ELECTRONICS OF THE FISSION FRAGMENTS SPECTROMETER COMETA-F

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The article describes the electronics for the two-arm time-of-flight fission fragment spectrometer COMETA-F. The time pick-off detector is comprised of a thin electron conversion foil, an electrostatic mirror, and two microchannel plates supplied by Baspik and mounted in a chevron configuration. The mosaics of Si PiN diodes is used to measure both energy and time-of-flight. The waveform of detected signals is digitized by V1742 modules, which sample signals through a DRS4[1] chip. The DRS4 chip is a switched capacitor array, which can sample the input signal at a frequency of 5 GHs. The start for registration is provided by a specially designed trigger module. The V945 discriminator thresholds are individually settable in a range from -1 mV to -255 mV via VME through an 8-bit DAC.

Keywords: fission fragment spectrometer, SCA ADC, distributed storage

1. Detectors

The study of nuclear fission, both spontaneous and induced, is still of great scientific and practical interest. The complexity of mathematical calculations of fission processes requires accurate experimental data to confirm the validity of the models used. In the applied field for fast neutron reactors, it is important how the additional energy from neutrons is shared between fissile fragments. Even for such elements as ^{235}U, ^{238}U, and ^{229}Pu, which are important for reactor fuel cells, the transfer of excitation energy by multiple neutrons affects the fission process differently [2]. Of interest is the study of neutron multiplicity depending on the masses of fragments, the total kinetic energy, and the energy of the irradiating neutrons, which makes it possible to determine the total excitation energy of a compound nucleus. Accurate data on fission of actinides depending on the energy of irradiating neutrons is required. All this leads to the creation/emergence of new spectrometers for detecting fission fragments. Of great interest is the study of rare decays of low-excited heavy nuclei in ^{252}Cf (sf) and ^{235}U(n_{th}, f). We called this decay mode a "collinear cluster tri-partition" (CCT) in view of the observed features of the effect, that is when the decay partners fly apart almost collinearly and at least one of them has a magic nucleon composition [3,4].

The Cometa-F spectrometer includes a start-up detector based on microchannel plates (MCP) with electrostatic mirrors and a matrix of semiconductor silicon detectors with 8 PIN diodes each. The length of each arm of the spectrometer is 15–25 cm. The spectrometer is placed in a vacuum chamber. The air inside the chamber is pumped out to a pressure of 10-5 torr by the Pfeiffer HiCube-80 vacuum station. The principle of operation of the starting detector is based on the use of the secondary emission of electrons knocked out by an ionizing particle. The detector consists of a conversion foil, an accelerating grid, an electrostatic mirror, and a MCP chevron assembly. A detected particle (from protons to heavy ions), when passing through the input foil of the start detector, knocks electrons that are accelerated in the electric field between the foil and the accelerating grid to an energy of about 3

keV. Then the electrons unfold in the space between two electrostatic mirrors at 90 degrees and after that they fall on the chevron assembly of the MCP. The start detector was designed so that its output time signal did not depend on the place of the particle entering the input foil. The foil is a 20-μg/cm2-thick mylar film with a sprayed layer of gold. The nets are wound from Cu-Be wire 20 μm in diameter in increments of 1 mm (transparency 98%).The potentials of each element of the detector are set using a resistive divider located in the vacuum chamber near the MCP. The time resolution of the detector is 100ps ÷ 130ps.

Each PIN diode having a size of 20x20 mm with a thin "dead layer" (less than 100 nm is the thickness of the implanted p + layer and aluminum coating) is used both to record the energy of the incident particle and to obtain a time stamp. Signals from PIN detectors are amplified by fast preamps. The mass of each recorded fragment is restored from the measured values of its flight time and energy (TOF-E method). Prior to registration fission fragments pass through the source substrate and the start detector foil where they lose part of their initial energy; therefore, the measured fragment velocities must be adjusted for energy loss. Energy losses depend on the charge and mass of the particle, its energy as well as on the substance of the absorber.

2. Preamplifier

To amplify and shape a signal from a PIN detector, two-stage transistor preamplifiers are used. Since the amplitude of the input signal of the V1742 digitizer should not exceed 1 V and because in experiments using the same detector it is necessary to register both heavy fragments and light particles (the energy range differs by 20 times), the gain is limited to the value of 50. The 300-MHz bandwidth is provided by BFR193 transistors. The consumption current is less than 10 mA, which makes it possible to place the amplifiers in the close proximity to the detector directly in the vacuum chamber.
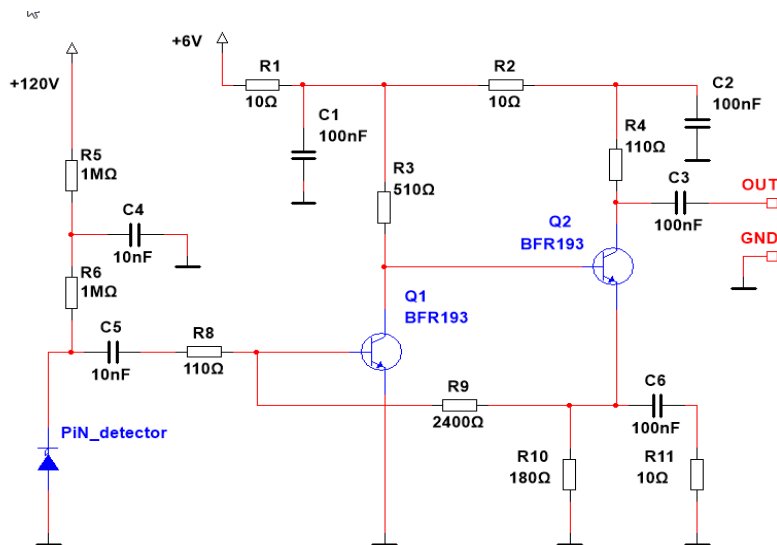

Figure 1. Preamplifier for PIN detector.

3. Data Acquisition System of the COMETA-F spectrometer

Figure 2 shows an electronic block diagram of the COMETA-F setup. Multichannel modules from CAEN in the VME standard are used in the spectrometer. After being formed by the preamplifiers through the passive matching splitters 1–2, the signals from the PIN diodes are fed to the V895 discriminators [4]. The V895 module has 16 inputs and generates NIM logic pulses when the input signal exceeds a threshold that can be set in the range from -1 mV to - 255 mV. The duration of the output pulse of the V895 block is essentially adjustable in the range from 5 to 40 ns, which is not enough for our experiments, so the range was increased to 200 ns. The discriminator thresholds are

individually configured using the USB / VME VX1718 [5] controller. A signal for starting the data acquisition system is generated following a signal from the start detector and at least one signal from PIN diodes.
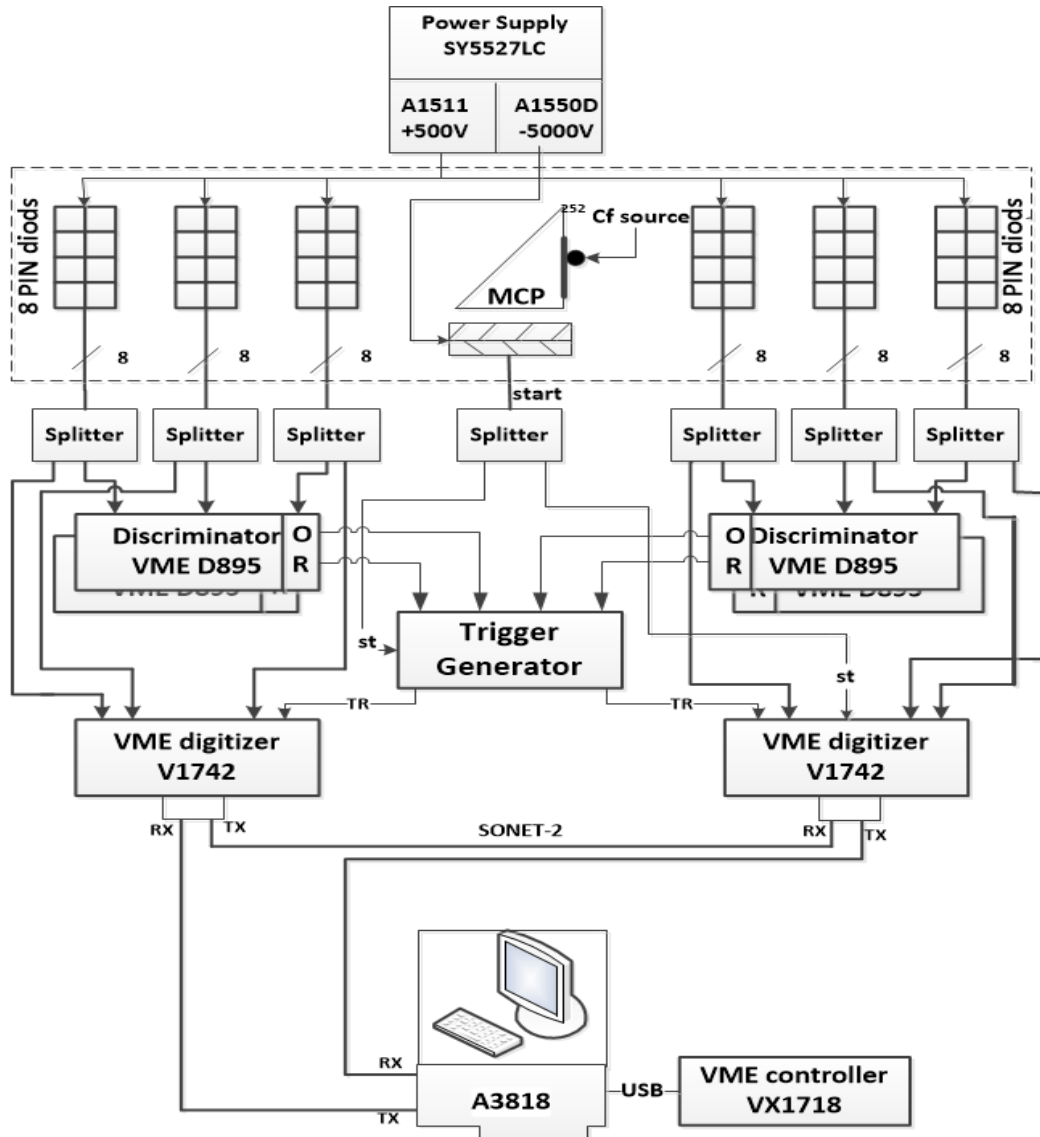

Figure 2. Data Acquisition System of the Cometa-F spectrometer.

The TRIGGER GENERATOR unit is used to generate the signal to start the process of recording events from two digital recorders V1742. The logic for generating the trigger is shown in Fig. 3. In the presence of at least one signal from the detector (the OR function is implemented for input signals installed in one of the arms of the spectrometer), a pulse is formed whose duration exceeds the time of flight of the slowest particle from the target to the PIN detector. This time depends on the span base of the spectrometer and does not exceed 100 ns at a base of 150 mm. This signal is applied to the trigger D-input. A delayed signal from the output of the START1 start detector is applied to the clock input of the same trigger. If the trigger has a resolving potential at the D-input of the trigger, which means that at least one particle has hit the detector, then a TR0 registration start signal is generated along the leading edge of the delayed "Delayed St" signal.
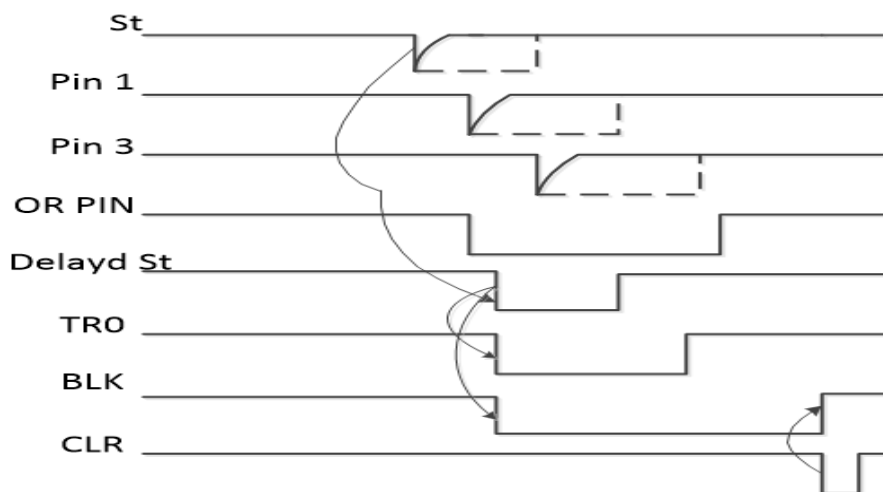
Figure 3. Time diagram of control signals of DAQ.

To synchronize the operation of the digitizer with other recording subsystems of the spectrometer, a VETO inhibit signal, a BLK block, and a CLR reset are used. The BLK lock trigger is set simultaneously with the TR0 signal, and is reset by the external input signal CLR. The external VETO signal blocks the passage of signals, inhibiting the formation of the TR0 registration trigger.

The mass determination procedure for fission fragments from the measured energy and time of flight taking into account PHD and PD in PIN detectors is used in our group, which is described in detail in [6] and is carried out off-line using specially developed algorithms.

Using two 32-channel V1742 recorders, signals are digitized and transmitted via a fiber-optic cable in accordance with the SONET-2 network standards.

The advent of multi-channel digitizers with speeds up to 5 G samples per second opens up new possibilities, making it possible to register the shape of signals lying in the nanosecond region.

The advantages of recording the shape of the signal under investigation are as follows:

- ability to isolate the situation with the imposition of pulses and to distinguish the interference and noise from signals, which is relevant when searching for rare events;

- further analysis of digitized and stored data is possible using various digital algorithms;

- reduction in the number of connecting cables, connectors, etc. in a multi-detector installation, which leads to an increase in reliability, ease of maintenance, and overall lower cost per channel;

- arm length of the time-of-flight system is limited by the working range of the digitizer. The arm lengths used in our vacuum chamber of tens of mm (the flight time of the recorded fragment lies in the nanosecond region) are in good agreement with the digitizer range of 200 ns;

- hardly any effect of low-frequency pickups on the determination of the amplitude (energy) of a short nanosecond detector signal;

- a possibility of obtaining a temporal and energy resolution, which is not worse than those obtained by the methods of classical analog electronics, using algorithms applied to the digitized signal.

A typical sequence of operations for processing digitized signals includes filtering, zero line determination, amplitude determination or calculation of the area of the signal to estimate the energy,

and timing determination. The experience of using DT5742 digitizers from CAEN (Italy) has shown that accuracy in the choice of filters is required. A simple median filter reduces the amplitude and worsens the timing. Particular attention is required when working with several digitizers.

When switching to work with high-speed digitizers, you must be prepared for a significant increase in the volume of accumulated data. Our group uses a terabyte storage Synology of the DS2415+ type with 12 removable drives organized as RAID-5. The network infrastructure of the Laboratory of Nuclear Reactions is used for communication.

The software for setting discriminator thresholds, V1742 recorder parameters and spectrometer data acquisition is implemented in a LabView environment using CAEN libraries.

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