Detector station and registering system of the NEVOD-EAS array cluster

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Abstract. The design features of the detector stations of the cluster type shower array NEVOD-EAS which is now under construction on the basis of the Unique Scientific Facility ‘Experimental complex NEVOD’, as well as the operation principle of the cluster registering system are discussed.

1. Introduction
At the present time, the cluster-type detector NEVOD-EAS [1–4] for the registration of extensive air showers (EAS) in the energy range of $10^{15}$–$10^{17}$ eV corresponding to the ‘knee’ region of the primary cosmic ray energy spectrum is under construction on the basis of the Unique Scientific Facility ‘Experimental complex NEVOD’ (MEPhI, Moscow).

![Image of NEVOD-EAS layout and structure]

**Figure 1.** The layout (a) and the structure (b) of the NEVOD-EAS array.

The new shower array will enable to define the size, the axis position and the arrival direction of the EAS, in order to significantly increase the accuracy of energy estimation of the primary particles responsible for generation of muon bundles registered by the NEVOD [5,6] and DECOR [7] detectors.
The NEVOD-EAS detector with a total area of ~ $2 \times 10^4$ m$^2$ will include 12 clusters of 16 scintillation counters in each for the detection of the EAS electron-photon component. Counters of the cluster are grouped into four detector stations (DS) arranged in one plane in the vertices of a rectangle with the characteristic side lengths of about ~ 20 m. Information from the DS of the cluster is fed to the registering system located inside the Local Post (LP). Registering system performs digitization of the DS analog signals using the FADC, selection of events according to the specified triggering conditions and transfers data to the Central DAQ Post. Distances between the clusters are ~ 50 m. The structure and the layout of the NEVOD-EAS array are shown in figure 1.

2. Detector station of the NEVOD-EAS array
Detector station consists of four scintillation counters of the extensive air shower electron-photon component (figure 2a).

Scintillation counters were previously used in the KASCADE-Grande [8] and EAS-Top [9] experiments. Main elements of the counter construction are: NE102A scintillator with the dimensions of 800×800×40 mm$^3$ and Philips XP3462 PMT installed inside the pyramidal stainless steel housing. The PMT is placed under the scintillator at a distance of 30 cm. The inner surface of the counter pyramid is painted with a special diffuse-reflective coating to improve the collection of light from the flashes in the scintillator caused by the passage of particles through its sensitive volume. The construction of the NEVOD-EAS counters allows installation of one additional Philips XP3462 PMT. For the protection against the environmental influences, the DS counters are enclosed inside the special external housings (figure 2b). The area of the detector station is about 2.5 m$^2$.

Three of the four DS counters are equipped with one (‘standard’) photomultiplier Philips XP3462 which is used for the time and density measurements during the EAS registration. The gain of the standard PMTs is chosen so that the response of scintillation counters to the passage of near-vertical single muon was practically the same (~ 13 pC).

The fourth DS counter is equipped with two (a ‘standard’ and an ‘additional’) photomultipliers. The additional PMT ensures the wide range of linearity of measuring signals at the high particle densities (~ 10000 particles/m$^2$) and has a gain 90 times smaller than the standard one. The additional PMT response to the passage of the near-vertical muon is ~ 0.15 pC.

The techniques and results of studies of the PMT and scintillator characteristics, as well as the techniques of the NEVOD-EAS counter assembly and adjustment are described in [3] and [4].
The photomultipliers are powered with a special block based on the TRACO PHV 12-2.0K2500N DC/DC-converter. This block is powered by the source of the constant voltage +12 V which is transformed into a constant high voltage in the range from -100 to -2000 V. The PMT power supply output voltage is adjusted using the multi-turn resistor. The operating voltage of the detector station is a maximal supply voltage of five DS PMTs. The supply voltage providing the required gain of the remaining DS PMTs is adjusted using the ballast resistors soldered into the PMT dividers.

Since the scintillator light yield depends on the ambient temperature, it is necessary to consider the temperature coefficient for the processing of counter amplitude information. To measure the DS internal temperature during the NEVOD-EAS operation monitoring, the K-type thermocouple Fluke 80PK-11 which is designed for measuring temperatures in the range of -30ºC to 105ºC is used.

The signals from the DS counters are transferred to the cluster LP using the RG-174 cables. The PMT high voltage power supply is powered via the twisted pair cable. The receiving of the DS thermocouple information is also performed with the twisted pair cable.

3. NEVOD-EAS array cluster DAQ system

The main elements of the cluster registering system (figure 3) are: block of primary data processing, 4-channel summator-multiplexor (SM), PET-7019 input-output module which controls the SM and receives information from the DS thermocouples.

The block of primary data processing ensures digitizing of analog signals from the DS of the cluster, selection of events according to the specified triggering conditions (coincidence of up to 4 detector stations within a time gate with a duration from 10 ns to 2 ms) and data transmission to the Central DAQ Post. It consists of two 2-channel boards of amplitude analysis (BAA) and a controller which are designed with the FPGA Xilinx Spartan-6. The communication between the controller and BAA is performed using the VME-bus. Each BAA channel has an active and a passive input. At each input, the signals are digitized by the 12-bit FADC in the amplitude range from -2.5 V to 2.5 V with a sampling frequency of 0.2 GHz. The registration threshold on the BAA channel active input is set using the 8-bit DAC. Each event is timestamped with an accuracy of up to 10 ns.
Registering system of the NEVOD-EAS cluster can operate in two modes: exposition and monitoring. Switching between two modes is performed using the 4-channels SM. Each SM channel has 4 inputs and serves one detector station. In the exposition mode, the analog signals from 4 standard PMTs of the DS are summed on the corresponding SM channels. The summed signals from the SM outputs are fed to the active inputs of the corresponding BAA channels. The additional PMT signals are fed directly to the corresponding BAA passive inputs. In the monitoring mode, only the defined input of each SM channel is turned on. That enables to register amplitude and charge spectra from the selected DS counters and, therefore, to control their parameters.

The control of the SM is performed using 4 discrete outputs of the PET-7019 I/O-module. Also this module has several analog inputs which are connected to the thermocouples installed inside the DS and LP housings. For the communication with the I/O-module the Modbus TCP protocol is used.

Control command receiving and data transmission are performed by the NEVOD-EAS cluster registering system via the fiber-optic communication line.

4. Conclusion
The NEVOD-EAS shower array designed on the basis of the scintillation detector stations with the dynamic range of up to ~ $10^4$ particles/m$^2$ combined by the intracluster registering system will allow determination of the size, position of the axis and the arrival direction of EAS with the energies in the range of $10^{15}$-10$^{17}$ eV. New data obtained in the conjunctive operation of the NEVOD-EAS array with other installations of the Unique Scientific Facility ‘Experimental complex NEVOD’ will enable to reduce the uncertainty of the PCR particle energy estimations with the NEVOD and DECOR detectors. The NEVOD-EAS array is now under mounting on the roofs of the MEPhI campus laboratory buildings (see figure 4).

![Image](image.png)

Figure 4. The NEVOD-EAS array clusters on the roof of the MEPhI laboratory building.

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