DEVELOPMENT OF THE AUTOCALIBRATION SYSTEM FOR THE DGFRS SPECTROMETER BASED ON THE DOUBLE-SIDED SILICON STRIP DETECTORS

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The detection system of the Dubna gas-filled recoil separator (DGFRS) aimed at the studying of the SHE nuclei and their decay properties has been modernized during last few years. The new set of multi-strips double-sided silicon detectors (DSSD) in focal plane of DGFRS is applied now instead of the old array of 12-strips position-sensitive Si detectors. The total amount of measuring spectroscopic channels of the registering system has increased also up to 224 channels. It leads to more precise measuring of the energy and coordinate of the implanted nuclei of the SHE into the focal detectors and of their decay products. It is important to test multi-channel registering system and perform energy calibration before carrying out of such unique experiments on the synthesis of new nuclei from the "Island of stability". This work is devoted to describe the designed method and produced specific digital module which allows performing an energy calibration for the all 224 individual spectroscopic channels independently. This device provides automatic bypassing of the all individual channels one after another imitating charge particles incoming to the each strip of detector array. Energy of the imitating signal can be chosen from the range of 1 MeV up to 150 MeV with high amplitude linearity and temperature stability.

Keywords: DGFRS, DSSD, registering system, energy calibration, nuclear electronics, multiplexer, encoder, operational amplifier

1. Introduction

More than 50 new isotopes of the nuclei with Z = 104-118 from the predicted "Island of stability" of superheavy elements (SHE) were synthesized for the first time at the Flerov Laboratory of Nuclear Reactions (JINR, Dubna) using Dubna Gas-Filled Recoil Separator (DGFRS) and heavy ions cyclotron U-400 during last 15 years [1]. Due to this research the Periodic Table of Elements was recently filled with six new elements Z=113 (Nh), 114 (Fl), 115 (Mc), 116 (Lv), 117 (Ts) and 118 (Og).

During these pioneering experiments in FLNR the appropriate detector module had being used at the DGFRS focal plane which consisted of the array of twelve position-sensitive Si detectors surrounded by six side Si detectors (Canberra NV) and of the time-of-flight module (two multi-wire proportional chambers fulfilled with pentane gas at low pressure about 1 Torr). More detailed descriptions can be found in our previous papers and references therein [2-4].

Recently, the focal-plane detector array has been modified to increase the position resolution of recorded signals and subsequently reduce the probability of observing sequences of random events that mimic decay chains of implanted nuclei. The new detector assemblage consists of 300 μm thickness double-sided Si strip detector (DSSD) with 48 mm by 128 mm active area in focal plane and surrounded by 500 μm six single-sided Si detectors 65 mm by 120 mm each (Micron Semiconductor Ltd.). Focal-plane DSSD has 1-mm wide strips, 48 at the front side and 128 at the back side, creating over 6000 individual 1×1 mm^2 pixels in one Si wafer. Such high pixelization helps to achieve superior position resolution for recoil-correlated decay sequences reducing potential random events. This new Si-detector array was designed, assembled, commissioned off-line and provided by ORNL. The signals from all detectors were processed using MESYTEC linear preamplifiers [5]. Further, these analog signals were split into two independent measurement branches by special spectroscopic splitter-amplifier PA32-64 [6] designed by the DGFRS group. Thus, all detectors' signals were processed simultaneously by "analog" electronics (TekhInvest Ltd., Dubna) similar to those used in previous DGFRS experiments [1], and by digital electronics system based on XIA Pixie-16 modules [7].

This new DSSD assembly and two new independent registering systems were successfully applied recently in ^{239}Pu, ^{240}Pu + ^{48}Ca experiments [8] and $^{249-251}$Cf + ^{48}Ca experiment [9] aimed at the synthesis and the study of the properties of the new $^{283-285}$Fl and ^{295,296}Og isotopes. The FWHM energy resolution of the implantation detector was 34 to 78 keV depending on the strip, while the summed signals recorded by the side and implantation detectors had an energy resolution of 147 to 263 keV. For getting better energy resolution for side detectors we plan to order new design with eight strips for every side detector, thus it will cause increasing of the total number of the spectroscopic channels by 48 ones in comparison with used present detectors design [8].

The detectors and registering systems should be calibrated prior to start every experiment, moreover before every finish of the experiment and sometimes during the experiments also. For this purpose we perform two reactions, ^{nat}Yb(^{48}Ca, *3*–*5*n)$^{215-220}$Th to calibrate α-range scale and ^{208}Pb(^{48}Ca,*2*n)^{252}No – to SF range scale, as it was described in [4]. There are no problem to calibrate individual PIXIE-16 channel in digital measuring system (based on the DSP and FPGA, see [7]); every PIXIE-16 channel is working independently. In "analog" system (CAMAC based, TekhInvest Ltd.) every measuring ADC works in combination with 16-input analog multiplexer for each of 16 strips; only first signal in time from every 16 strips will be processed by corresponding ADC.

Besides of nuclear reactions, for the linearity test of the scales we can calibrate our systems by means of spectroscopic pulser module (for example, ORTEC 419) with precise stable preset amplitudes [10] imitating income of α-particles and SF events to surface of the Si detectors.

2. 16-channel charge-sensitive preamplifier

Choosing of MPR-64 from Mesytec [5] as multi-channel charge-sensitive preamplifier with high resolution, linearity in the energy range of signals up to 300 MeV and with long-term stability are satisfying our needs during the experiments at the DGFRS. There is just one disadvantage of using these devices together with "analog" measuring branch. Preamplifier MPR-64 has 64 individual channels performed as four separate PCBs containing 16 channels each. There is also separate Pulser Input for each PCBs, thus signals from outer pulser can go just simultaneously to all 16 channels of one PCB. So, due to this feature of MPR-64 there is no possibility to perform the energy calibration for the individual channel in "analog" registering system based on ADP-16 (TekhInvest Ltd.) which has on-board SAR ADC working in combination with 16-input multiplexer with priority encoder. To bypass this inconvenience in calibration of the individual channel in the "analog" branch we designed new multi-channel charge-sensitive PA-16 preamplifier (Figure 1), which was recently tested and presented during the symposium NEC'2015 [6].

The main characteristics are presented below and in Table 1:

✓ Input/Output polarity - Inverted

✓ Energy sensitivity (Si) - 8 mV/MeV

✓ Noise output performance - See Table 1

✓ Negative feedback constant - 10MΩ/5.6 pF

✓ Power supply +6V 200 mA
-6V 110 mA

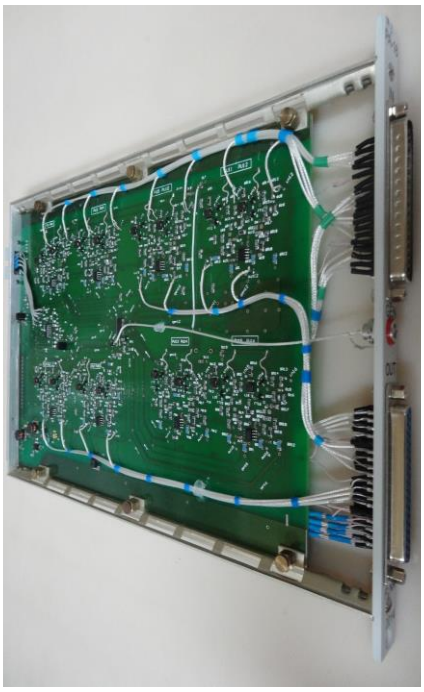

Figure 1. The front panel and PCB view of 16-channel charge-sensitive PA-16 preamplifier [6]

For calibration of the individual channels with external pulse generator, the CMOS low-voltage 16-channel ADG706 multiplexer [11] was applied operating in de-multiplexing mode. It switches the input pulse from the precision spectroscopic pulser to one of the 16 outputs with a number chosen by address code preset by special control BOKAL module.

To process signals from the whole detector module (48 'front' strips and 128 'back' strips of DSSD; and 48 'side' strips) we need 14 preamplifier PA-16 modules. They are realized as 1M CAMAC modules, and have LEMO input for pulser and two DB-37 connectors for 16 input signals from detectors and 16 – output, correspondently. At the back of the PCB of every PA-16 module there are 4 pins going to CAMAC bus for controlling the number of certain spectroscopic channel in the preamplifier by BOKAL module providing binary code "1 of 16" through CAMAC bus to the each preamplifier in the crate. The characteristics of the spectroscopic pulses from PA-16 are presented in Figure 2.

Table 1. Noise performance measured for PA-16 using the ORTEC 575A spectroscopy amplifier set at 1.5 μs, near-Gaussian shaping

C_{source}, pF	Noise, keV, FWHM, Si	Rise time, nanoseconds
0	5	26
70	10,5	30
132	14	40
175	16	60
225	17,5	90

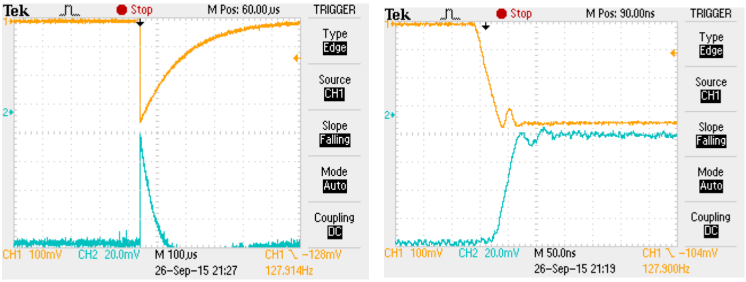

Figure 2. The shapes of the input signal from precise СГ-219 [12] pulser (in orange) and output signal after PA-16 (in bleu) are shown

3. Controller for spreading out and counting of the pulses

New mixed analog-digital Block for Organization of CALibration (BOKAL) was design to perform testing and energy calibration "off-line" of the individual measuring channels of the DGFRS registering system. Impulses of certain amplitudes (corresponding to the energies of 6, 12, 70 and 140 MeV) from precise spectroscopic СГ-219 generator [12] calibrated by α–source comes to the input "Гек" of the module and then are shared into three groups of outputs (128 ПУ (yellow LEMO) connectors for rear DSSD strips, 48 ПУ ФОК (red) for front strips and 48 ПУ БОК (blue) for side strips). Every connector goes to Pulser input of the preamplifier PA-16 serving corresponding front, rear and side strips of the detector array. BOKAL module allows calibrate measuring channels both automatically with pre-defined energy amplitude of the pulser or in manual mode. In auto-mode pulses start from pressing button "ПУСК" and will stop after BOKAL will count 1024 (or 2048/4096 – optionally) events for every channel. The calibration procedure can be stopped also manually by "СТОП" button. In manual mode user should choose needed block of preamplifiers by button "+1 № блока" and needed channel by button "+1 № ПУ". The start will be after push the button "ПУСК ГЕК" and will finish after push "СТОП". The counting and numbers of the chosen block and preamplifier channel can be reset by button "СБРОС". The blue LED lamps indicate current block in binary code, and green lamps indicate current channel. After reset the counting will begin from the first module and the first channel (with the lamps off). The output signals from BOKAL are shown in Figure 4.

Figure 3. Front view of the module BOKAL (Block for the Organizing of the CALibration)

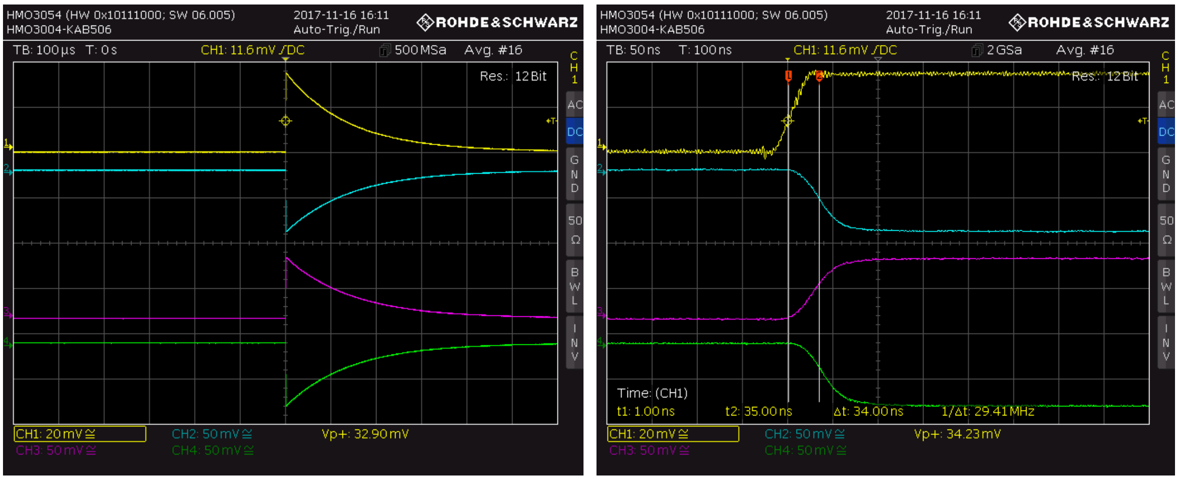

Figure 4. The input СГ-219 [12] pulser signal and output signals going to corresponding PA-16 (front, rear and side) are shown in yellow (1), in blue (2), magenta (3) and green (4)

The propagation delay of the input signal for BOKAL is 34 ns. The module can process the spectroscopic signals with rise time starting from 10 ns. The upper speed limit for coming pulses is 100 kHz. The transmission coefficient equals to 1. The output polarity of the signals (for front, rear and side preamplifiers) can be set by user on-board. The requested power is +6V/-6V and 180mA/100mA. The device can be performed both as CAMAC-standard module or NIM-standard.

4. Conclusion

The unique system for the calibration of the registering system based on the multi-strip double-sided silicon detectors has been designed and realized by our research team. It allows imitate incoming of the charge particle to the surface of the DSSD. User can choose appropriate energy from 1 MeV up to 150 MeV with pulser preset. To achieve such functionality we designed 16-channel spectroscopic charge-sensitive preamplifier and specific logical module (BOKAL) which provides automatic energy calibration of every channel of the multi-channel measuring system using globally controlled sequential distribution of spectroscopic pulses. This allows perform calibration both in manual "channel by channel" mode or in auto mode. The auto mode is important time saver before every experiment in comparison with using manual calibration by connecting the pulser to each channel by cable manually. Presented part of the spectrometer also minimizes the human errors during the calibration process.

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