HE 6.3.09

Large Area Coordinate Detector for Horizontal Cosmic Ray Flux Investigations (Status Report)

A.A.Petrukhin[1], V.M.Aynutdinov[1], T.T.Barnaveli[6], A.Castellina[2], D.V.Chernov[1], A.A.Ezubchenko[1], W.Fulgione[2], V.V.Kindin[1], R.P.Kokoulin[1], K.G.Kompaniets[1], A.A.Konovalov[1], G.Mannocchi[2], Yu.N.Rodin[3], O.Saavedra[2], V.V.Shutenko[1], S.V.Ter-Antonian[5], G.Trinchero[2], S.Vernetto[2], N.N.Vonsovsky[3], E.E.Yanson[1], I.I.Yashin[1], E.Zas[4]

[1]*Moscow Engineering Physics Institute, Moscow 115409, Russia*
[2]*Istituto di Cosmogeofisica del CNR, Torino 10133, Italy e*
Dipartimento di Fisica Generale dell Universita di Torino
[3] *Scientific and Engineering Centre "SNIIP", Moscow 123060, Russia*
[4] *Universidade de Santiago de Compostela, Santiago de Compostela 15706, Spain*
[5] *Yerevan Physics Institute, Yerevan 375036, Armenia*
[6] *Institute of Physics of Academy of Science, Tbilisi 380077, Georgia*

Abstract

Construction of coordinate detector DECOR with working area 70 m^2 for investigations of horizontal cosmic ray flux has been completed. The detector represents a multi-layer system of limited streamer tube chambers and is located in the galleries around the Cherenkov water calorimeter NEVOD. Detector description and some preliminary results of the studies with its pilot assembly are presented.

1 Introduction:

At the last cosmic ray conferences, the project of the large area coordinate detector intended for horizontal cosmic ray flux investigations (Aglietta et al., 1995) and the results of the study of the performance of the first detector supermodules (Aglietta et al., 1997) were reported. Coordinate detector (DECOR) is located in the galleries of the building of Cherenkov water detector NEVOD (Aynutdinov et al., 1995) around the water tank. Combination of a high resolution coordinate detector (1 cm and 1° measurement accuracy) with a massive Cherenkov calorimeter (2000 ton of water) will allow to study a wide range of cosmic ray physics problems related with angular and energy distributions of high-energy cosmic ray muons, angular and spatial characteristics of muon groups at large zenith angles, observation of horizontal air showers produced by the penetrating component of horizontal cosmic ray flux deep in the atmosphere.

To the moment, the assembling of the main part of the detector has been completed. In the present paper, a brief detector description and some preliminary results obtained with a pilot working assembly of DECOR are presented.

2 Detector description:

A general lay-out of the coordinate detector and Cherenkov water calorimeter is shown in Fig.1. The basic sensitive elements of DECOR are plastic streamer tube chambers with resistive cathode coating and bi-dimensional external strip readout, used earlier in the NUSEX experiment (Battistoni et al., 1986). Each chamber contains 16 tubes with 9×9 mm^2 inner cross section and 3.5 m length. Chambers are operated at 4.45 kV on the wire with a continuous flow of three-component gas mixture (argon and carbon dioxide in 1:2 ratio plus saturated n-pentane vapour at 5° C). Sixteen chambers arranged vertically together with plates for coordinate readout (256X + 256Y strips with 1.0 cm and 1.2 cm pitch, respectively) form streamer tube module (STM). Modules have 8.4 m^2 effective area (2.7 in vertical and 3.1 m in horizontal direction). STM are hanged on the supporting constructions and can be moved along the galleries, thus allowing to change the

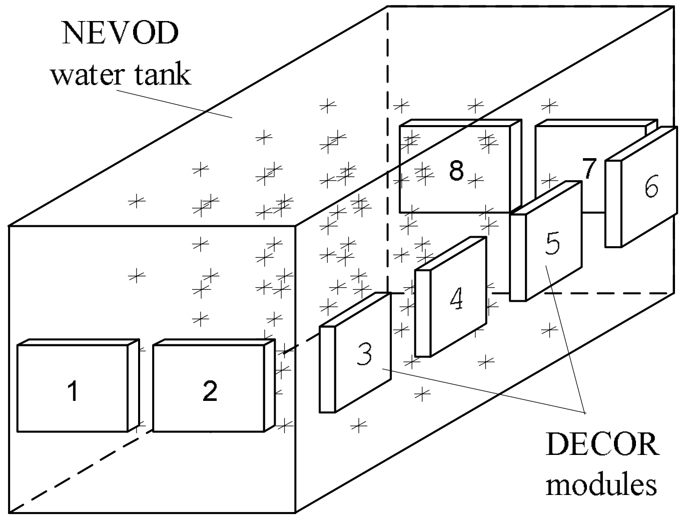

Figure 1: General lay-out of NEVOD - DECOR complex. Crosses indicate NEVOD optical sensors.

number of chamber planes and their positions. The present DECOR configuration includes 8 groups of 8 STM each arranged from three sides of the water tank (see the Figure). Distance between adjacent planes equals to 6 cm. In all, the detector contains 1024 chambers and 32768 registration channels.

The basic unit of the data readout system is 32-channel electronics card LeCroy STOS M4200 used earlier in the NUSEX detector. The card provides discrimination, shaping, temporary storage in shift registers, and subsequent serial output of signals from 32 strips. However, the large sizes of the detector and a high counting rate (in comparison with NUSEX experiment) required the elaboration of new, distributed and sufficiently fast data acquisition system. For this purpose, a specialized 4-input controller operated on ISA bus of IBM PC was designed. The controller combines functions of data readout from four STM, first-level trigger formation (two- or three-fold coincidences between individual module signals), and STM counting rate monitoring. Every peripheral computer houses 4 controllers; in all, the DAQ system includes 4 peripheral and 1 central computer (IBM PC-type) connected via Ethernet link. The total data readout time for the events selected by the trigger system does not exceed 2 ms. Different modes of a higher level trigger (based on the coincidences between the groups of STM and/or different NEVOD triggers) are foreseen.

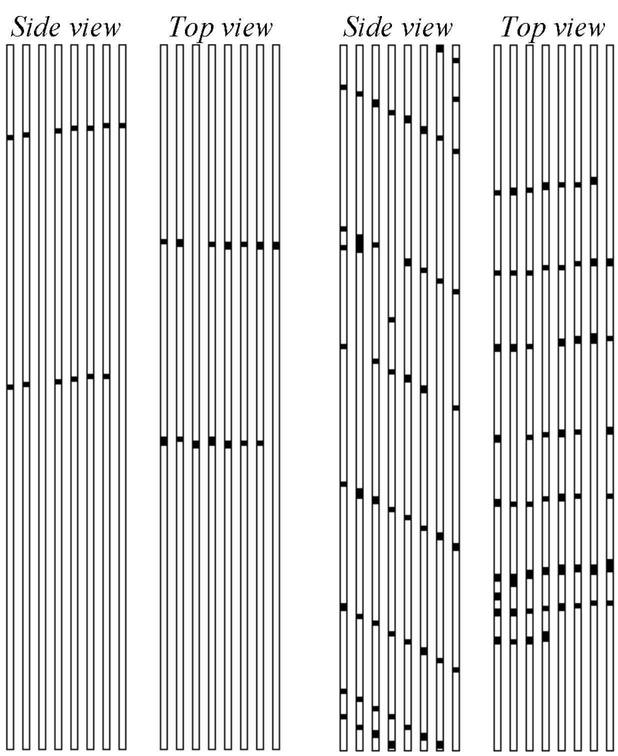

Figure 2: Examples of events detected in the pilot DECOR assembly. Left: near horizontal pair ($\theta = 83°$); right: group of EAS muons.

3 Tests of performance:

During January - May 1997, several experimental runs with a pilot working assembly of the detector (8 planes, group 1 in Figure 1) were conducted. Measurements were performed both in autonomic regime of coordinate detector operation and in coincidence with Cherenkov water detector. NEVOD configuration included 91 quasispherical optical modules arranged in the knots of a spatial lattice with the size $6\times6\times7.5$ m^3. Examples of events detected in the assembly are shown in Figure 2.

In all, about 2.1×10^6 events in autonomic mode and 3.5×10^6 events with a combined trigger of NEVOD and DECOR (120 hr net operation time) were registered. Over 90% of the events corresponded to single muons crossing all 8 modules of the working assembly. These events were used to evaluate basic setup characteristics such as detection efficiency and track reconstruction accuracy. Average (in angles) single particle detection efficiency of an individual module appeared equal to about 90%, decreasing down to 80% for orthogonal track incidence because of constructive features of the chambers and the modules. However, even in this worst case, the efficiency of the detection of particles by a multi-layer system of modules remains sufficiently high.

In order to estimate the measurement accuracy, each of the tracks was reconstructed from the data of two enclosed sub-groups of four planes separately, and the distribution of the difference between these two fits was analyzed. It was found that the angular accuracy corresponded to about 0.9° for 4-plane configuration, or about 0.6° for eight module structure of the detector.

As a whole, methodical measurements conducted with a pilot assembly of DECOR allowed to check operation of chambers and electronics systems, and showed that basic detector parameters are close to the expected ones.

4 Muon bundle selection:

Study of muon bundle characteristics at large zenith angles is one of the top priority tasks of the coordinate detector (both in autonomic mode of operation and in combination with NEVOD). These investigations are of special interest since the main trivial mechanism of muon bundle generation (in EAS) is greatly suppressed near horizontal direction, and less well-studied sources of muon bundles may become important.

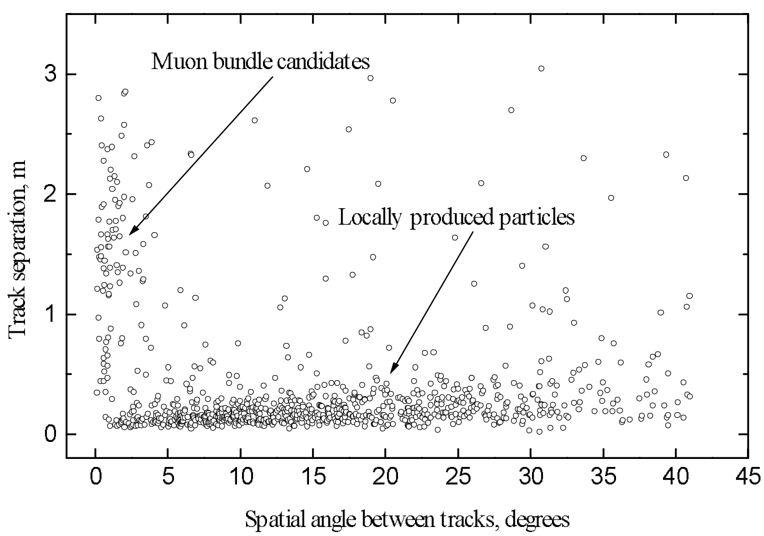

Figure 3: Correlation of two-track event parameters.

Selection of muon bundles in the coordinate detector is based on the fact that tracks of muons produced in the atmosphere and hitting the setup are nearly parallel. To check the possibility of parallel particle identification with a real DECOR structure, two-track events have been selected (Aynutdinov et al., 1998). For every event, two parameters were calculated: the distance D between the tracks in the setup middle, and reconstructed spatial angle ψ between the tracks. Two-dimensional distribution in these parameters for a sample of one thousand events is presented in Figure 3. Two classes of events are clearly seen. One of them is characterized by small angles between tracks, distribution in the distance being flat and determined mainly by the setup sizes. The second class is featured by small track separation which is increasing on the average with the angle. These events are caused by muon interactions in the gallery walls, and form the most important background in the search of muon bundles of atmospheric origin. However, this background may be effectively suppressed by the condition $D > 0.4$ m; the latter restriction leads to a loss of only a small fraction of events really produced at large distances from the detector.

Results of pilot assembly operation have been used to obtain preliminary estimates of the ratio of the intensity of double muons to single muon events (Figure 4). As double muon candidates, the events with $\psi < 3°$ and $D > 0.4$ m arriving from the side of the water tank (muon energy threshold about 5 GeV) have been selected. In calculations of the ratio plotted in the Figure, it was assumed that the rate of double muon events in a small size detector is proportional to its squared area; therefore, the observed ratios of the

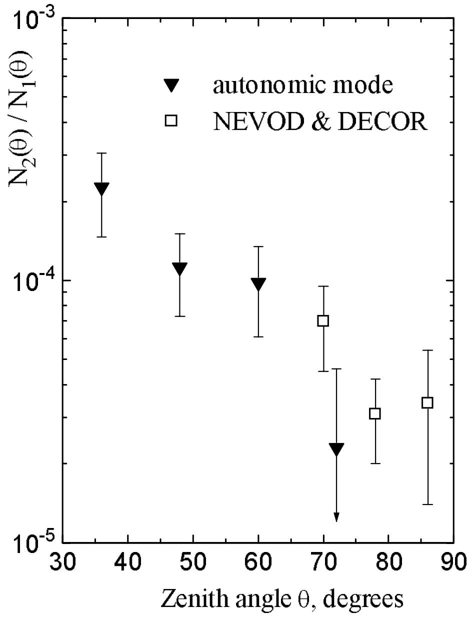

Figure 4: Relative intensity of muon pairs (normalized to 8 m^2 area).

numbers of events have been multiplied by the factor (S_0 = 8 m^2) / $<S(\theta)>$, where denominator is the average effective setup area in a corresponding angular bin. It is seen from the Figure that the intensity of muon pairs decreases with the angle appreciably faster than the intensity of single muons. Measurements with a full-scale detector will allow to obtain quantitative data on horizontal muon bundles.

5 Conclusion:

The first part of the coordinate detector with area 70 m^2 intended for horizontal cosmic ray flux studies has been constructed. Methodical measurements conducted with a pilot working assembly allowed to check the performance of basic detector elements and systems. Start of experiments on measurements of muon bundles at large zenith angles is planned for the end of this year. Ten-fold increase of the area of the detector in comparison with a pilot assembly will allow to reach a high event statistics and to get quantitative data on angular and spatial muon bundle characteristics. Comparison of these results with theoretical calculations will give a possibility to separate the contribution of various processes of muon bundle generation.

In the analysis of this kind, conduction of measurements in a full zenith angular range (θ = 0 - 90°) with the same technique and, preferably, with a single experimental setup is important. For this purpose, the deployment of an additional part of the detector (about 40 m^2) on the top of the NEVOD water tank is foreseen. Works on the construction of the top coordinate detector are now in progress.

Acknowledgments:

The authors are indebted to Prof.C.Castagnoli for his encouraging support at the initial step of works and continuous kind attitude during detector construction. Thanks are due to H.Rigoni and D.Fromm for manufacture and adjustment of the gas supply system. The work is supported by Russian Ministry for Science and Technology, by INTAS-RFBR grant 95-0703, and RFBR grant 98-02-17367.

References

Aglietta, M., Aynutdinov, V.M., Castellina, A. et al. 1997, Proc. 25th ICRC, Durban, 7, 297.

Aglietta, M., Castagnoli, C., Castellina, A. et al. 1995, Proc. 24th ICRC, Roma, 1, 982.

Aynutdinov, V.M., Castellina, A., Chernov, D.V. et al. 1998, Presented at Xth ISVHECRI, Gran Sasso. To be published in Nucl. Phys. B (Proc. Suppl.) 75A.

Aynutdinov, V.M., Kindin, V.V., Kiselev, S.A. et al. 1995, Proc. 24th ICRC, Roma, 1, 1076.

Battistoni, G., Bellotti, E., Bloise, C. et al. 1986, Nucl. Instr. Meth. A245, 277.