Spectrometer of Charged Particles on the EG-5 FLNP, JINR

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1. Introduction

The modernization of the equipment on the channel №5 EG-5 FLNP, JINR for the study of reactions induced by fast neutrons (neutron, charged particle) was carried out. To obtain fast neutrons based on the reactions Li (p, n) and D (d, n) new two targets were created; gas-state and solid-state. A new detector that includes 5 helium counter tubes for neutron beam monitoring was developed. A special ionization chamber with five pairs of exchangeable samples is being used as a detector [1,2].Two new data acquisition systems were elaborated. The first one is based on CAMAC standard using the Kmax controller (Sparrow Corp., USA).The second one is based on PXI standard and uses the high-speed digitizers PIXIE-4 (XIA, USA). The paper presents detailed characteristic of the setup.

2. Experimental Setup. Detector

In the study of nuclear reactions (n, p), (n,α) there are widely used ionization chambers of various designs as a detector since they have quite a good energy resolution. They allow one to register charged particles in almost 4π-geometry, which is very important when one works with small amounts of the investigated substance (eg, radioactive targets, separated isotopes) and relatively small reaction cross sections).

A two-piece high pressure ionization chamber consists of two identical sections with a common cathode. It has a volume of 17 liters and can be operated at pressures up to 10 atmospheres. Fig.1. shows a schematic view of the internal Li Xuesong structure of the chamber. The chamber is placed in a stainless steel cylinder with a diameter of 28.2 cm and a height of 27.2 cm. The thickness of its side wall is 1.8 mm. Two anodes measuring 16x16 cm are made from 0.1 mm aluminum foil and are fixed in the aluminum frame. The Frish grids consist of gold-plated tungsten wires 0.1 mm in diameter 2 mm apart. The wires are soldered on a rectangle of foil glass textolite. The distance between the grids and the electrodes can be varied in a quite wide range allowed by the construction of the chamber. The cathode shared by both sections is a rotating disk placed between two aluminum plates. The plates have openings in the center 48 mm in diameter, which corresponds to the size of the sample. The rotating disc has five positions to fix samples. Thus, in the chamber 10 samples can be simultaneously placed in the geometry "back-to-back", 5 per section, only two of which can be in the beam thanks to the electrode design [2].

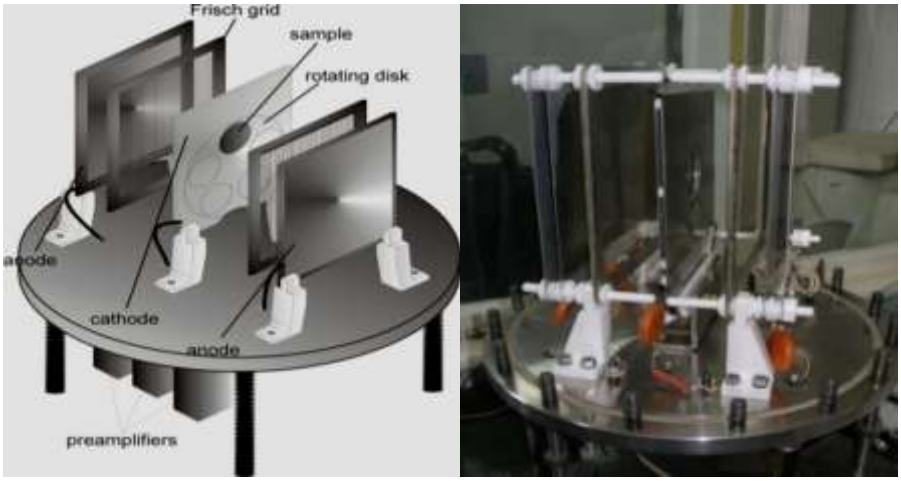

Fig.1. Schematic view (left picture) and photo (right picture) of the ionization chamber.

3. Neutron source

To obtain fast neutrons based on the reactions ^{7}Li(p,n) two new deuterium targets were created: gas-state and solid-state ones.

1) Solid-target

a) Lithium target.

The reaction ^{7}Li(p,n)7Be is widely used for obtaining monoenergetic neutrons in the nuclear physics experiments and it is quite well studied. Lithium has been deposited on copper substrate by ion coating. The target dimension is 20 and 2 mm in diameter and thickness, respectively. Also we develop cooling system for the lithium target.

b) Deuterium target.

Neutron induced nuclear reactions experiments were initiated with the solid targets made from titanium loaded with deuterium gas on receipt of reports of the experiments. When titanium is heated in a deuterium atmosphere, the reaction will continue until the concentration of deuterium in the metal attains an equilibrium value. This equilibrium value depends on the specimen temperature and the pressure of the surrounding deuterium atmosphere. Any imposed temperature or pressure change causes rejection or absorption of deuterium until a new equilibrium state is achieved. If the surface of titanium is clean, the rate of absorption increases rapidly with temperature. At temperatures above 500°C, the equilibrium is achieved. However deuterium absorption is considerably reduced if the surface of Ti is contaminated with oxygen. Keeping in view these facts, a procedure was evolved for titanium target preparation and subsequent deuteration. Copper has been used as substrate, because of its high thermal conductivity. Its dimension is 20 and 2 mm in diameter and thickness, respectively. Its diameter is the same as of target holder diameter in our neutron generators. Titanium (m=1mg/cm^2) has been deposited on copper substrate by ion coating (Fig.2.).

The targets were first degassed by heating to ~900°C in a vacuum chamber using a 3 kW induction heater. Degassing was continued 2 hours. It is essential keep the target substrate

in deuterium gas around 500 degrees C for a while in order to adsorb deuterium to the titanium layer deposited on the target substrate. We developed a deuterium adsorption chamber, which can keep a vacuum and have a heater for temperature control of the target substrate.

Figure 2 shows the scheme of the deuterium adsorption system. The deuterium adsorption system consists of a deuterium adsorption chamber, deuterium storage line, vacuum line and pressure, temperature monitors. The target adsorption chamber volume is small and the heating power is 3kW. It can handle two small targets at a time.

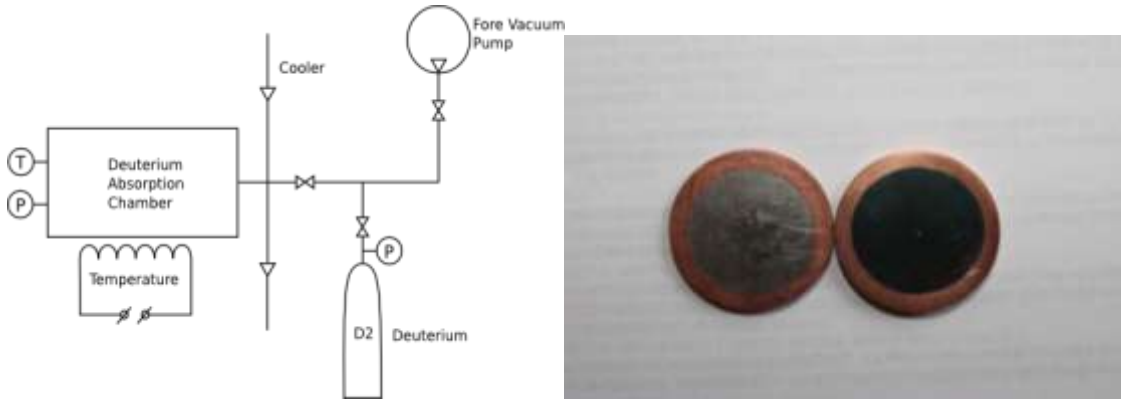

Fig.2. The scheme of the deuterium adsorption system (left picture) and the solid target (right picture).

2) Gas target

The target is a stainless steel cylinder 2 cm long and 1 cm in diameter. From vacuum ion guide, the target is separated molybdenum foil 6 μm. Deuterium pressure in the cylinder is supported by ~ 2-3 atm. The current at the target varies within 2-3 μA intensity received ~ 10^8 neutrons/s. The gas target and the gas-filling system are shown in Fig. 3.

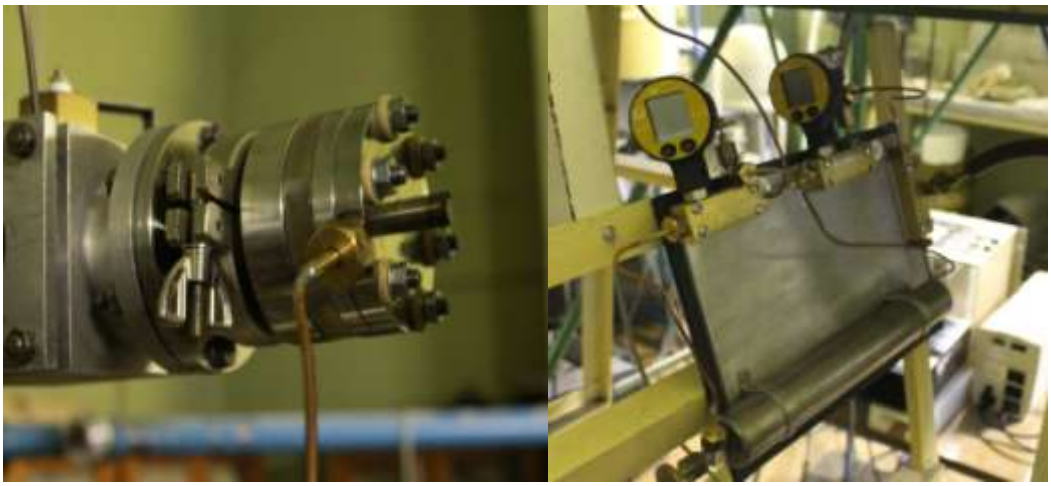

Fig.3. The gas target (left picture) and the gas-filling system (right picture).

4. Data Acquisition System

Two new data acquisition systems based on CAMAC and PXI standard were elaborated for the study of the reactions (n, p) and (n, α) with fast neutrons.

1) CAMAC standard

Figure 4 shows a schematic view and photo of CAMAC DAQ system. The main parts of CAMAC system are controller (SCM-301, Sparrow corp. USA), list processor (Hytec LP-1342, Great Britain) and four channel ADC (AD413A, Ortec, USA). During measurements signals from both anodes and the cathode are amplify, digitized and recorded by the CAMAC system. In online regime, one and two dimensional amplitude spectra are obtained and displayed.

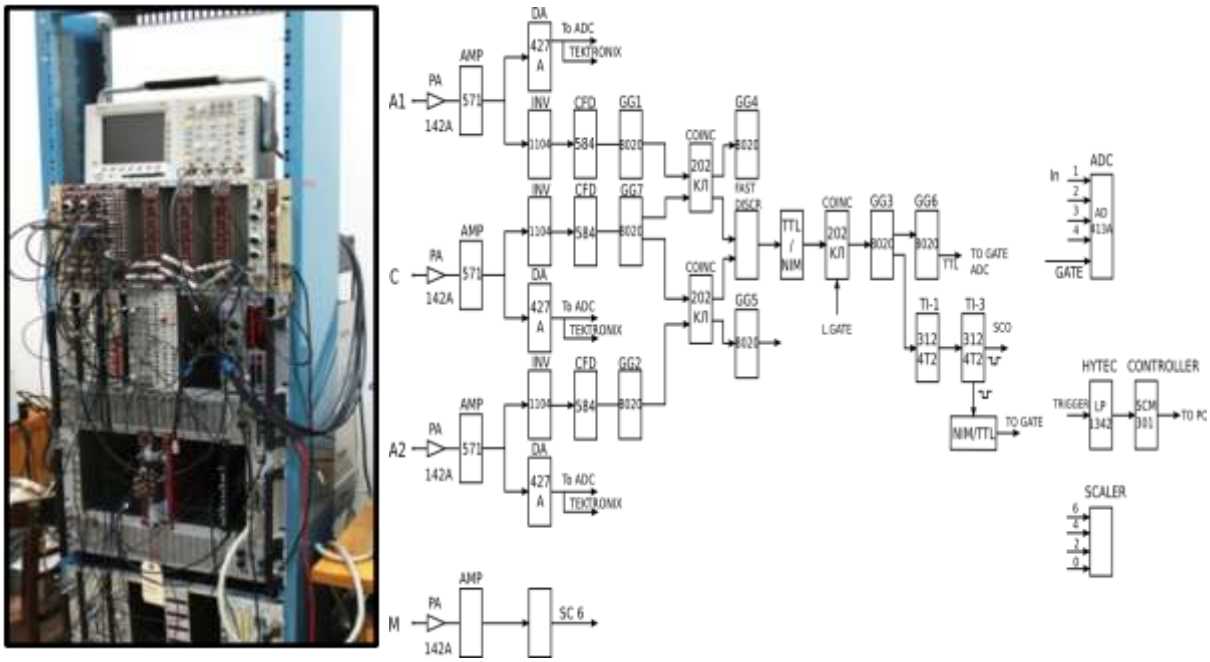

Fig.4. Schematic view of the CAMAC DAQ system.

2) ***PXI standard***

The PXI system consists of chassis (NI PXI-1031 from NI, USA), embedded controller (NI PXI-8820 from NI, USA) and one high-speed digitizer (Pixie-4 from XIA, USA). The Pixie-4 is a 4-channel all-digital waveform acquisition and spectrometer card based on the Compact PCI/PXI standard for fast data readout to the host. It combines spectroscopy with waveform capture and on-line pulse shape analysis. Incoming signals are digitized by 14-bit 75 MSPS ADCs. Waveforms of up to 13.6 μs in length for each event can be stored in a memory. Waveforms, timestamps, and the results of the pulse shape analysis can be read out by the host system for further off-line processing. Pulse heights are calculated to 16-bit precision and can be binned into spectra with up to 32K channels. The PIXIE-4 supports coincidence spectroscopy and can recognize complex hit patterns. Figure 5 shows schematic view of the PXI DAQ system.

Features:

- Simultaneous amplitude measurement and pulse shape analysis for each channel.
- Input signal decay time: as fast as 150ns and up to 10ms, exponentially decaying.
- Wide range of filter rise times: from 53ns to 109μs, equivalent to 27ns to 50μs shaping times.
- Programmable gain and input offset.
- Excellent pileup inspection: double pulse resolution of 50 ns. Programmable pileup inspection criteria include trigger filter parameters, threshold, and rejection criteria.
- Triggered synchronous waveform acquisition across channels, modules and crates.
- Dead times as low as 1 ms per event are achievable. Events at even shorter time intervals can be extracted via off-line ADC waveform analysis.
- Digital constant fraction algorithm measures event arrival times down to a few ns accuracy.
- Supports 32-bit 33 MHz PCI data transfers (>100 Mbytes/second).

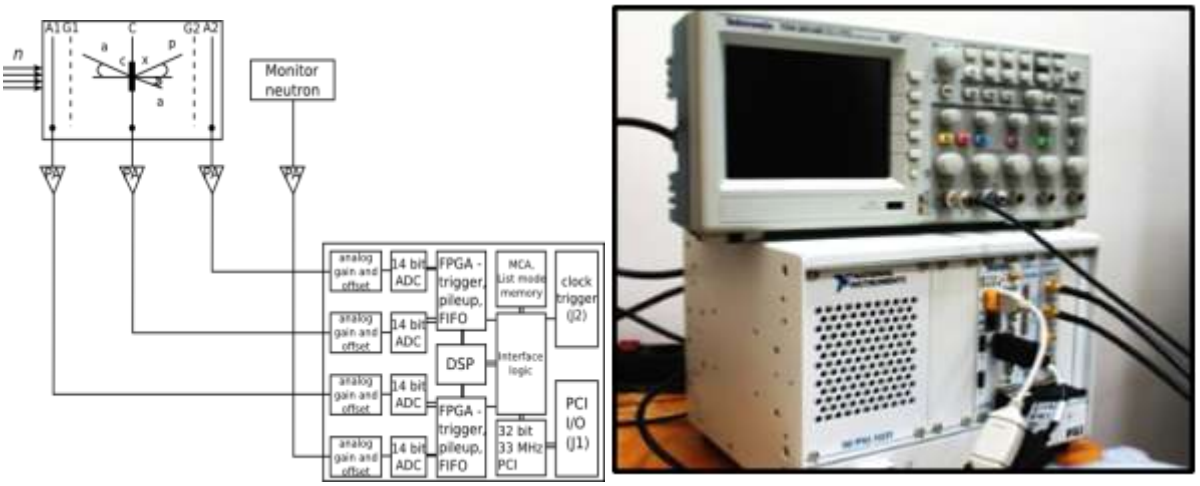

Fig.5. Schematic view of the PXI DAQ system.

5. Results

The results of testing experiments are shown on Figures 6, 7, 8 and 9. On Fig. 6two-dimensional energy spectra of the anode and cathode obtained with the two different DAQ systems (CAMAC and PXI) are shown. Working gas is Kr + 4%CO2, at a pressure of p = 2.5 bar. On Fig. 7 the projection on anode axis is shown. The energy 4.22 MeV corresponds to α-particles from a ^{238}U source and the energy4.77 MeV corresponds to α – particles from a ^{234}U source. On Fig. 8 and Fig. 9 the two-dimensional spectra (cathode-anode and time-anode respectively) obtained from reaction ^{6}Li(n,α)^{3}H at E_n=4MeV are presented as an example. In this case the PXI system was used.

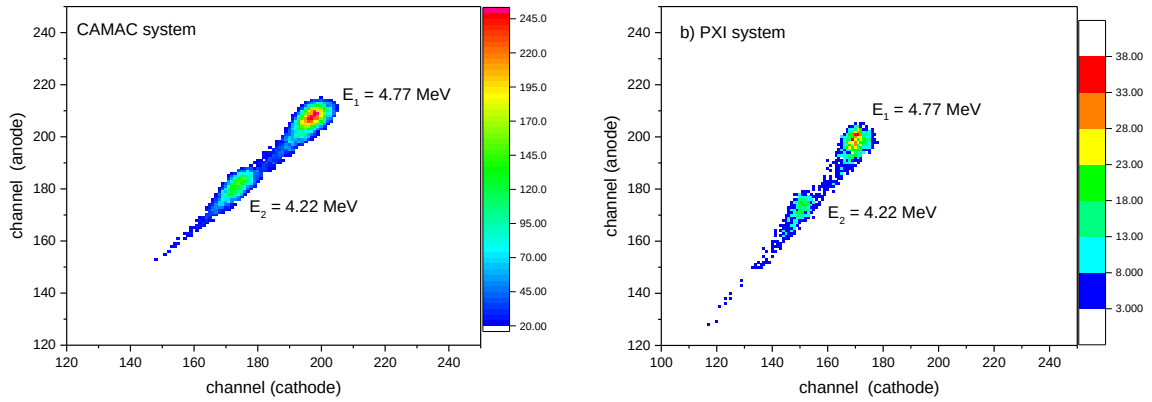

Fig.6. Two-dimensional amplitude spectra (anode – cathode) obtained with two different DAQ systems by using the ^{nat}U source. Left picture CAMAC system, right picture PXI system.

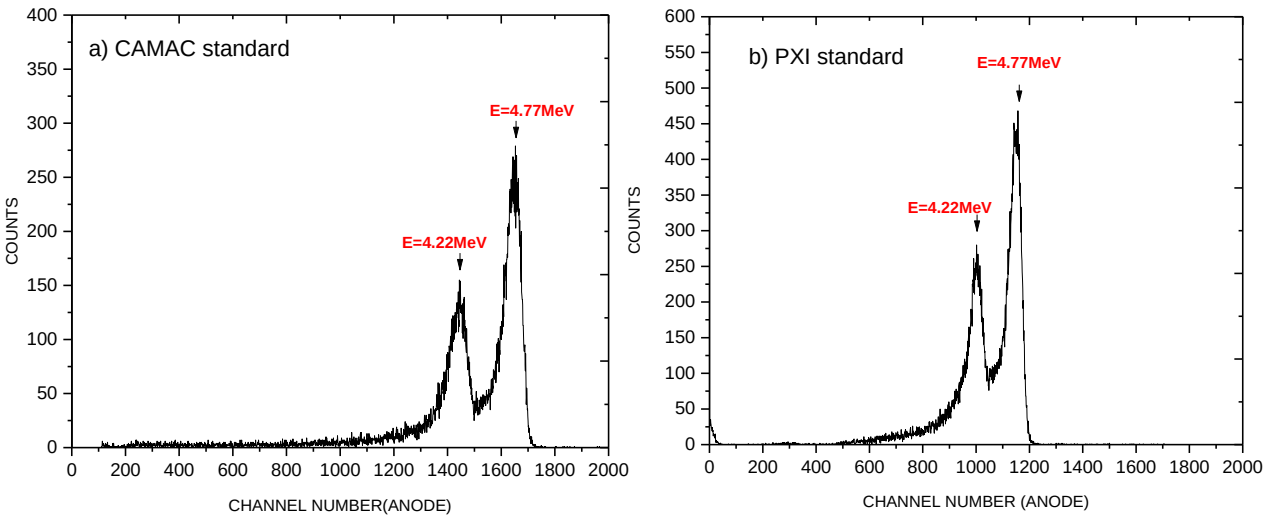

Fig.7. Amplitude spectra from anode using the α-source ^{nat}U. Left picture CAMAC standard, right picture PXI standard.

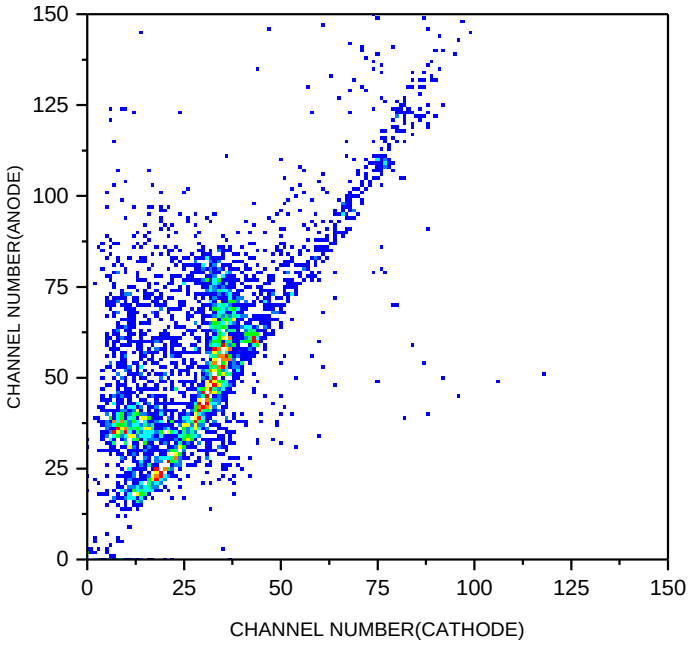

Fig.8. Two-dimensional spectra (cathode-anode) for the reaction $^{6}Li(n,\alpha)^{3}H$ at E_n=4MeV,PXI system.

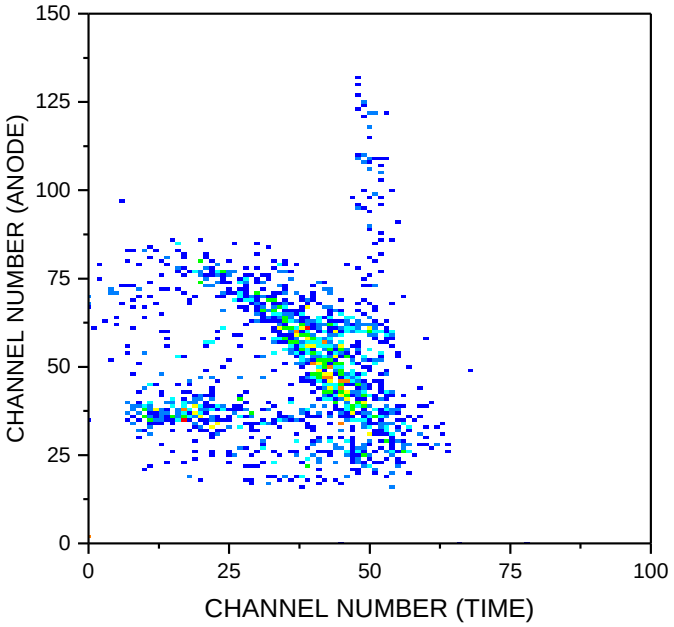

Fig.9. Two-dimensionalspectrum(time - anode) for the reaction $^{6}Li(n,\alpha)^{3}H$ at E_n=4MeV,PXI system.

6. Conclusion

Two data acquisition systems were developed and put into operation. The first one is based on CAMAC standard, the second one is based on PXI standard. A special ionization chamber with five pairs of exchangeable samples was used as a detector. Test measurements were carried out with two different DAQ systems to measure alpha spectra from ^{nat}U source and from $^{6}Li(n, \alpha)^{3}H$ reaction at the neutron energy E_n = 4 MeV. In the case of PXI system we are able to obtain also time information from test measurements due to using the high-speed digitizer Pixie-4.The PXI DAQ system turned out to be more compact, simple and even more cheaper than CAMAC one.

References

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