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Wu H Y, Li Z H, Wu J, et al. A general-purpose data acquisition system and a waveform analysis algorithm based on digitization (in Chinese). Chin Sci Bull, 2021, 66: 3553–3560. doi: [10.1360/TB-2021-0552](https://doi.org/10.1360/TB-2021-0552)



Figure 1 (Color online) Diagrams of the analog acquisition system (a) and the digital data acquisition system (b)

1.1

Pixie-16 [8,10]

10

(fast/trig filter),

(constant-fraction

discrimination, CFD filter)

[8,11]

1

Pixie-16 [8]

based trigger I/O(MZTIO)[9]

CompactPCI/PXI

10MB/s

8366/PXI-8368

Pixie-16

8

[5] I/O

MicroZed

Pixie-16

Pixie-16

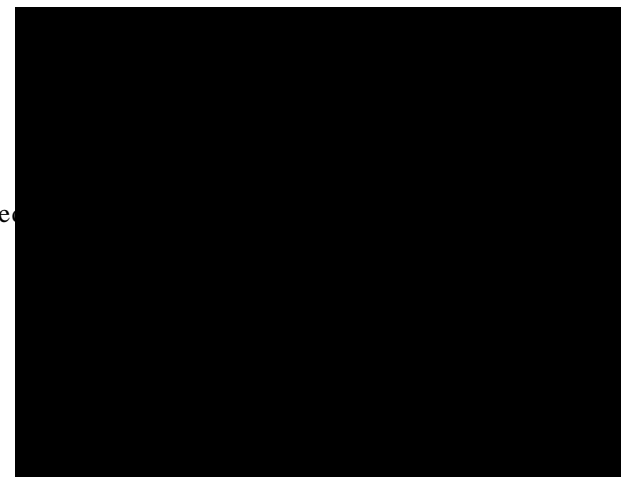


Figure 2 (Color online) A typical digital data acquisition system



Figure 3 (Color online) The response of the digital filtering algorithm. (a) Generic signal from a detector's preamplifier. (b) Response of the trigger filter algorithm when applied to the signal as shown in panel (a). (c) Response of the digital CFD algorithm when applied to the signal as shown in panel (b). (d) Response of the energy filter algorithm when applied to the signal as in panel (a)

(slow/enhance),

[10] 3(a)

3(b) (c)

3(a) 3(d) , Pixie-16 , Pixie-16

[8] 48

1.2

XIA LLC

MZTIO

MZTIO

[12]

VHDL/verilog

MZTIO

FPGA

MZTIO

MZTIO ,

1.3

FPGA

4

2

2.1

ba LABS

HPGe

MZTIO HPGe

5

^{62}Cu 925V

(3000/1000/s)

iThem-

6

HPGe

3.1 8.8/s

(

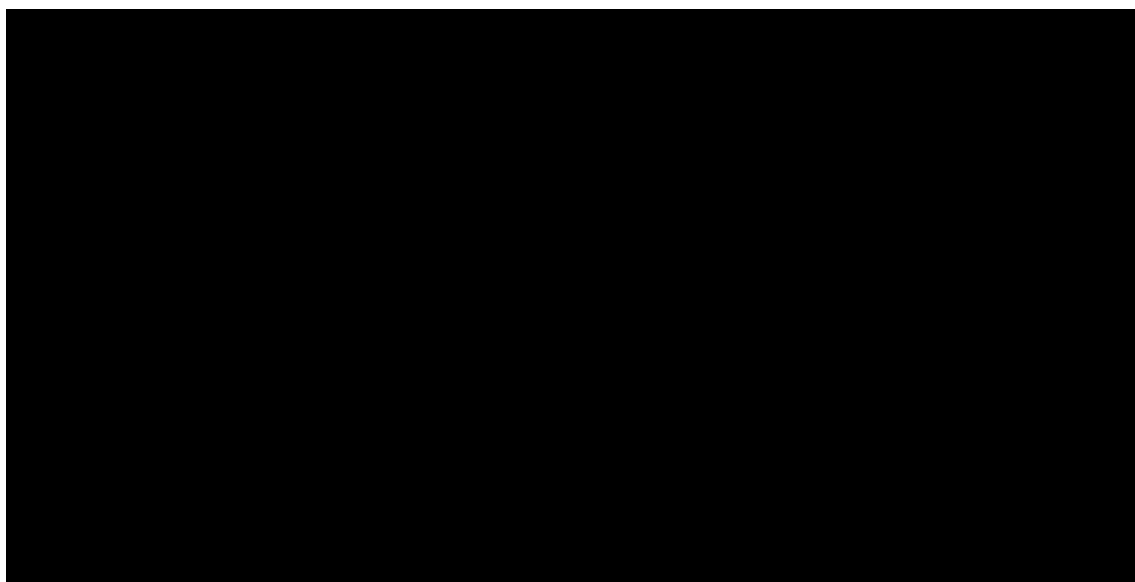
),

2.2

(ns), 100

ADC

VersaModule Eurocard(VME)



4 ()

Figure 4 (Color online) Offline parameters optimization interface

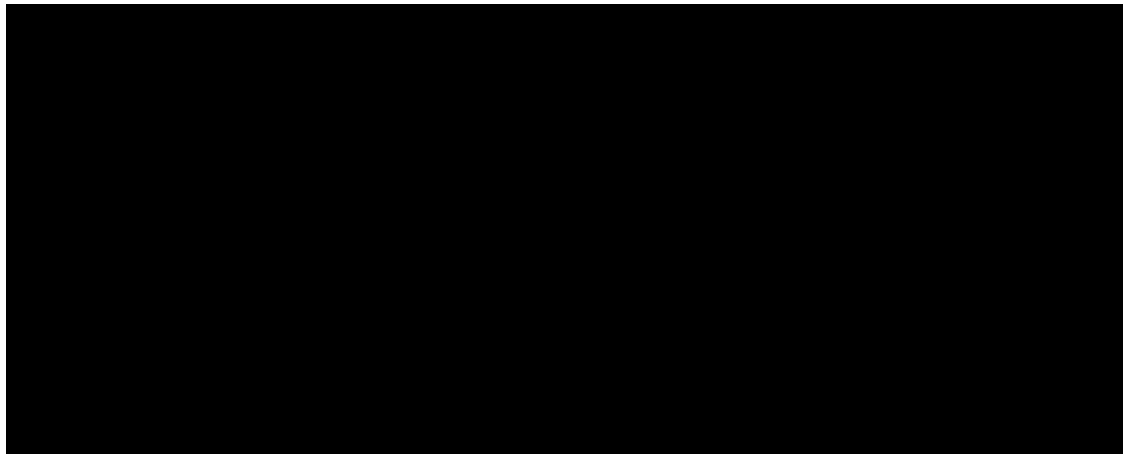


Figure 7 (Color online) Decomposition method of the pile-up pulse^[13]. (a) A pile-up trace originating from a heavy ion isomer and its subsequent internal conversion electron decay; (b) the corresponding triangular filters with parameters $k=1$ and $k=10$. (c) Energy spectra obtained from the fitting

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[14]

[15,16]

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Summary for

A general-purpose data acquisition system and a waveform analysis algorithm based on digitization

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Given that the nuclei studied in the nuclear physics experiments are expanding away from the stable nuclear region, traditional analog electronics acquisition systems cannot satisfy the requirements of experiments that involve short-lived, low-yield nucleus productions under high background. In recent years, digital data acquisition systems have shown significant advantages over the analog electronics system and have been widely used in nuclear physics research such as studies of short-lived charged particle emitters which involve overlapping ion-particle or particle-particle signals, and studies of sub-microsecond isomers observed in fragmentation reactions. A general-purpose digital data acquisition system and a dedicated waveform analysis algorithm recently developed by the Group of Experimental Nuclear Physics, Peking University are introduced in this paper.

This digital data acquisition system which is composed of 16-channel digital pulse processor Pixie-16 modules from XIA LLC is a versatile, flexible, and expandable data acquisition system designed for nuclear physics research. Although the triggerless mode, which records all live events without event selection, provides an attractive option for users because it has great flexibility for offline data analysis, it generates significant data streams in the experiments with high counting rates, which may then exceed the digital data acquisition system's I/O capability. Therefore, a flexible trigger system based on the field programmable gate array has been developed to accommodate different experimental needs. The trigger system is configured through the hardware description language (VDHL/verilog), which can set up and debug different experiment logics conveniently. Many offline analysis tools have been developed to help users quickly optimize parameters for various types of detectors without time-consuming tests and measurements.

A comparison between this digital data acquisition system and the conventional analog data acquisition system has been made. At a low count rate, both systems exhibit good and comparable energy resolution. At a high count rate above 8.8 k/s, while the energy resolution obtained by the analog system deteriorates significantly, the energy resolution obtained by the digital data acquisition system remains nearly unchanged. Moreover, experimental data with higher statistics can be collected by the digital data acquisition system. The advantage of this digital data acquisition system over the conventional analog system is ascribed to its excellent capability of handling pile-up pulses at higher count rates, and nearly zero dead time in data transmission and conversion.

An effective digital pulse processing method has been developed for the decomposition of pile-up pulses which result from the signals of μs decay. This method is able to decompose the multiple pile-up pulses with very close separation in time scale and large range of relative amplitude. The method was validated with the very short-lived emitter ^{219}Th ($T_{1/2}=1.08\text{ }\mu\text{s}$) and the internal conversion electron decays of $^{210,211}\text{Ra}$ isomers ($T_{1/2}=2.27, 4.0\text{ }\mu\text{s}$) produced by $^{40}\text{Ar}+^{186}\text{W}$. The results show that this method can resolve pile-up pulses with time separation as short as 80 ns. The energy resolution for signals with time separation down to 80 ns is 32 keV. The internal conversion electron decay with energy as low as 70 keV can be well identified.

This digital data acquisition system has been successfully used in many experiments performed at China Institute of Atomic Energy, Institute of Modern Physics, Chinese Academy of Sciences, Dongguan Campus, Institute of High Energy Physics, Chinese Academy of Sciences, and South Africa iThemba LABS, and has demonstrated its versatility and high efficiency.

digital data acquisition system, trigger, parameters optimization, waveform analysis

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