DAQ system for the complex of BUST – Andyrchy – Carpet-2 facilities

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Abstract The work in the field of multi-messenger astronomy imposes increased requirements to the experimental facilities and their data acquisition systems. Therefore the fundamental modernization of data acquisition systems of experimental facilities of the Baksan Neutrino Observatory (BNO) is now performed. In this paper the upgrading of data acquisition systems and processing data of the Baksan Underground Scintillation Telescope (BUST), "Carpet-2" and "Andyrchy" EAS arrays is discussed.

Keywords: EAS, VME, DAQ, Gamma-Ray Burst, Cosmology

1. Introduction

The study of astrophysical objects by methods of multi-messenger astronomy demands increased requirements to the data acquisition (DAQ) systems. Especially it concerns the fast response astronomy, i.e. the quick searchers of other messenger partners after an alert. The development of modern experimental facilities and fast data acquisition systems (DAQ) gives a possibility to analyze experimental data in the real-time mode. The fundamental modernization of data acquisition systems of experimental facilities of the Baksan Neutrino Observatory is being performed now. This modernization will make it possible to produce the low-latency alerts from experimental facilities of BNO to a great number of various telescopes. New data acquisition systems of the Baksan Underground Scintillation Telescope, "Carpet-2" and "Andyrchy" EAS arrays are based on the VME interface and provide full compatibility with existing front-end electronics.

2. BUST

The BUST consists of four horizontal and four vertical planes. Its size is 16.7 x 16.7 x 11.1 m^3. All planes are completely covered with standard scintillation counters. Eight planes of the telescope consist of 3180 scintillation counters. The existing DAQ system, the architecture of which was developed in the 70s of the last century, does not allow the full use of the capabilities of scintillation counters. The dead time of the new DAQ system is an order of magnitude less than that of the previous one. The new system is based on a VME interface and is totally compatible with existing front-end electronics of the BUST. A hodoscope of pulse channels (HPC) is developed anew and is iimplemented using FPGA and LVDS chips.

Figure 1 shows the functional diagram of the DAQ system. HPC consist of 3180 channels, according to the number of scintillation counters of BUST. Constructively the entire HPC is located in four CAMAC crates. All crates have controllers that serve all receiving blocks of their crates and provide data transmission and control signals via the V1495 module. Each plane of the BUST is divided into groups - structures. The time measurements of eight planes and 29 plane structures are made by the TDC V1190 module. In this case, the signals coming from the shaper with front compensation (SFC) should be converted from the NIM standard to the LVDS standard.

To measure the energy release, the analog signals from the scintillation counters are summed by 100 and fed to the trigger block. In the trigger unit the analog signals are matched to the wave impedance of flat cable of twisted pairs for transmitting them to QDC V792 module. The trigger unit delays analog signals by 30 nanoseconds. Such a delay is necessary for formation of the QDC GATE input signal before arrival of the measured analog signals. The duration of the GATE signal must be greater than the measured signal.

The Hodoscope of amplitude channels (HAC), in contrast to QDC, measures not the charge of the planes, but the individual charge of each counter. HAC was developed and launched in 2002. All signals from logarithmic converters of eight BUST planes are connected to seven CAMAC blocks. In addition to the HAC blocks, a dead time DAQ block and two four-channel blocks with 12-bit analog-digital converters (ADC) are installed in the crates.

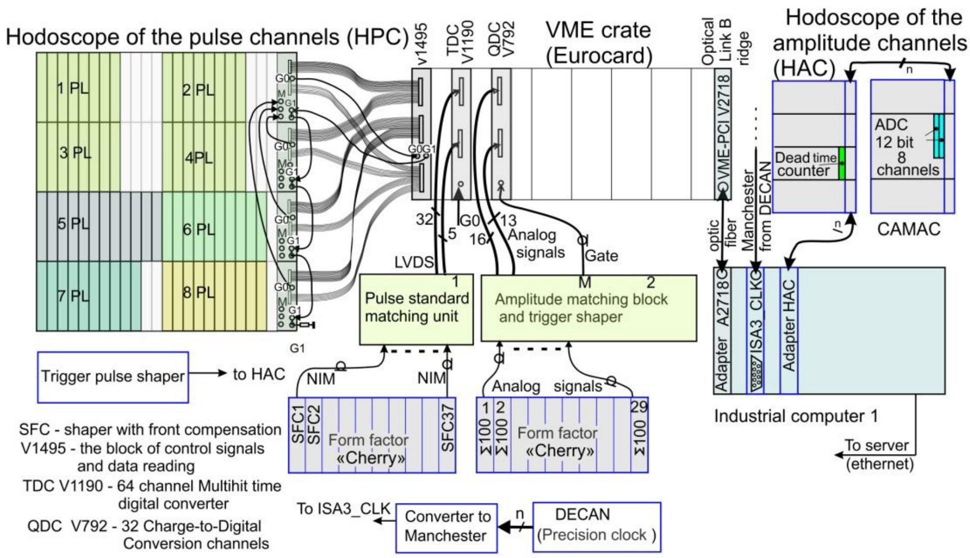

Fig1. Block diagram of the BUST.

To study the energy spectrum it is necessary to know not only the energy release, but also the waveform of the signals. The waveform of signals allows us to separate a useful signal from the noise and to analyze parameters of particles, to study the decay processes inside the scintillation counters. The total energy release signals from the eight planes are fed to the inputs of the NI PCI 5124 fast ADC boards located in the industrial computer. The ADC boards make it possible to measure the energy release of events with high accuracy, which allows studying the energy spectrum of neutrinos emitted by collapsing stars.

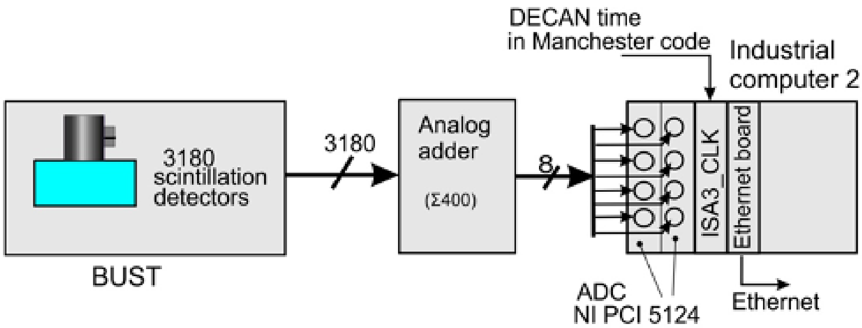

Fig2. *Functional diagram of signal form measurement from each plane by fast ADC.*

3. "Carpet-2"

The diagram of the DAQ system of the «Carpet -2» EAS array is presented in Fig.3. This array consists of the ground part of the «Carpet» (400 liquid scintillation counters, continuous covering square of 200 m^2), six remote vans (in each van there are 18 similar liquid scintillation counters), and an underground Muon Detector (MD) with an area of 175 m^2 (175 plastic scintillation counters). Signals from six remote vans are used to determine the direction of arrival of showers. EAS muon component with energy above 1 GeV is registered by MD.

Analog signals from «Carpet» and vans modules are branched into two groups. One part passes into trigger block 2, in which the GATE control signal for QDC is generated, the cable delay of all analog signals is produced and then signals are fed to the measuring inputs QDC V792 module. The second parts of signals via SFC are fed to trigger block 1. There the signals are converted from NIM to the LVDS standard and are fed to the measuring inputs TDC V1190B module.

The signals from MD come in different kinds: analog, signals from SFC, signals from logarithmic converter, and signals from RC converters. In MD, the analog signals from scintillation counters are summed by 35 (5 signals) and fed to the inputs of QDC module implemented in the CAMAC standard. Also, these signals are summed and fed to the 6th input QDC. Signals from RC converters (175 signals) are fed to the hodoscope inputs of amplitude channels implemented in the CAMAC standard

The MD is being upgraded. It is planned to connect 205 already manufactured detectors. The MD DAQ system based on CAMAC standard will be replaced by the system in the VME standard.

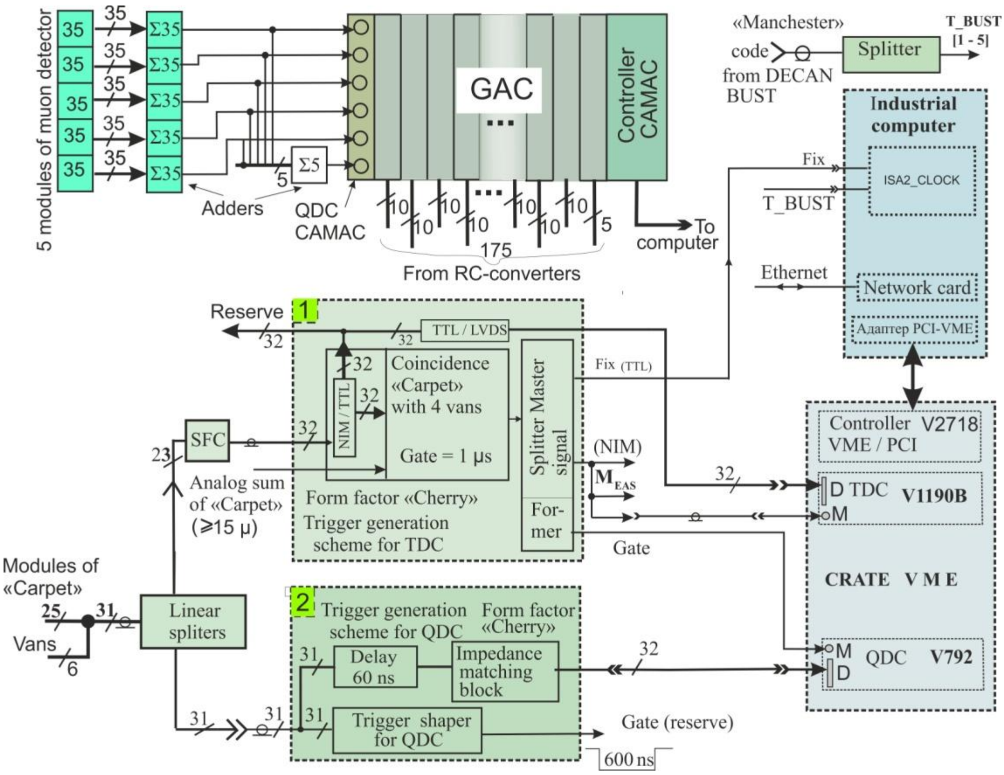

***Fig3**. Block diagram of the "Carpet-2" EAS array.*

4. "Andyrchy"

The DAQ system of the "Andyrchy" EAS array (Fig. 4) is similar to the "Carpet-2" DAQ system discussed above. Energy release of the 36 scintillation counters is measured by the QDC V792 and V965A modules. The analog signals in this case pass through the QDC trigger block 2 and fed to the inputs of QDC V792 and V965A modules, as in the previous scheme, the analog signals are also delayed. The signals from the RC converters are fed to the TDC trigger block 1, from which, after conversion to the LVDS standard, are fed to inputs of the TDC V1190B module and, through the TBI-24/DC-3 galvanic isolation board, to the modules UNIO-96-5 to measure count rates of all scintillation counters of the array.

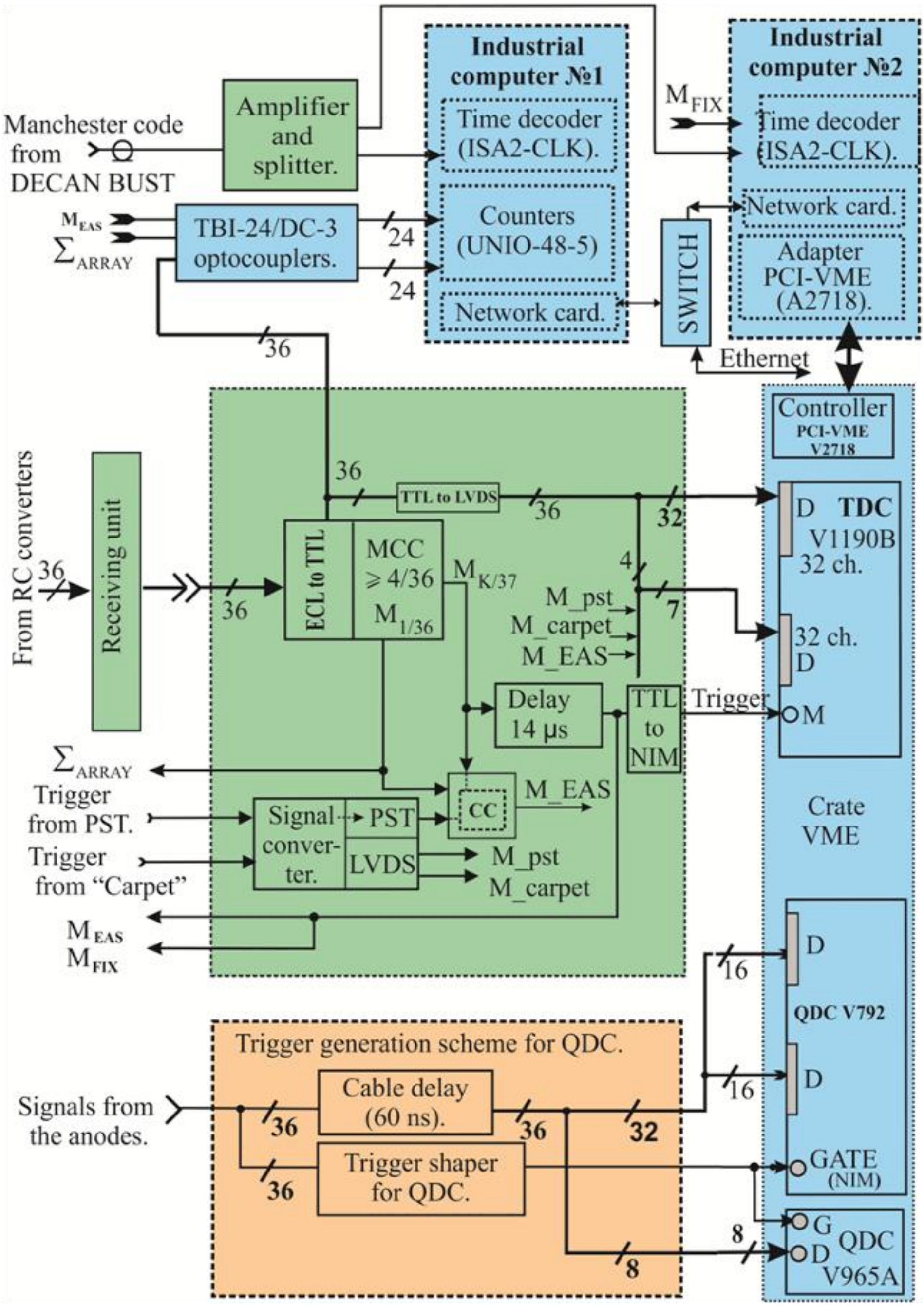

Fig4. *Block diagram of the "Andyrchy" EAS array.*

5. Software, data storage and transmission

The structure of on-line programs of BUST, “Carpet-2” and “Andyrchy” EAS array have the following architecture: at the beginning the equipment is initialized, then several data reading streams from devices and several information processing flows are formed. DAQ systems transfer the collected information to the file-server. Two dedicated workstations process the received information (Fig.5). First, the EAS direction is calculated in the local coordinate system, then in the astronomical one. Then the search for spatiotemporal concentrations (clusters) of showers recorded by the Underground Telescope or EAS array is performed. Search results are written to files on a dedicated server. A dedicated server sends information to the mailing list and provides access via HHTP and FTP. Currently, three event search algorithms are performed during the processing of information: the search for neutrino events in the BUST, the search for event clusters on the BUST, and the search for clusters of showers at the “Carpet-2” EAS array.

The main problem in searching of clusters from astrophysical object is their separation from background ones. For the problem of finding clusters, a method of the separating of events [7] was developed. The method has high reliability of separating events from the background according on the multiplicity of cluster events and time interval of cluster.

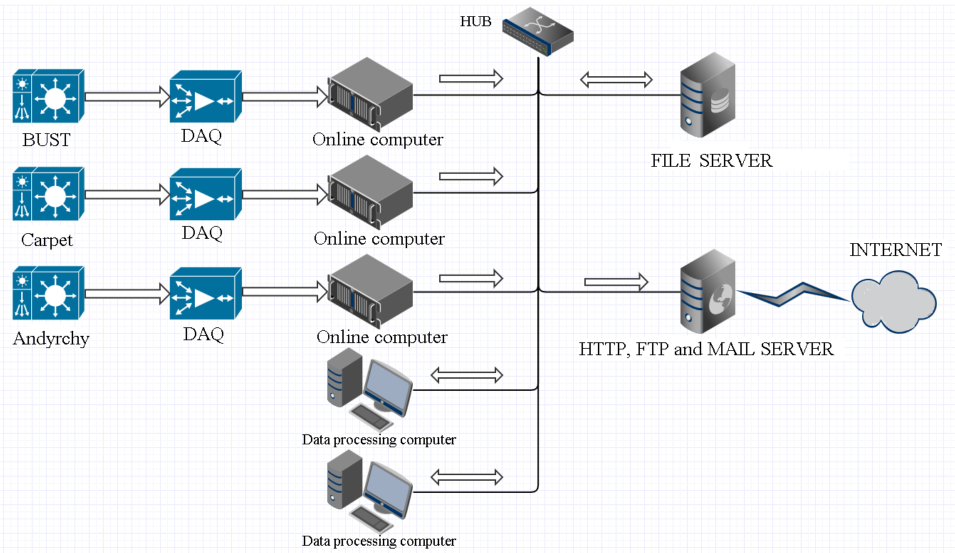

***Fig5**. Network diagram.*

6. Conclusion

At present the fundamental modernization of data acquisition systems of experimental facilities of Baksan Neutrino Observatory is performed. This modernization will make it possible to produce the low-latency alerts from experimental facilities of BNO to the great number of various experimental facilities, including global nets of optical robotic telescopes.

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