

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)**ScienceDirect**

Physics Procedia 74 (2015) 465 – 469

Physics

**Procedia**

Conference of Fundamental Research and Particle Physics, 18-20 February 2015, Moscow,  
Russian Federation

## New data acquisition and triggering systems for the DECOR coordinate detector

K.O. Yurin\*, K.G. Kompaniets, V.V. Shutenko, I.I. Yashin

*National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse, 31, Moscow, 115409, Russia*

---

### Abstract

The description of the new data acquisition and triggering systems for the DECOR coordinate-tracking detector is presented. The hardware of the DECOR supermodule controller providing effective triggering events of various classes, their readout and transmission to the central computer of the detector was designed and manufactured. The description of the structural solutions used in the design is presented. The results of comparing of the performance of the old and new systems are discussed.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)

*Keywords:* Cosmic rays, muons, Cherenkov water detector, coordinate-tracking detector, streamer tube chamber, data acquisition, trigger

---

### 1. Introduction

For the development of a new method of study of extensive air showers (EAS) on the basis of detection of the muon component in a wide range of zenith angles, up to the horizon, in the framework of the Russian-Italian cooperation around the Cherenkov water detector (CWD) NEVOD (NRNU MEPhI, Moscow) the DECOR coordinate-tracking detector of large area was created [1]. As a result of experiments carried out on the complex NEVOD-DECOR in 2001 – 2014, it has been demonstrated that the energy spectrum and composition of cosmic rays in the energy range  $10^{15}$  -  $10^{19}$  eV can be investigated by means of the detection of muon bundles at large zenith angles. Based on the experimental distributions of muon multiplicity of the bundles and zenith angles, a new approach to the study of the characteristics of the primary cosmic rays on the basis of the local muon density spectra (LMDS) of extensive air showers (EAS) was elaborated [2-4].

---

\* Corresponding author. Tel.: +7-915-214-28-51; fax: +7-499-324-87-80.

*E-mail address:* [koyurin@mephi.ru](mailto:koyurin@mephi.ru)

The basis of the complex is a Cherenkov water detector NEVOD which detecting system is implemented in the form of a lattice of quasi-spherical modules for detecting Cherenkov radiation from any direction in water [5] (Fig. 1a). The lattice is placed in a water pool, located in a special building in the MEPHI campus. DECOR is installed in the gallery outside the water basin (Fig. 1b) and consists of 8 assemblies-supermodules (SM) of streamer tube chambers, the total area is  $\sim 72 \text{ m}^2$  (32 768 detection channels).

Besides the CWD NEVOD and DECOR in the complex currently the following measuring systems are included: the calibration telescope system (CTS) for calibration of quasi-spherical modules and measurements of multi-particle events both above the CWD surface and at the bottom of the water detector with a threshold of 2 GeV [6]; PRISMA detector for registration of the neutron component of EAS [7].

To ensure the effective operation of the DECOR measuring system, a three-level system of registration has developed. The first lever is provided by electronics of every layer of DECOR supermodules. Second level provides at SM level the triggering, readout and transmission of data to a central computer. Third level triggers are generated by the external triggering system to select determined classes of events. However, the existing data acquisition and triggering systems were created about 20 years ago and do not meet modern requirements. Besides the operation of DECOR, the compatibility with other detectors should be ensured. For this purpose, we developed a new system of registration on a new element basis.

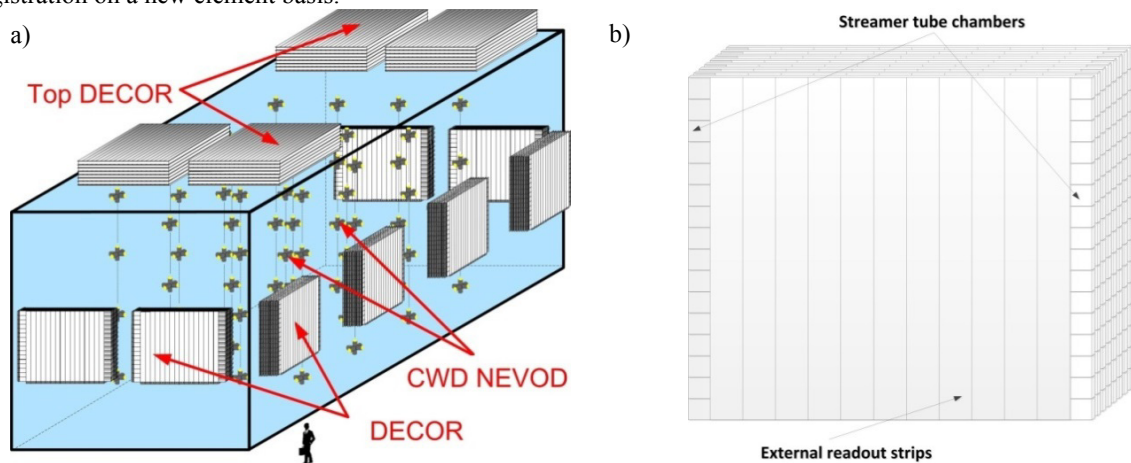


Fig. 1. (a) Experimental complex NEVOD; (b) the structure of DECOR supermodule.

## 2. DECOR measurement system

DECOR has a modular structure and consists of individual supermodules placed in the gallery around the water basin. Each SM is an eight-layer assembly of streamer tubes, which are the main registration element of the detector. Each layer-module consists of 16 plastic chambers of streamer tubes arranged vertically one above the other, and the outer plates of the two-coordinate readout system ( $256X + 256Y$  channels with step 1.0 and 1.2 cm, respectively). Each chamber represents a PVC profile forming 16 square cross section tubes with internal dimensions  $1 \times 1 \text{ cm}^2$ , coated with resistive graphite cathode. The sensitive area of the module is  $2.7 \times 3.1 \text{ m}^2$ . For signals readout from the strips, we use the 32-channel electronic boards LeCroy STOS M4200 [1], including amplifier-comparator-shapers for each channel and a chain of the shift registers, as well as specially designed four-channel data acquisition controllers, each of which serves four layers-modules of streamer tube chambers. One readout board includes 16 twin amplifier-comparator-shapers, four shift registers and circuit of common signal OR formation. The signals coming from the strips are amplified and, in the case of exceeding the established threshold, shape the pulses up to 10 microsecond duration, each of which generates on the board a common signal OR. Data from the shapers with the appearance of an external signal LOAD are loaded into the shift registers, where are stored and can be read sequentially by the protocol compatible with SPI, QSPI and Microwire. At the reset of signal LOAD, all register bits

are reset to zero. One card serves 32 strips. Boards are serially connected with each other. Output signals OR are organized according to the "open collector" scheme and merged in parallel. One module includes eight boards on the X-axis and eight on the Y-axis.

Supermodule trigger is the coincidence of at least two odd and two even modules within the time gate of 250ns. The design of the girders where the modules are located and the fastening of the suspension of modules give the possibility to move the modules along the gallery that allows to change the detector configuration according to the physical task. Coordinate-tracking detector allows to select the tracks of charged particles with high angular (better  $1^\circ$ ) and spatial (about 1 cm) accuracy, as well as to measure the relative time of the muon passages through different SM that provides additional information to select the albedo muons from the near-horizontal muon flux.

The selection of events is performed under the following conditions:

- coincidence of 4 or more signals OR from the modules of one SM;
- coincidence of signals of two and more supermodules;
- coincidence of signals from supermodules located opposite each other in short galleries (see Fig. 1a).

### 3. The new DECOR DAQ and triggering systems

The new DECOR data acquisition and triggering systems consist of following subsystems and blocks:

- The central triggering system, which generates a signal "HOLD" for the selection of events according to predetermined logic.
- Supermodules with readout boards.
- The Controller board, which generates control signals, provides the receiving and transfer of data via ISA interface.
- The Cross-board is the hardware part of the ISA interface and provides the transfer of data to the PC via the ISA interface.
- The Bridge board is used to the hardware connection of PC to the Cross-board.
- PC for data transfer from the controller board to the server for storage. It has a port LAN, which allows to organize data transfer on a local network.
- The central computer, which allows carrying out the monitoring of the systems in real time and receives data from PCs.

The block diagram of the new DAQ and triggering systems of coordinate-tracking detector DECOR is shown in Fig. 2.

### 4. Controller

The controller board contains the following functional units (see a functional diagram in Fig. 3):

- FPGA (field-programmable gate array): is used for the receiving signals from the SMs modules and processing them in a predetermined logic. It generates control signals of the load of triggers, load of data and download of flags in the status registers.
  - EPC2: the flash memory to store the FPGA configuration.
  - CPLD (complex programmable logic device): FPGA, providing links via the ISA interface.
  - Digital isolator: provides galvanic isolation and noise protection.
  - Clock: provides the controller operation at a predetermined frequency.
  - Bus driver: a buffer capable to provide exchanging data between of the PC and the FPGA via 16-bit data bus.
- The DAQ local station is executed in the standard of 6U Euromechanics crate. One crate contains:

- Cross-board with four ISA interface slots.
- Adapter plate for communication of PC with cross-board.
- Two controller boards that serve the 2 supermodules.
- PC for data transfer via Ethernet.
- Power supply for PC and controller boards.

The configuration of the controller FPGA is performed with program Quartus by means of Altera FPGA, is stored in external memory EPS2, and is loaded to the FPGA when the power supply is switch on (see Fig. 3). The

configuration of the FPGA allows to realize the following modes: autonomous mode; operation in the DECOR measuring system; noise measurement; read-out mode. The communication between the PC and the controller board is implemented through the registers. In total, controller includes seven 16-bit registers. Each of the two boards in the crate has own base address: 0x300 for the first board, and 0x310 for the second one. The base address of the board to access it is written in the form of CPLD type FPGA (Fig. 3) and is set once at compiling of the project. For the access to the required registers it is necessary to add the register number (offset) to the base address.

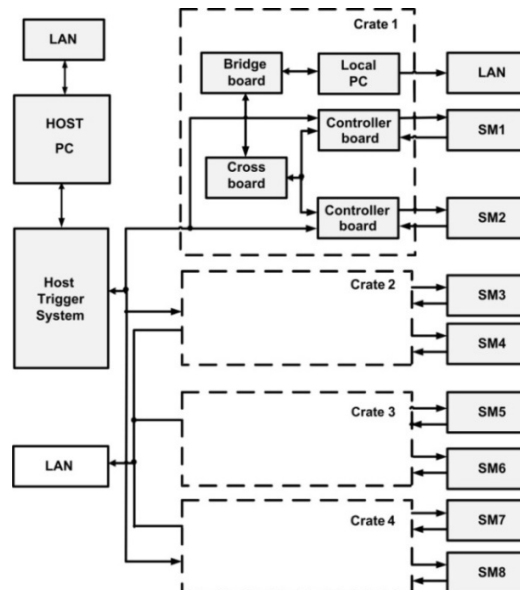


Fig. 2. Block diagram of the DAQ of the DECOR.

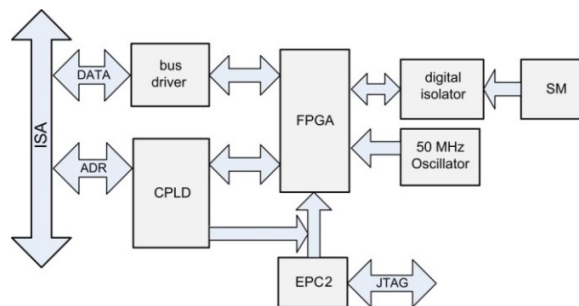


Fig. 3. Block diagram of coordinate tracking detector DECOR

## 5. The analysis of the new DECOR DAQ system

After mounting in the DECOR, the special series of test measurements with the new registration system was carried out for the study of the basic characteristics of the system, its adjustment and the subsequent comparison with the characteristics of the previous system. Table 1 shows the results of the comparison. We analyzed the following values:

- $N(\text{TrN8})$ : the number of events detected at any condition of DECOR triggering.
- $F(\text{TrN8})$ : the frequency of TrN8 events ( $\text{s}^{-1}$ ).
- $N(\text{OneTr})$ : number of OneTrack events.
- $F(\text{OneTr})$ : the frequency of OneTrack events ( $\text{s}^{-1}$ );

- New/Old: ratio of parameters of the system to the “old” ones, corrected for the barometric effect.

Table 1. Comparison of characteristics of the new and “old” systems.

Parameter	Series #11 (“old” system)	Special runs (new system)	New/Old
Date	04.06.2013- 08.04.2015	22.04.2015- 12.05.2015	
Numbers of runs	000-455	815-828	
Average pressure, mmHg	746.6	744.6	
Period of controller operation, s	$4.533 \cdot 10^7$	$1.269 \cdot 10^6$	
$N(\text{TrN8})$	$4.176 \cdot 10^8$	$1.180 \cdot 10^7$	
$F(\text{TrN8}), \text{s}^{-1}$	$9.2130 \pm 0.0004$	$9.2950 \pm 0.0027$	$1.0036 \pm 0.0039$
$N(\text{OneTr})$	$2.664 \cdot 10^6$	75106	
$F(\text{OneTr}), \text{s}^{-1}$	$0.05876 \pm 0.00004$	$0.05918 \pm 0.00022$	$1.0032 \pm 0.0037$

As it follows from the data, the frequency of events of the “old” and the new DAQ systems coincide with the sufficient accuracy, in spite of different conditions of run conducting (pressure, time of the run etc.). The ratio of the frequencies of triggers of the new to the “old” is  $1.0036 \pm 0.0039$ .

Another important indicator is the ratio of the rate of OneTrack events of “old” and new systems. “OneTrack” is an event which triggered two (and only two) of DECOR supermodule in the opposite short galleries of the basin (see Fig. 1), and tracks reconstructed on the basis of the responses of individual SM are located within the cone angle less than  $5^\circ$ .

The ratio of the frequencies of OneTrack events with the new and the “old” systems is equal to  $1.0032 \pm 0.0037$  that indicates a correct operation of the new data acquisition and triggering systems for the DECOR coordinate detector.

## 6. Conclusion

The elaborated new data acquisition and triggering system represents 4 crates, each of them including 2 controllers of coordinate detector DECOR, cross-board and bridge board for the connecting with PC. The controllers are intended for processing, selecting and transmitting signals from the detector. The constructive is made in the Euromechanics 6U standard. The new system has been tested during special series of measurements at the NEVOD-DECOR complex. The analysis of obtained results showed the correctness of the operation of the system, which significantly enhances the ability of the detector DECOR in operation with the Cherenkov water detector NEVOD and other detectors of the complex.

## Acknowledgements

This work was performed at the Unique Scientific Facility “Experimental complex NEVOD” with the financial support of the RF Ministry of Education and Science (project No. RFMEFI59114X0002).

## References

- [1] Barbashina N.S., Ezubchenko A.A., Kokoulin R.P. et al. A coordinate detector for studying horizontal fluxes of cosmic rays. *Instrum. Exp. Tech.* 2000;43:743-746.
- [2] Bogdanov A.G., Gromushkin D.M., Kokoulin R.P. et al. Investigation of the properties of the flux and interaction of ultrahigh-energy cosmic rays by the method of local-muon-density spectra. *Phys. Atom. Nucl.* 2010;73:1852–1869.
- [3] Saavedra O., Amelchakov M.B., Barbashina N.S. et al. NEVOD-DECOR experiment: results and future. *J. Phys.: Conf. Ser.* 2013;409:012009.
- [4] Petrukhin A.A. Muon puzzle in cosmic ray experiments and its possible solution. *Nucl. Instrum. Meth. Phys. Res. A.* 2014;742:228-236.
- Aynutdinov V.M., Kindin V.V., Kompaniets K.G. et al. Neutrino Water Detector on the Earth's Surface (NEVOD). *Astrophys. Space Sci.* 1997;258:105-116.
- [5] Yashin I.I., Amelchakov M.B., Ashikhmin V.V. et al. Status of the NEVOD-DECOR experiment. *Proceedings of the 32th International Cosmic Ray Conference, held in Beijing, 11 August-18 August, 2011.* 2011;3:76-79.
- [6] Gromushkin D.M., Alekseenko V.V., Petrukhin A.A. et al. The ProtoPRISMA array for EAS study: first results. *J. Phys.: Conf. Ser.* 2013;409:012044.