Proposal of NEVOD-EAS shower array

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Abstract. New setup for detection of EAS electromagnetic component at the knee region of primary energies is under construction on the basis of the experimental complex NEVOD (Moscow, Russia). The measuring system of the EAS array has a cluster organization. Clusters are located on the roofs of laboratory buildings of MEPhI (Moscow). Features of measuring and DAQ systems, results of investigations of characteristics of a single counter and the event formation algorithm from the data of separate clusters are discussed.

1. Introduction
Studies of muon bundles in a wide range of zenith angles and multiplicities carried out at the NEVOD-DECOR experimental complex [1, 2] during 2001-2007 showed that the use of such not a large setup allows to investigate primary cosmic ray spectrum and hadronic interaction characteristics in a wide energy range $10^{15} \sim 10^{19} \text{eV}$ on the basis of the analysis of local muon density spectra (LMDS) [3]. However, the energy interval of particles responsible for the formation of bundles with a fixed multiplicity detected at a certain zenith angle is relatively wide. The deployment of the shower array around the NEVOD-DECOR complex for detection of EAS in the energy range $10^{15} \sim 10^{17} \text{eV}$ will significantly extend experimental possibilities since it will allow to determine the shower size, the position of its axis and therefore to compare the energy estimates obtained by the traditional method and by LMDS technique.

2. NEVOD-EAS shower array
The setup for EAS registration (NEVOD-EAS) represents a scintillation detector array deployed on the roofs of the laboratory buildings of MEPhI (total area will be about $10^4 \text{m}^2$). The measuring system of the NEVOD-EAS has a cluster structure. Each cluster consists of several detectors that are served by a local station (LS) of data acquisition. The typical distance between the clusters is about 30 m. In total, the array will contain up to 40 clusters.

3. Scintillation detector of the NEVOD-EAS setup
Registering system of the shower array is created on the basis of scintillation detectors of electron-photon component that were previously used in the registering system of the KASCADE-GRANDE setup [4]. Each detector consists of a plastic scintillator NE102A with area of $80 \times 80 \text{cm}^2$ and thickness of 4 cm located in an individual stainless steel box. The inner surface of the box is painted with a
diffusely reflecting primer to ensure a good uniformity of light collection from any place of scintillator area. The photomultiplier (XP3462B) is mounted under the scintillator at a distance of 30 cm. This photomultiplier has a high gain and is used for time and particle density measurements. Apart from this, an additional low-gain photomultiplier optimized to provide a wide linear range of the measured signals at high densities of particles is installed in part of the detectors. The detectors are placed in special boxes that provide protection from moisture and smooth out daily temperature variations.

The cluster is formed by four detectors. Three of them are equipped with one photomultiplier, and the fourth one – with two PMTs. The detectors are installed close to each other. The scheme of the detector and the cluster is shown in Figure 1.

![Figure 1. The scheme of the detector and the cluster of the NEVOD-EAS setup. A cluster is formed by four detectors. Three of them are equipped with one photomultiplier, and the fourth one – with two PMTs.](image)

The amplitude information from each detector of the cluster comes to a special board which provides four channels for signals from the high-gain photomultipliers and one channel for the signal from the low-gain photomultiplier. The board carries out the summation of the amplitudes of the signals from the high-gain photomultipliers as well as the digitization of signals. Thus, two signals appear at the output of the board. Then the signals are transmitted to the LS via Ethernet.

Each cluster is an autonomous part of the setup. Independence of the functioning of individual clusters simplifies the organization of their operation but the absence of system-wide trigger imposes higher requirements to the labeling of data and the subsequent data processing. Time synchronization of the clusters is performed with the global positioning system (GPS/GLONASS). Data are collected and stored in the cluster LS, and then are transmitted asynchronously to the central station (server) via a wireless (Wi-Fi, WiMAX) interface.

![Figure 2. An example of location of data packages from the various clusters of the NEVOD-EAS setup and an algorithm of events selection according to the array data.](image)
As the clusters operate independently and for the part of time may not participate in the registration (due to the maintenance works and performance monitoring), the transmission of data packages to a central server of the setup is asynchronous. On a central server data are stored in separate files for each cluster. On the time axis, the data packages could be located randomly (Fig. 2). The problem of association of data of separate events that are located in packages of different clusters is assigned to a special program. This program will analyze packages of separate clusters and place the event data on the basis of the time labels sequentially on a single time axis in a special file. Further processing will involve the sequential movement of a time gate with the width that is determined by the distance between the outer clusters along the time axis. According to the data of the events falling within the time gate the parameters of the EAS will be reconstructed.

4. Characteristics of the detectors of the NEVOD-EAS setup

Detector of the shower array should have a good resolution, a wide dynamic range and a high uniformity of light collection over the area of the scintillator. Study of the operation of the prototype which has a similar construction with detectors that are expected to be used in the NEVOD-EAS setup (with the exception of the scintillator) was carried out. Scintillator which is used in the prototype has dimensions of $50 \times 50 \times 5$ cm$^3$ and is made of a mixture of polystyrene (98.4825 %), p-terphenyl (1.5 %) and POPOP (0.0175 %).

Measurements of the light collection non-uniformity of the detector were performed using the supermodule (SM) of the URAGAN setup [5]. The chambers of the gas discharge tubes operating in limited streamer mode with external two-coordinate readout are the main registering elements of the SM. The SM consists of eight layers of chambers with a system of readout strips (each layer: 320X + 288Y channels with a step of 1.0 and 1.2 cm respectively). The layers are separated from each other by styrofoam plates with the thickness of 5 cm (Fig. 3).

![Figure 3. Mobile platform of the supermodule (side view).](image)

Each layer is assembled of 20 chambers. Each chamber contains 16 tubes with inner cross section of $9 \times 9$ mm$^2$ and a length of 3.5 m. Readout X-strips are parallel to the anode wires. Y-strips are perpendicular to the X-strips and located at the other side of the chambers. SM has an area of 11.5 m$^2$.

The triggering condition of the measuring system of SM is the coincidence of at least four trigger signals from different planes within 300 ns that identifies the passage of a charged particle through the SM with the efficiency of 99 %. The response of the supermodule is information about the triggered strips in each of the two projections of X and Y. High spatial resolution of the SM allows to study in detail the structure of the scintillation detector placing it on the surface of the SM.

During the measurements with the SM (~ 10 hours) more than 2 million events have been registered. To analyze the uniformity of light collection, only events in which single muons passed through the scintillator at zenith angles less than 15° were selected.

Figure 4a shows a matrix of values of the average amplitude of the response of the detector to the passage of single muons selected by the SM. The axes at the bottom left figure represent the geometric
dimensions of the triggering area in cm. The color reflects the average amplitude of the response of the detector in mV. The top and the right side figures show the change of light collection in two mutually perpendicular sections. Positions of these sections on the matrix are marked with light lines. The RMS non-uniformity according to the matrix amounts to about 20%.

![Matrix and spectrum of amplitudes of responses of the detector](image)

**Figure 4.** The matrix (a) and the spectrum (b) of amplitudes of responses of the detector to the passage of single muons.

The spectrum of the amplitudes of the response of the detector (Fig. 4b) obtained in self-triggering mode has a well-defined peak with the most probable amplitude of ~250 mV and the resolution of about 65%.

5. **Conclusion**

The shower array that will be created on the basis of the NEVOD-DECOR experimental complex will allow to determine the EAS size and the position of its axis. New data obtained by this setup will provide an opportunity to compare the energies of showers estimated by a traditional method with estimates of LMDS technique.

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