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Real-time data of muon hodoscope URAGAN

I.I. Yashin *, I.I. Astapov, N.S. Barbashina, V.V. Borog, D.V. Chernov, A.N. Dmitrieva, R.P. Kokoulin, K.G. Kompaniets, Yu.N. Mishutina, A.A. Petrukhin, V.V. Shutenko, E.I. Yakovleva

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow 115409, Russian Federation

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Abstract

Muon hodoscope URAGAN continuously detects the angular distribution of muons in a wide range of zenith angles and allows to obtain information about the variations both in the intensity and angular characteristics of the muon flux related with active processes in the heliosphere, the magnetosphere and atmosphere of the Earth. This paper describes the procedure of organizing of real-time URAGAN data presented in the Internet.

Keywords: Muon hodoscope; Muon diagnostics; Variations of muon flux; Heliospheric processes; Magnetosphere

1. Introduction

The main advantage of a wide-aperture muon hodoscope compared to a multidirectional muon telescope is the possibility of reconstruction in real time the track of each muon arriving from any direction of the celestial hemisphere. As a result, a continuous angular distribution of the muon flux is formed. Secondary muons are generated in the interactions of primary cosmic rays (CR) with the nuclei of the atoms of the atmosphere and keep quite well the directions of parent particles. Therefore, variations of primary CR caused by different phenomena associated with solar activity may be studied on the basis of the analysis of variations of the angular distribution of the muon flux measured in real time mode. On the other hand, the flux of muons is affected by the atmospheric processes. Hence, it allows to study with muon hodoscopes the development of powerful processes in the atmosphere. These approaches are the basis of the method of muon diagnostics (Astapov et al., 2013; Barbashina et al., 2010) developed recently in the Moscow Engineering Physics Institute by means of a specially designed muon hodoscope URAGAN.

Objectives of muon diagnostics are early recognition and forecasting of the development of destructive atmospheric phenomena over large territories (thunderstorms, squalls, tornados, hurricanes, etc) as well as of processes in the heliosphere of solar origin, which may cause negative influence on the vital activity of people (transpolar flights, orbital and interplanetary missions and other) and disruptions of information and energy infrastructures.

2. Experimental setup

Muon hodoscope URAGAN (Barbashina et al., 2008) (55.7° N, 37.7° E, 173 m a.s.l.) is a coordinate-tracking detector which detects in a real-time mode the muon flux at the Earth's surface in a wide range of zenith angles (0–80°) with a high angular resolution (~1°) and allows to study variations of the angular distribution of the muon

* Corresponding author.
E-mail address: IIYashin@mephi.ru (I.I. Yashin).

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flux caused by different atmospheric and extra-atmospheric processes.

URAGAN consists of four independent supermodules. Each supermodule (SM) (Fig. 1) represents an assembly of eight planes of streamer tube chambers blown with a gas mixture $Ar + CO_2$ + n-pentane. Sixteen gas discharge tubes, with size $9 \times 9 \times 3500\ mm^3$ and resistive cathode coating operated in a limited streamer mode, are enclosed in a single plastic container. Each plane contains 320 tubes equipped with an external two-coordinate strip readout system. Thin aluminum "X"-strips, with 1.0 cm pitch, are located along the streamer tubes at one side (320 pcs), and 288 "Y"-strips with 1.2 cm pitch, perpendicular to the "X"-strips, on the other side of the streamer tube layer. Sensitive area of one SM is $\sim$11 m^2. Three SMs (SM1, SM3 and SM4) are continuously under operation, while one (SM2) is used mainly for tests and calibration of different types of charged particle detectors.

At the passage of a charged particle through the internal volume of the tube a local streamer is formed, and electric pulses are induced on the strips and enter into the detection system.

Trigger condition of the event detection is the coincidence of signals from the strips of 4 or more X-planes within the time gate of 250 ns. The scheme of a muon detection in the SM is shown in Fig. 2.

Energy threshold of muons detected in the supermodule depends on zenith angle and is varying from 200 up to 600 MeV. Synchronization of all SMs operation is provided by GLONASS/GPS. The total counting rate of one SM is 1700–1800 triggers per second. The counting rate of events with reconstructed muons tracks is about $1300\ s^{-1}$. Exposure process is divided into equal one-minute intervals within which monitoring of detection channels (2 s), the detection (about 54 s) and the transfer of one-minute frame data are carried out. The "live"-time of a one-minute frame is 53–54 s and depends on the SM counting rate. Thus, the total operational time is the sum of the "live"-times of one-minute intervals of the total measurement exposition.

3. Data format

The track parameters (two projection angles) are reconstructed in a real-time mode by means of the software, which is based on the histogramming technique in each projection plane XZ and YZ, and are stored in a two-dimensional data array over one-minute time interval. This data array is a "muon snapshot" of the upper hemisphere (limited by the detector aperture), which is acquired over one-minute exposure.

The monitoring data include results of testing serial data readout circuits, measurements of the SM plane noise intensity, hit channel mapping and estimates of the efficiency of particle track detection by the planes.

The angular distributions of the tracks detected during 1 min intervals are stored in three types of binary arrays–matrices with dimensions 90×90 cells: by zenith and azimuth angles, $M_a \equiv [\theta_i, \varphi_j]$, by projection angles, $M_{pa} \equiv [\theta_{Xi}, \theta_{Yj})$ and tangents of projection angles, or slopes, $M_{tg} \equiv [\tan\theta_{Xi}, \tan\theta_{Yj}]$. Every matrix stores the angular distribution of muons measured during 1-min interval. The sequence of such matrices gives unique possibility to study the temporal changing of muon angular distributions. Depending on the analysis to be performed, matrices can be collected in different time intervals Δt. For example, for the analysis of muon flux variations of the heliospheric origin, the matrix data summed of measuring minute intervals during $\Delta t = 1$ h may be used. For the study the dynamics of rapidly developing atmospheric processes that cause variations in the intensity of muons, five-minute matrices are analyzed.

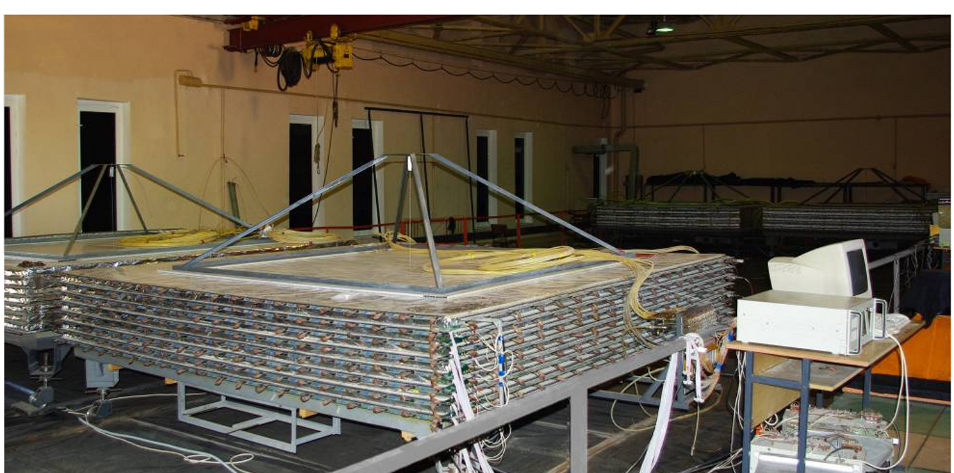

Fig. 1. The muon hodoscope URAGAN. In the foreground, one of the supermodules is seen. On the left and in the background the other three SM a located.