Cluster of scintillation counters for shower array of NEVOD-EAS project

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***Abstract*—New setup for detection of EAS electromagnetic component at the "knee" range of primary energies is under construction in Moscow (Russia) on the basis of the experimental complex NEVOD. The main element of triggering and detection systems is the cluster of 4 - 6 scintillation counters equipped with local DAQ station. Features of the cluster organization and results of investigations of properties of a single counter and of a whole cluster are discussed.**

I. Introduction

EXPERIMENTAL complex for studies of new physical processes at the "knee" range of energy spectra of cosmic rays (10^{15}-10^{17} eV) located in Moscow Engineering Physics Institute (MEPhI) includes: a water Cherenkov calorimeter (2000 m^3) intended for detection of basic components of cosmic rays at the Earth surface [1] and coordinate-tracking detector DECOR [2] with large area (115 m^2), high spatial (~1 cm) and angular (<1°) resolution for investigations of spatial-energy characteristics of muon component of cosmic rays in a full range of zenith angles. The results of the study of muon bundles in a wide range of zenith angles and multiplicities showed that this compact complex is able to provide information about the spectra of primary cosmic ray particles in the range 10^{15} -10^{19} eV [3]. Deployment of a shower array for detection of EAS in the "knee" energy range will significantly increase capabilities of NEVOD-DECOR complex. In this paper, description of scintillation counter and some results of testing of the cluster of scintillation counters for this array are presented.

II. The NEVOD-EAS setup

The NEVOD-EAS setup will be deployed in MEPhI campus. The total area of shower array is about 3×10^4 m^2 which is determined by the intensity of cosmic rays at the "knee" energies. The basic element of the detection system is a scintillation counter with 1 m^2 area. Counters must provide a required accuracy of measurements of time (for determination of EAS direction) and of energy release (for reconstruction of EAS core location and total number of particles). The clusters of 4 – 6 scintillation counters combined with a local DAQ stations will be placed at the roofs of campus buildings. The information from each cluster is transferred to the central computer by a wireless interface.

III. Scintillation counter of the setup

There are several main requirements for EAS scintillation counters: a good energy resolution, high accuracy of time measurements, and a wide dynamic range of registered signals. The counter has the form of truncated pyramid with 2 steel boxes (Fig. 1). A flat plastic scintillator and photomultiplier (FEU-200) with FE electronics that provides pickup and transfer of signals from the anode, 12th and 10th dynodes to the outer registration systems are located in the inner box. The inner box has a diffusely reflecting surface to ensure a good uniformity of light collection from any place of scintillator area. Scintillator is built up of 4 blocks 50 cm × 50 cm × 5 cm made of a mixture of 98,4825% polystyrene+ 1,5% p-terphenyl+ 0,0175% POPOP and bensole.

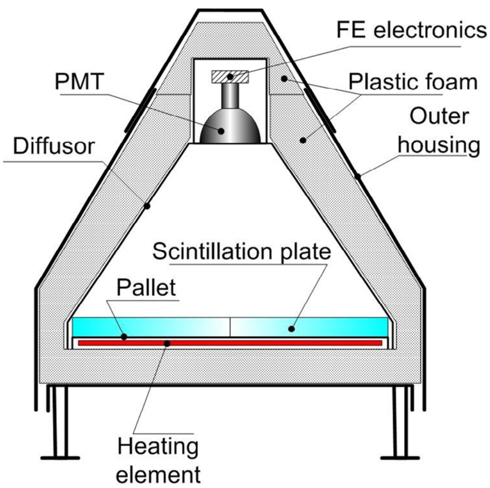

Fig.1. Cross-section view of scintillation counter

Outer steel box with 2 mm thickness is designed to protect the counter from environmental hazard. The space between two boxes is filled with plastic foam. To keep temperature stability in the inner box when the outer temperature falls down, a heating element is placed under the inner box.

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Investigations of counter parameters were carried out at a specialised test facility (Fig. 2) comprising 16-channel 12-bit QDC and 6-channel constant-fraction discriminator (CFD). A test facility is equipped with a telescope of two additional small size ($10\times20\times2$ cm^3) scintillation counters with 5 cm lead filter for muon track location. The thickness of 5 cm of scintillator is sufficient to provide a good resolution for detection of single muons with the light yield more than about 10^3 photons. Most probable value of counter response for vertical muons corresponds to average energy release of 10 MeV. Trigger from the telescope is used for study of time measurement accuracy of the counter for muon events. This value was defined as FWHM of arrival time distribution of signals from CFD and appeared equal to about 5 ns. The muon telescope is located in different places of the scintillator area for studies of uniformity of light collection. Non-uniformity is defined as:

$$d = \frac{s}{\overline{A}} \times 100\%, \qquad (1)$$

where $\overline{A}$ is the average response of the counter, and σ is rms spread of this value over the counter area. The mean value of non-uniformity for 4 counters was about 12%.

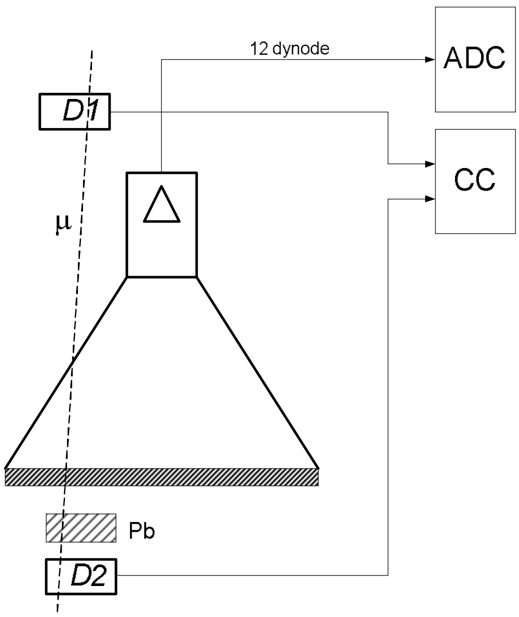

Fig.2. Test facility for investigations of counter parameters

In order to improve the uniformity of light collection we used an idea of a light-absorbing mask [4] which was placed under the scintillator to reduce the fraction of reflected light in the central part of scintillator. To optimize the mask, counter response simulations for vertical single muons were performed with Geant4 [5]. A mask pattern is shown in Fig. 3. The use of the mask has allowed to reduce the non-uniformity down to 8%.

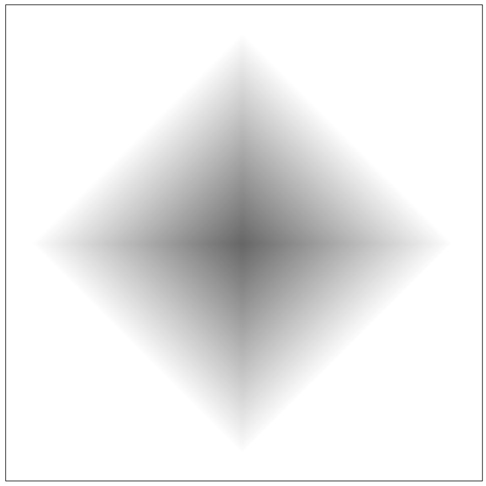

Fig.3. Light-absorbing mask

IV. Cluster of Scintillation Counters

The cluster organization of EAS array of counters allows to simplify triggering system, service procedures and to significantly decrease the cost of the whole setup. The cluster may include from 4 to 6 counters served with a single local DAQ station (Fig. 4). Local station additionally contains microPC with Ethernet controller, GPS receiver and time tagging unit.

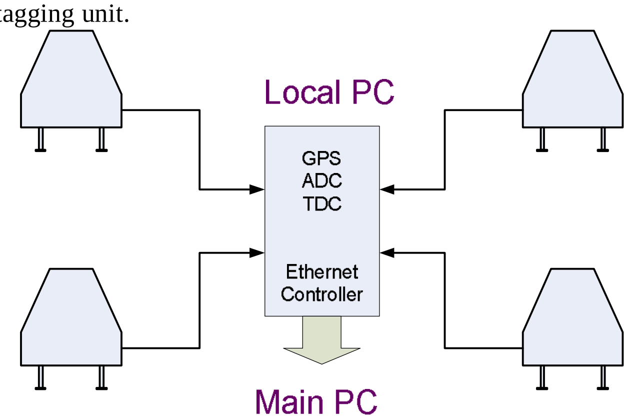

Fig.4. Cluster of scintillation counters

For pilot sample of the cluster, the basic trigger was 3-fold coincidence of counter signals. The coincidence time gate was set to 70 ns. The centers of counters were located in vertices of the square with side 1.5 m. In this configuration, the FWHM of signal time distribution for each of the counters was less than 6.5 ns (Fig. 5). Two different schemes of triggers were used to investigate parameters of cluster with 4 counters. Fig. 6 shows amplitude distributions for each counters in self-triggering and 3-fold triggering schemes. “Narrow” distributions with mean amplitude $\langle A_1 \rangle$ correspond to self-triggering, while “wide” distributions with mean amplitude $\langle A_3 \rangle$ correspond to 3-fold triggering. In the latter case, there are events with amplitudes less than the threshold for registration, and at the same time the number of events with amplitudes more than single muon is increased.

The 3-fold coincidences correspond to triggering of the cluster by EAS and extension of the distribution to high amplitudes is due to increasing probability of registration of more than one charged particle.

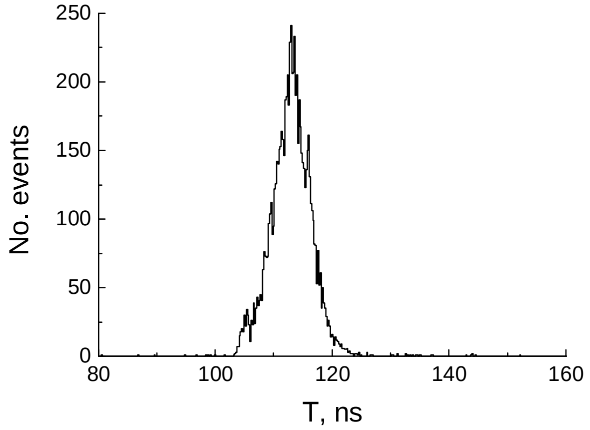

Fig.5. Signal arrival time distribution of a single counter with 3-fold coincidence trigger.

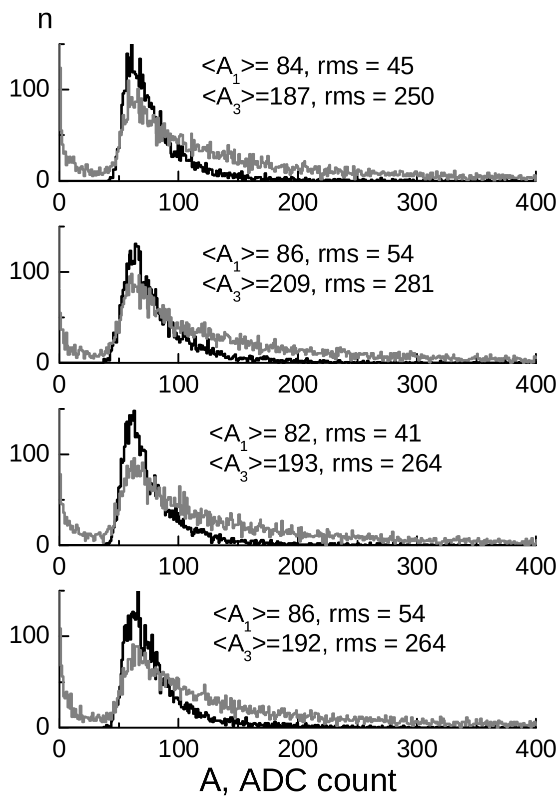

Fig.6. Amplitude distributions for each of the counters in self-triggering (dark histograms) and 3-fold triggering (gray histograms) modes.

V. Conclusion

The first test results show that the use of absorption mask decreases non-uniformity of the light collection. Peak of the amplitude distributions measured in the cluster triggering mode does not strongly change its location in comparison with a muon hump obtained in self-triggering regime, thus providing a convenient tool of absolute calibration of counters.

References

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