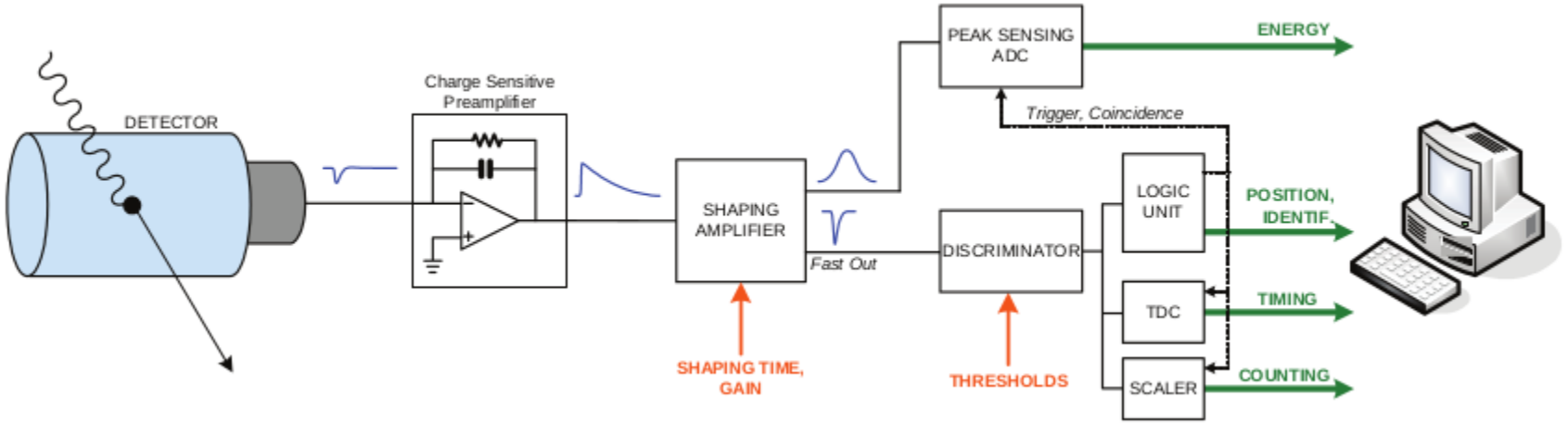
Traditional (analog) nuclear electronics

Scheme with charge-sensitive preamplifier



Scheme with current-sensitive premaplifier

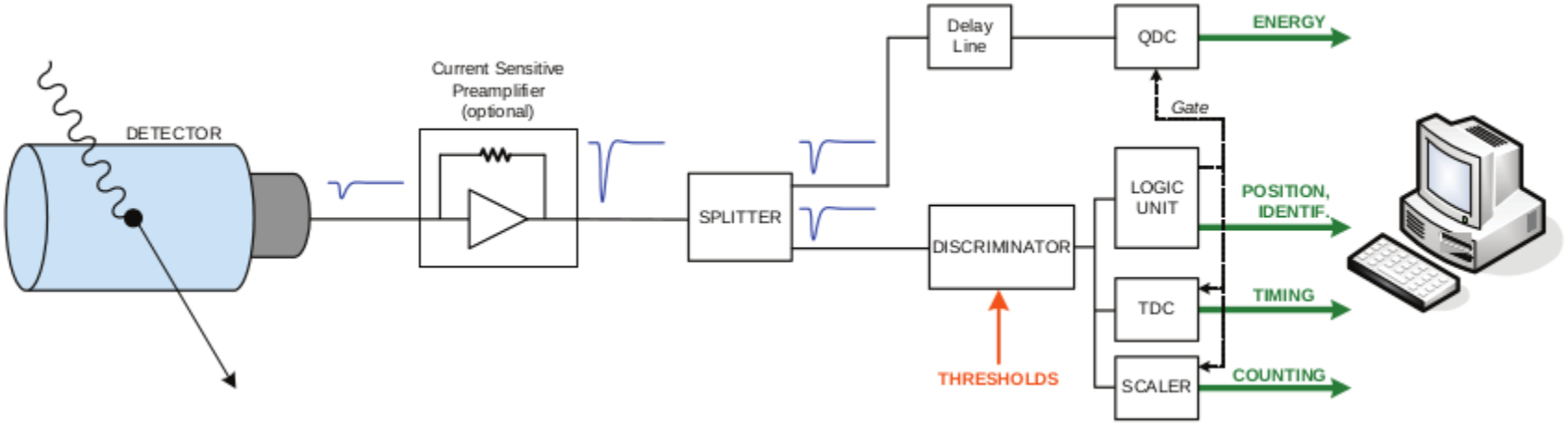


Figure from www.caen.it

Analog pulse processing

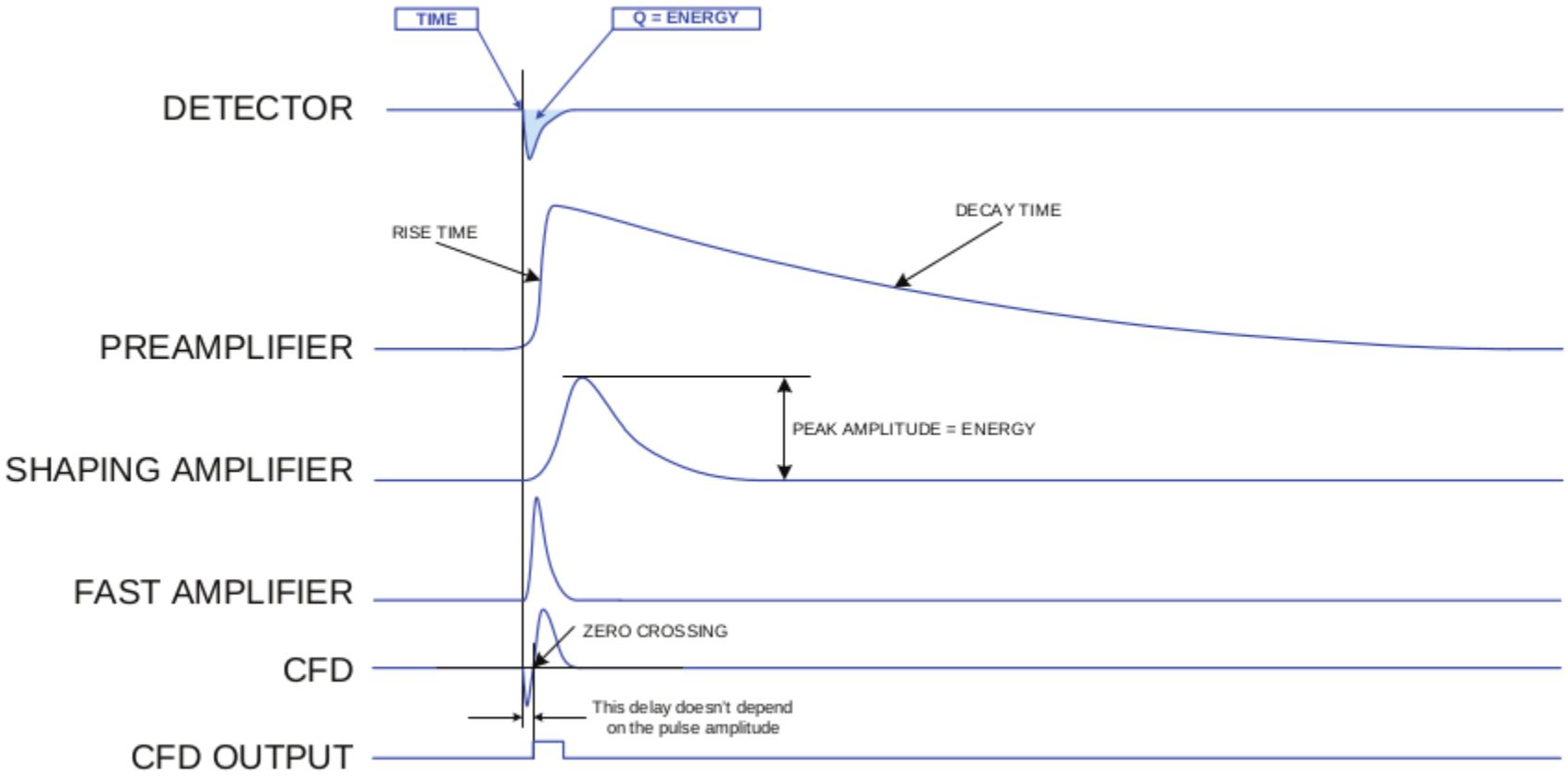


Figure from www.caen.it

Digital pulse processing

The input signal is digitized continuously at a given clock frequency. The digitized ADC values are written to a circular buffer. When a trigger (internal or external) is triggered, the part of the buffer containing the waveform is written to channel memory and transmitted to the computer or processed.

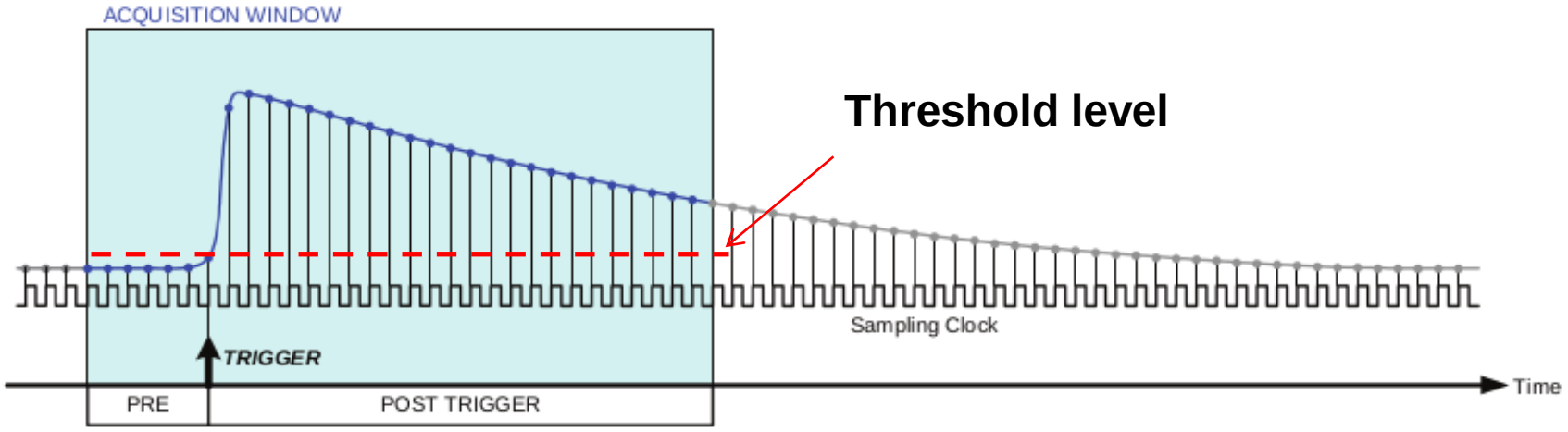
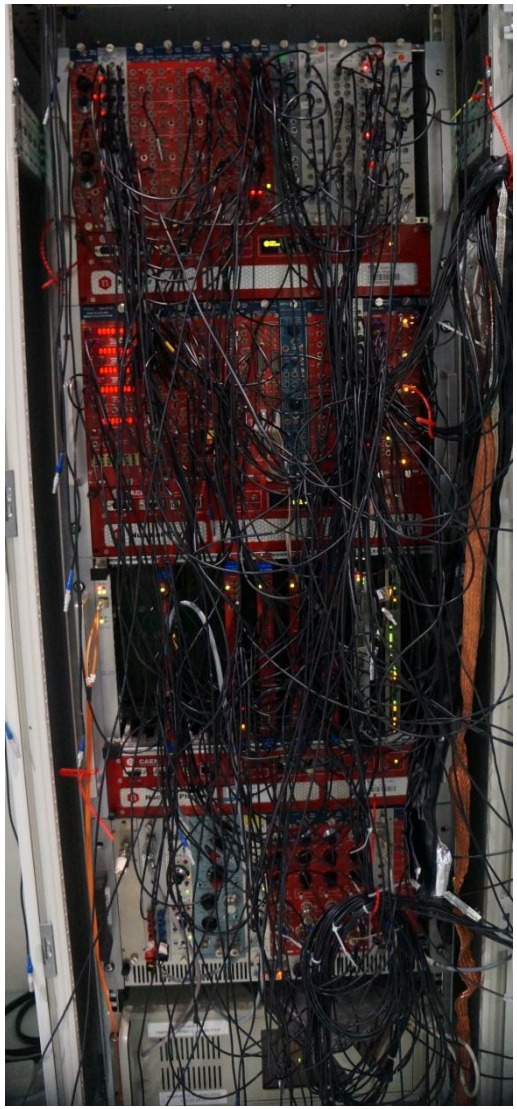


Figure from www.caen.it

Comparison of analog and digital electronics



Experimental electronics in an experiment to measure T-odd effects at the FRM-II reactor in Garching (Germany).

Almost all electronics can be replaced with one 32-channel digitizer

Digitizers

A digitizer or waveform digitizer is an electronic data acquisition device that collects analog signals, processes them using analog-to-digital converters (ADCs) with a given sampling frequency, stores the digitized samples in a buffer, which is processed or written to disk or memory for later processing.

Typical differences between digitizer and oscilloscope

Oscilloscope	Digitizer
Limited number of channels: 2-4	Large number of channels
Low resolution: 8-12 бит	Higher resolution: 10-16 бит
Low data throughput	High data throughput
Higher power consumption	Lower power consumption

Advantages of digital electronics

- Compactness
- Low power consumption
- Low price
- Simultaneous analysis of energy and time characteristics of a pulse
- The ability to save all information about signals with subsequent processing offline
- Ability to save / read settings
- The ability to implement your own algorithms for processing and accumulating data
- Greater opportunities for organizing coincidence / anticoincidence, incl. offline.
- Higher counting rate
- Low (virtually, zero) dead time

Disadvantages

- To correctly configure the parameters of digital pulse processing, knowledge of digital algorithms and at least minimal programming skills are required.

Commercially available digitizers

CAEN

XIA - PIXIE

ACQIRIS

STRUCK

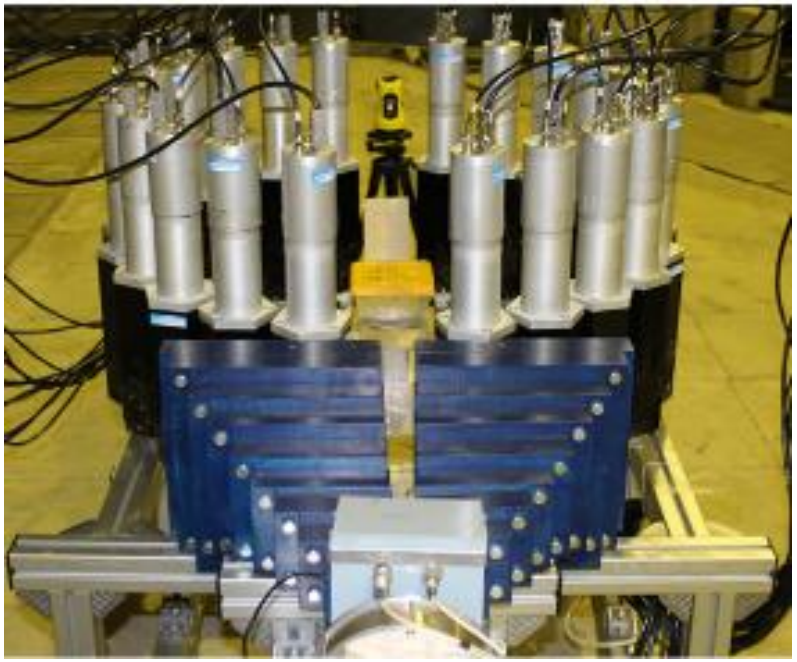
And more…

Many institutes/labs develop their own electronics

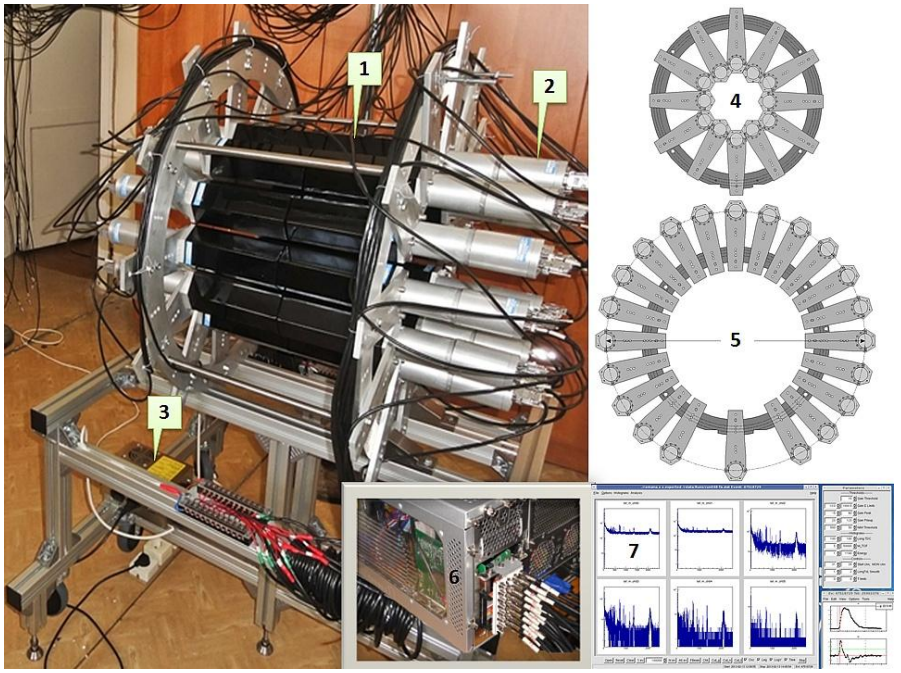
Using digitizers for nuclear physics experiments at FLNP

2014:

The TANGRA project at FLNP



The “Romashka” setup for experiments at IREN



Using digitizers for nuclear physics experiment at FLNP

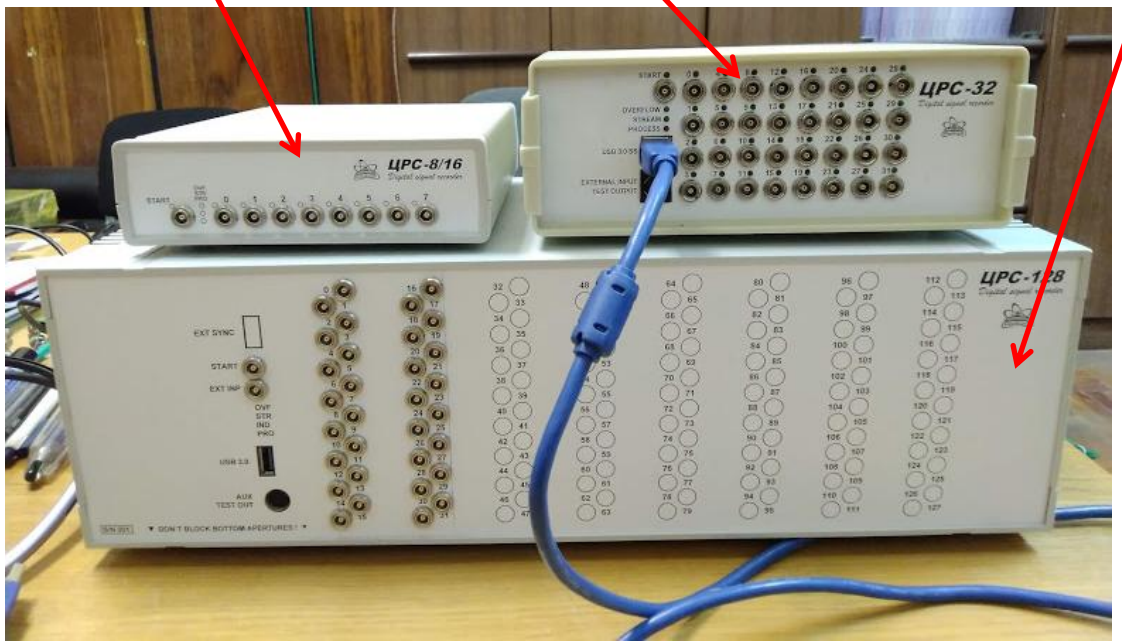
Digitizer ADCM-16 (developed by AFI-electronics, Dubna)

- 16/32/64-channel digitizers in the form of one or several PCI-E cards.
- Sampling frequency 100 MHz
- ADC number of bits 14 bits

- Maximal counting rate ~ 10^5 events/sec
- Doesn't support high resolution measurements (HPGe detectors)

Development of digitizers DSR (Digital Signal Recorder) at FLNP in cooperation with S. Alpatov

DSR-2 DSR-8 DSR-32 DSR-128

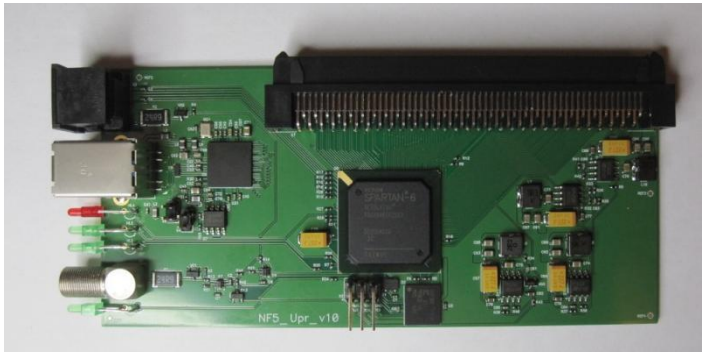


All digitizers use the same interface and software.

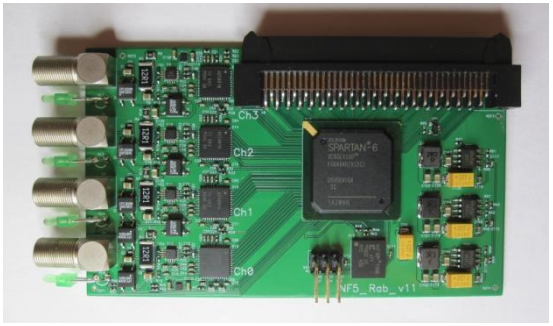
Digitizer DSR-32

Backplane

Control board

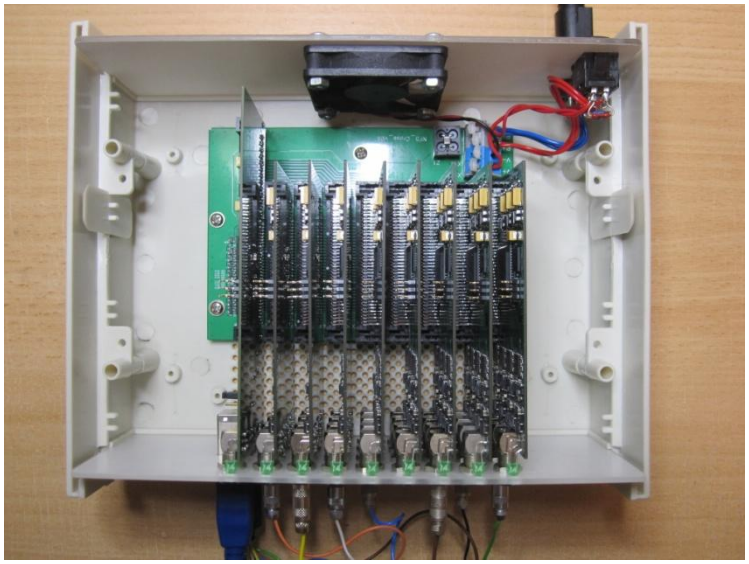


Physical channel board 4-11



Physical channel board 2-16

Digitizer DSR-32

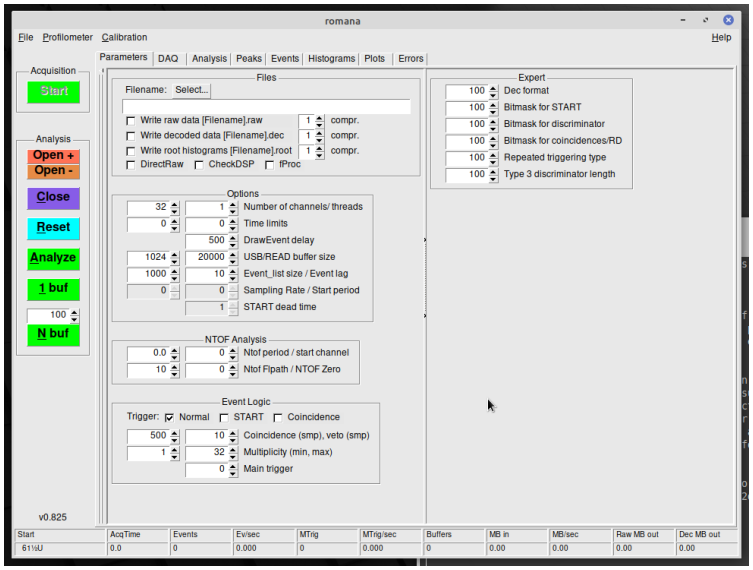


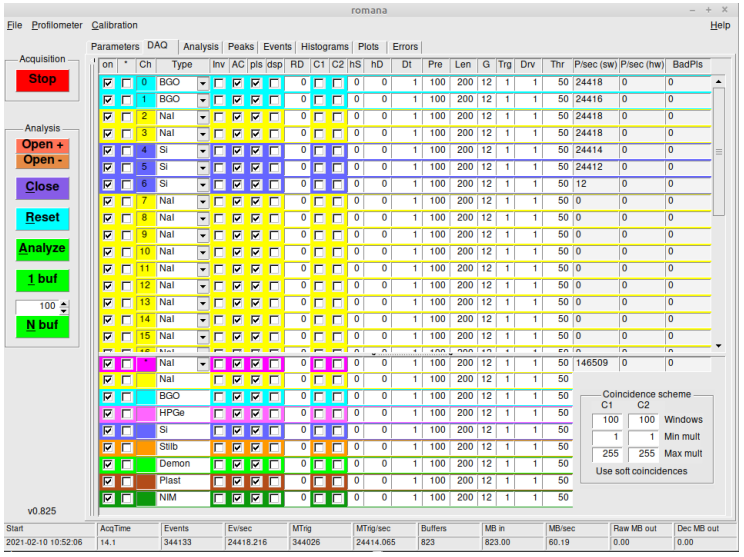
- Computer connection via USB3: data transfer rate up to 5 Gbits/s (real speed 186 MBytes/s)
- Modular design. Depending on the task, you can use from 4 to 32 channels; if one module fails, the rest remain operational.
- An autonomous, portable, compact device, it can work with both a stationary computer and a laptop.

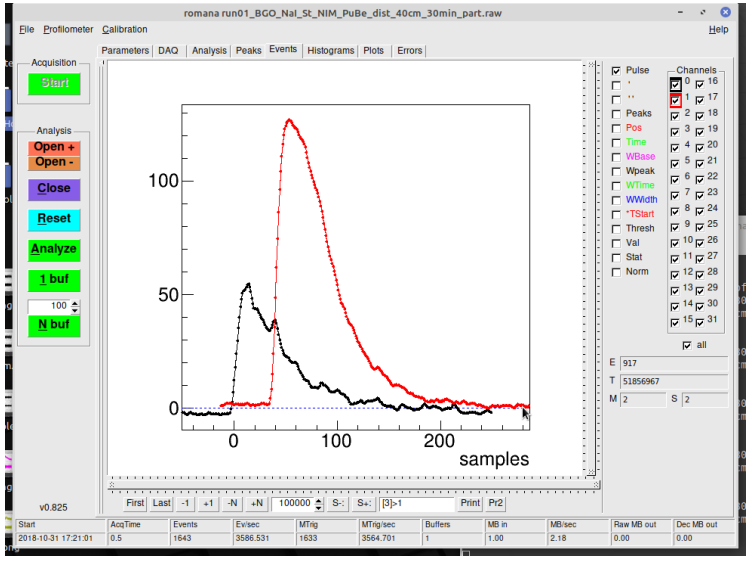
Main characteristics of DSR-32

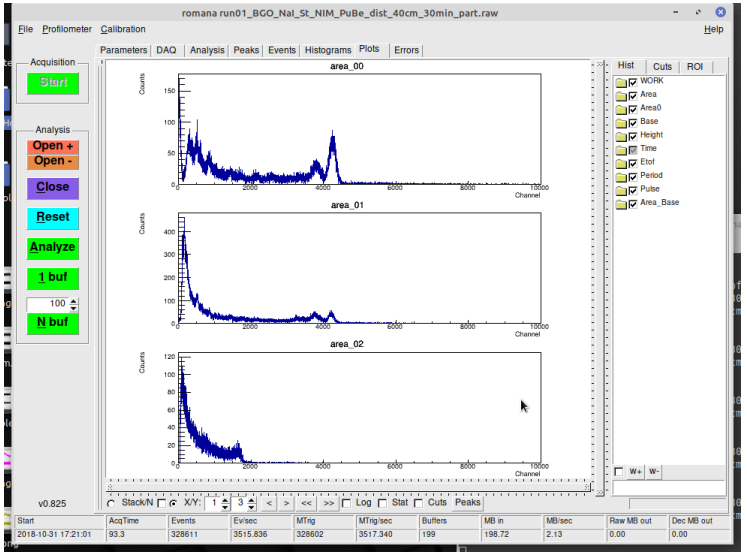
Parameter	Board 4-11	Board 2-16
Number of input channels:	4 to 32	2 to 16
Sampling frequency:	200 MHz	100 MHz
Number of bits in the ADC:	11	16
Input signals range:	-1 .. 1 V	-0.2 .. 0.2; -5 .. 5 V
Additional gain:	+50%	+50%
Pulse window:	-5 .. 20 mks	-10 .. 30 mks
Data throughput:	186 Mbytes/s (~$3x10^6$ events/sec)	
Pulse counter in each channel		
On-board digital pulse processing (time, amplitude, width)		
External START input		
External slow control input (e.g., polarization measurement)		
Test inputs		

Data acquisition and control software









Possibilities of the data acquisition software for the control and data processing of the digitizers

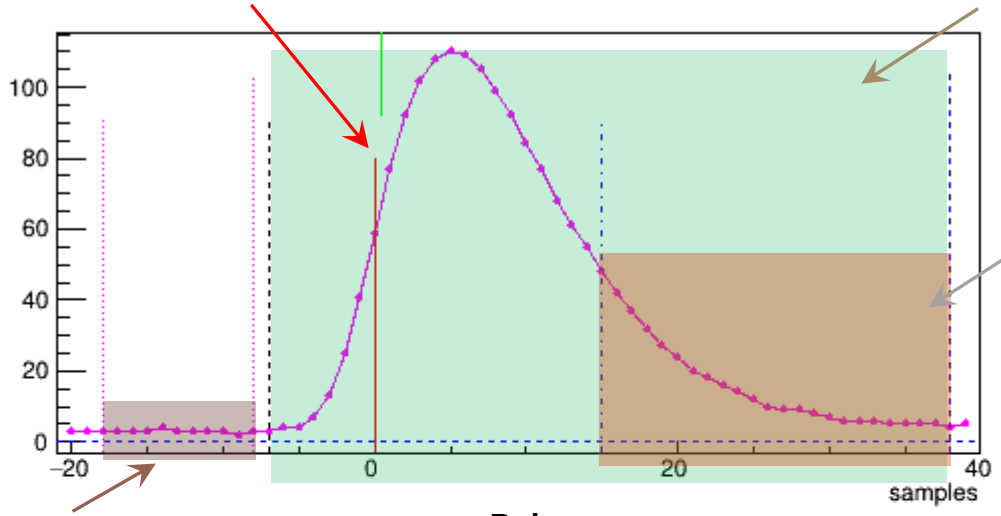
- Raw data recording in “RAW” format - digitized pulses are recorded.
- Complete re-analysis of recorded data with variation of all parameters.
- Recording of decoded data in the “DEC” format - only the pulse parameters are recorded: the discriminator response time relative to the start of accumulation; pulse area, exact time relative to the start, pulse width.
- Integral spectra recording in ROOT format.
- Selection of "conditional windows" in the spectra.
- View the buffer containing the last accumulated pulses.
- Implementation of the coincidence/anticoincidence scheme.
- Energy and time calibration of channels.
- Creation and accumulation of one-dimensional and two-dimensional spectra.
- Implementation of the time-of-flight technique.
- Recording the state of an external control signal (for example, the state of a neutron polarizer).
- Smoothing, differentiation, pulse delay.

Pulse processing

The moment when the discriminator was triggered

Determination of the pulse area/amplitude

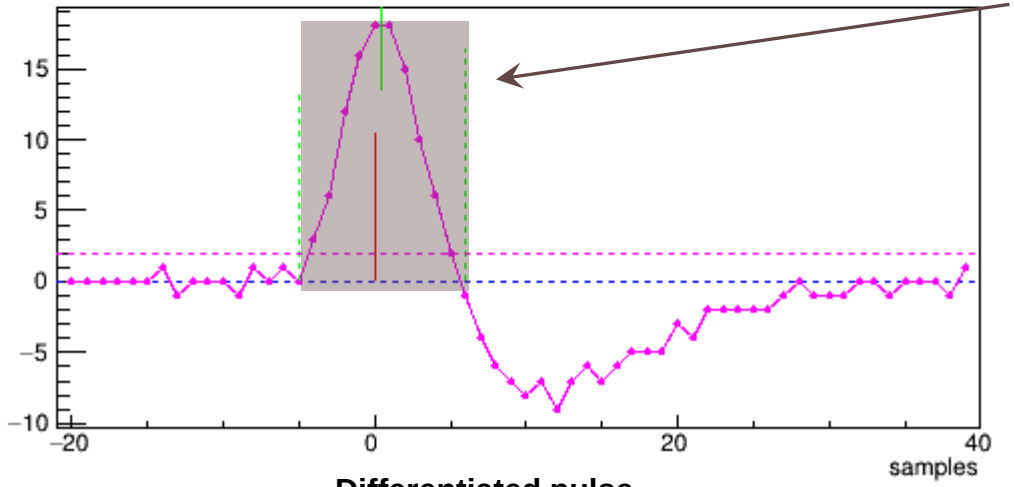
Determination of the pulse width (e.g., for n-γ discrimination)



Pulse

Determination of the pulse baseline

Determination of the pulse time

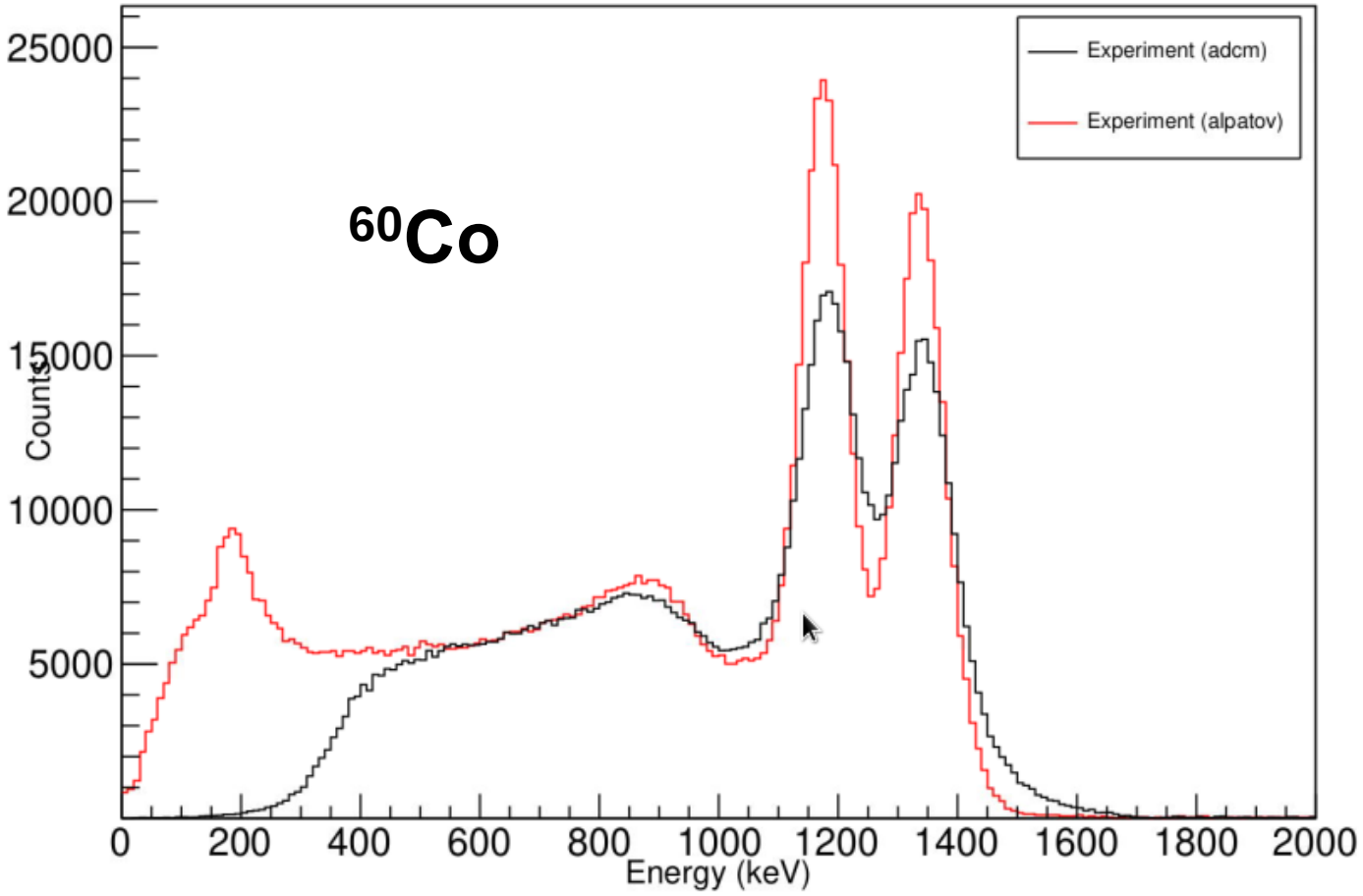


Differentiated pulse

Intrinsic amplitude resolution: < 10^{-3}

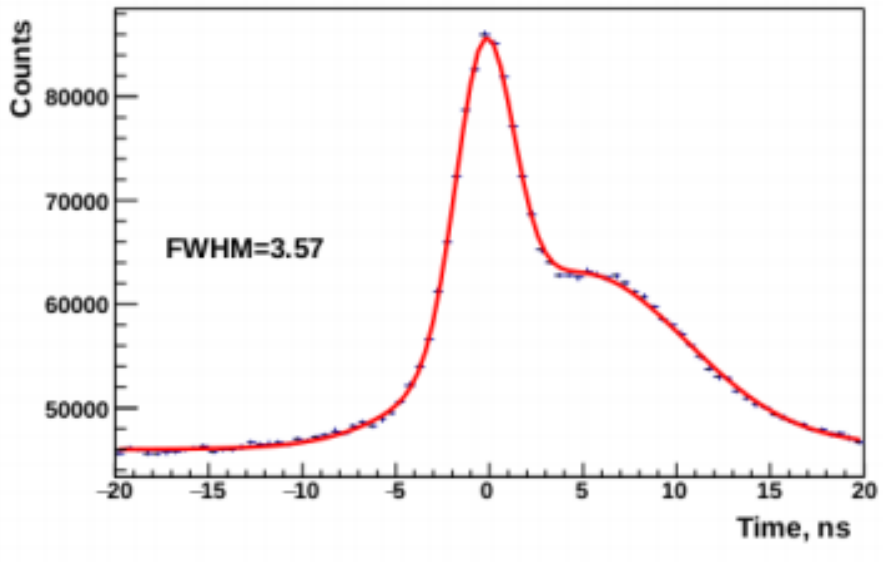
Intrinsic time resolution: < 200 ns

Comparison of energy spectra measured by ADCM and DSR-32

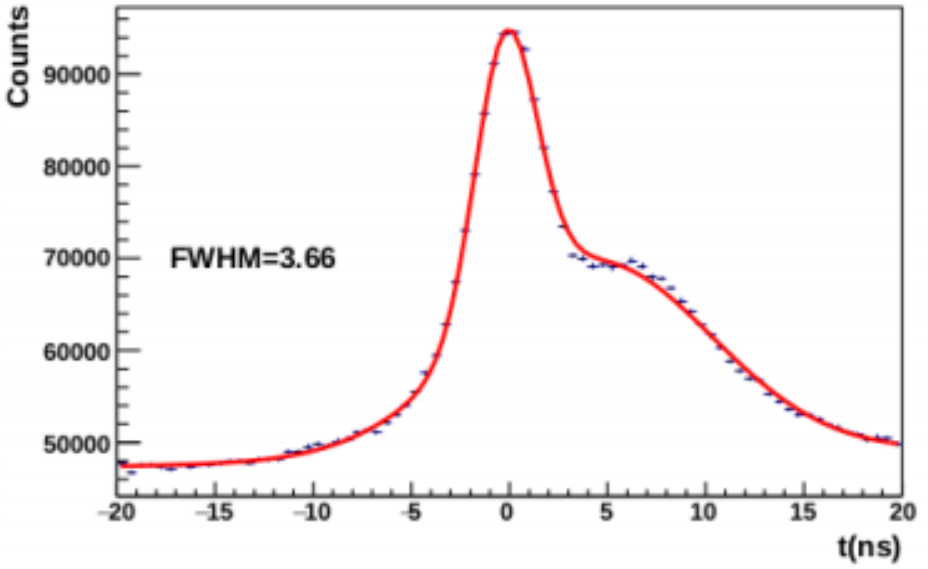


Comparison of the time resolution of ADCM and DSR-32: α-γ coincidence

(measured at the AGP-K facility of LLC "Diamant")

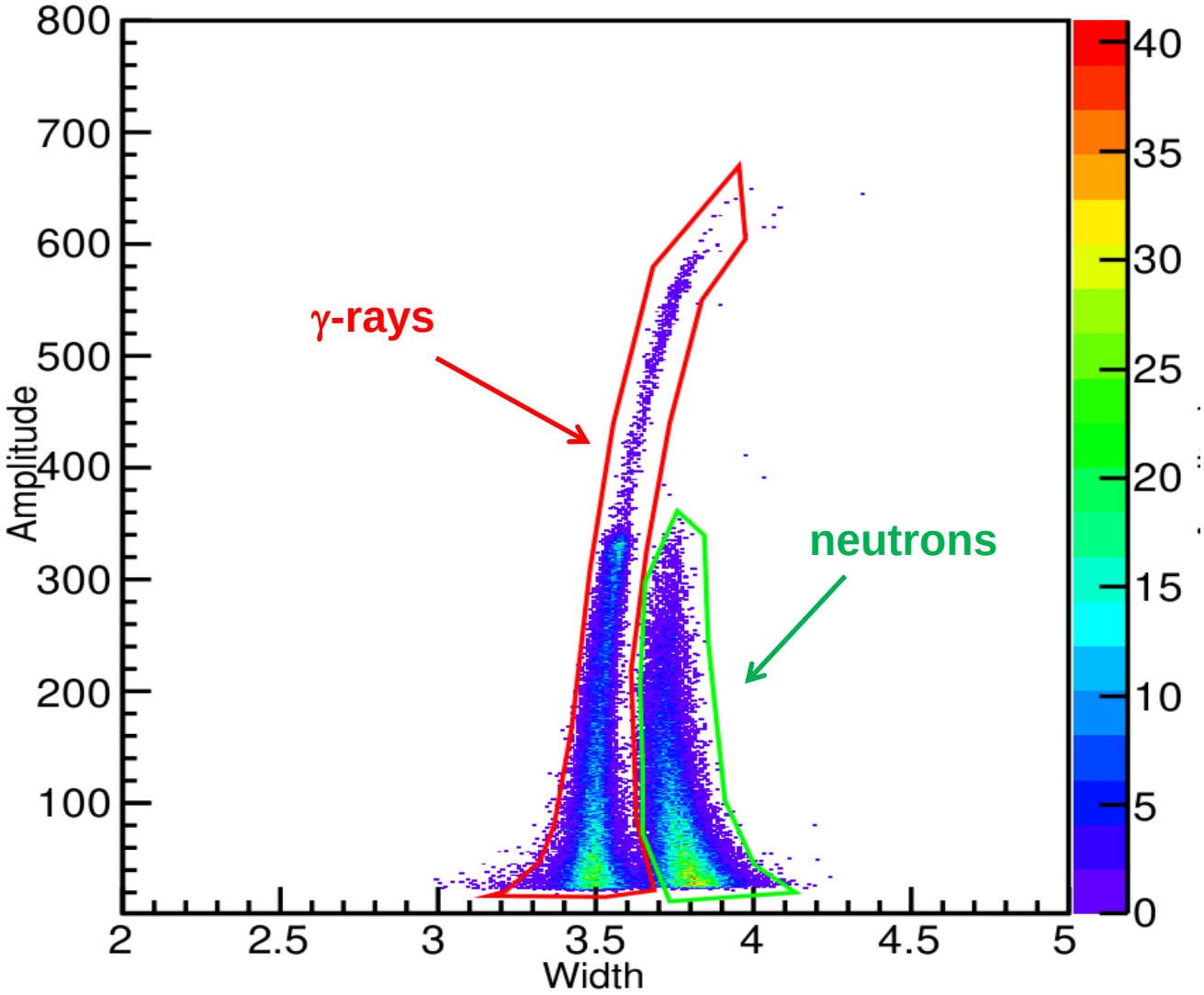


ADCM: 3.57 ns

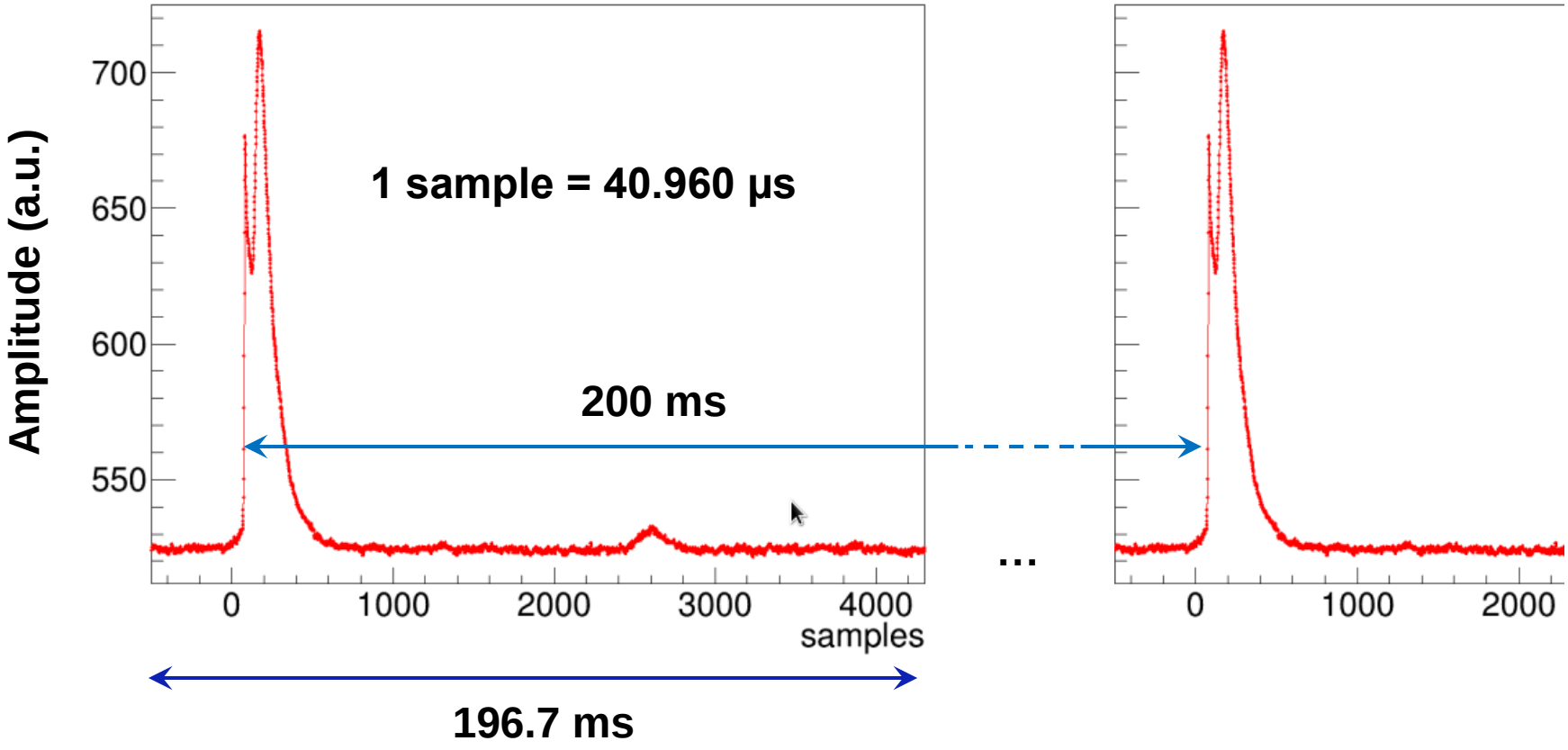


DSR: 3.66 ns

An example of the n-γ pulse shape separation spectrum obtained with a DSR-32 digitizer



Time spectrum from the IBR-2 reactor obtained by the integral (current) method using a DSR-8 digitizer



Comparative characteristics of the DSR modules

Parameter	DSR-2	DSR-8	DSR-32	DSR-128
Number of input channels	2	8	2÷32	16÷128
Sampling frequency (MHz):	200	0.006 ÷ 100	200/100	0.006 ÷ 100
Number of bits in the ADC:	11	16	11/16	16
Input signals range:	-1 ÷ 1 V	-0.5 ÷ 0.5 V	-1 ÷ 1 V	-0.5 ÷ 0.5 V
Data throughput (MBytes/sec):	186	390	186	390
Data throughput (pulses/sec):	$\sim 3 \cdot 10^5$	$\sim 7 \cdot 10^6$	$\sim 3 \cdot 10^6$	$\sim 7 \cdot 10^6$
Data throughput in coincidence mode for 1% coincidence rate (pulses/sec)	$\sim 3 \cdot 10^5$	$\sim 7 \cdot 10^8$	$\sim 3 \cdot 10^6$	$\sim 7 \cdot 10^8$
Data processing:	CPU PC	FPGA	FPGA	FPGA
Coincidence scheme:	CPU PC	FPGA	CPU PC	FPGA
External START input	no	yes	yes	yes
External slow control input	no	yes	yes	yes

Conclusions

- **We have designed and developed a series of digitizers DSR which can be used to carry out experiments in the field of nuclear physics of almost any degree of complexity.**

- **A universal software has been developed that allows to carry out full-fledged data processing from any of the digitizers of the DSR family.**

- **The use of digitizers leads to significant savings in financial resources, and also increases the quality and reliability of experimental data.**

Thank you for your attention!